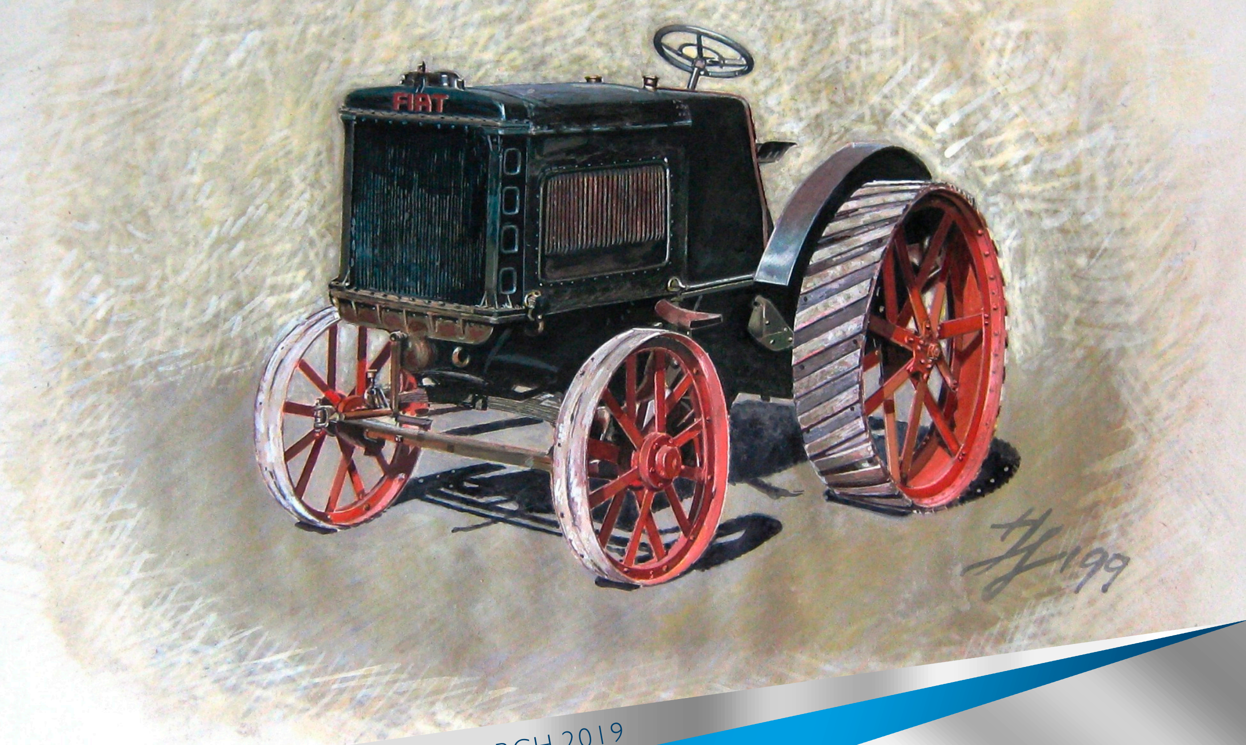
UDC 631

ISSN 1848-4425



OPATIJA, CROATIA, 5th - 7th MARCH 2019

PROCEEDINGS OF THE
47th INTERNATIONAL SYMPOSIUM

ACTUAL TASKS ON AGRICULTURAL ENGINEERING

UNIVERSITY OF ZAGREB FACULTY OF AGRICULTURE
AGRICULTURAL ENGINEERING DEPARTMENT
FACULTY OF AGROBIOTECHNICAL SCIENCES UNIVERSITY OF OSIJEK
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NATIONAL INSTITUTE FOR AGRICULTURAL MACHINERY - INMA BUCHAREST
CROATIAN AGRICULTURAL ENGINEERING SOCIETY

SVEUČILIŠTE U ZAGREBU AGRONOMSKI FAKULTET
ZAVOD ZA MEHANIZACIJU POLJOPRIVREDE
SVEUČILIŠTE J. J. STROSSMAYERA U OSIJEKU
FAKULTET AGROBIOTEHNIČKIH ZNANOSTI
UNIVERZA V MARIBORU
FAKULTETA ZA KMETIJSTVO IN BIOSISTEMSKE VEDE
KMETIJSKI INŠTITUT SLOVENIJE
INSTITUT ZA POLJOPRIVREDNU TEHNIKU, BOKU, BEČ
NACIONALNI INSTITUT ZA POLJOPRIVREDNU MEHANIZACIJU
INMA BUKUREŠT
HRVATSKA UDRUGA ZA POLJOPRIVREDNU TEHNIKU

AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

ZBORNIK RADOVA

47. MEĐUNARODNOG SIMPOZIJA
Opatija, 5. – 7. ožujak 2019.

Published by	University of Zagreb, Faculty of Agriculture Department of Agricultural Engineering, Svetošimunska 25, 10000 Zagreb
Izdavač	Sveučilište u Zagrebu, Agronomski fakultet Zavod za mehanizaciju poljoprivrede Svetošimunska 25, 10000 Zagreb
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Technical editor / Tehnički urednik	Igor Kovačev

ISSN 1848-4425

http://atae.agr.hr

Cover painting / Slika s naslovnice: Dušan Jejčič
Cover design / Oblikovanje naslovnice: Kreativna Točka by Marko Košutić

All papers in the Proceedings are peer reviewed / Svi radovi u Zborniku su recenzirani

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PRIČA O TRAKTORU S NASLOVNICE

FIAT 702

U počecima razvoja traktora najveći doprinos dale su englesko - američka, njemačka i talijanska "škola traktora". Italija, koja se danas smatra jednim od vodećih proizvođača strojeva i opreme za poljoprivredu, do 1918. nije imala industriju traktora, slično kao i Njemačka ili Velika Britanija. Čak i u tim zemljama ubrzani razvoj i proizvodnja traktora započinje nakon Prvog svjetskog rata. U to vrijeme u Italiji su korišteni razni američki tipovi traktora, koji su uglavnom dolazili kao američka vojna pomoć tijekom Prvog svjetskog rata (International, Mogul, Titan, Fordson, itd.) kako bi se olakšala proizvodnja hrane. Prva se u proizvodnju traktora u Italiji uključila legendarna tvrtka FIAT, koja je zagovarala raznovrsnost svoje proizvodnje – „biti prisutan na kopnu, u vodi i u zraku“ bila je ideja osnivača tvornice. Cilj je bio masovna motorizacije Italije po pristupačnoj cijeni. Godine 1918., u vrijeme završne faze Prvog svjetskog rat u Europi, u Italiji je zbog potrebe za intenzivnom proizvodnjom hrane, svjetlo dana ugledao Fiatov traktor Model 702. Traktor je omogućio rješavanje problema nedostatka radne snage u poljoprivredi, potrebne za obradu velikih površina za proizvodnju hrane. Nakon opsežnog testiranja, FIAT je talijanskim vlastima 14. kolovoza 1918. predstavio Model 702 u oranju. Na ovoj prezentaciji se traktor pokazao u najboljem svjetlu, bio je daleko ispred svih suparnika, pa je 1919. izabran za opremanje talijanske poljoprivrede traktorima.

Zanimljivo je da je FIAT, za razliku od ostalih talijanskih proizvođača koji su ugrađivali motore s užarenom glavom, izabrao svoj razvojni put temeljen na traktorima s četverotaktnim benzinskim motorima. U dizajniranju modela 702 iskorišteni su neki elementi dizajna legendarnog traktora Fordson (samonosiva konstrukcija traktora bez šasije, gdje motor, mjenjač i stražnji most traktora od čeličnih odljevaka predstavljaju nosivu konstrukciju cijelog traktora). Model 702 bio je prikladniji za nagnute terene zastupljene u europskim uvjetima poljoprivredne proizvodnje, te zbog veće snage motora i za obradu težih tala. Fordson je bio prikladniji za ravne površine s prevladavajućim lakšim tlom. Serijska proizvodnja Fiatovog modela 702 započinje 1919. godine. Benzinski četverocilindrični tekućinom hlađeni motor razvijao je 30KS pri 800 o/min. Masa traktora je bila 2.700 kg, a bio je opremljen nesinkroniziranim mjenjač s tri stupnja prijenosa za kretanje naprijed i jedan nazad. Na temelju modela s kotačima, razvijene su i verzije traktora gusjeničara. 1932. godine na tržište je uveden model 700 C (oznaka C prema talijanskoj riječi *cingoli* - gusjenica) s motorom od 30 KS, a Model 702 C je opreman motorima od 28-35 KS. Model 702 je otvorio put za uspješno uvođenje mnogih narednih modela traktora. Proizvodnja modela 702 je s velikim uspjehom trajala do 1927. kada je zamijenjen modernijim modelom 700, koji je uz modifikacije u proizvodnji ostao do 1950. godine. FiatTrattori je 1970-ih bio vodeći Europski proizvođač traktora, a 1991. preuzima Američki Ford Tractor koji je nešto ranije preuzeo proizvođača kombajna New Holland. Danas tradiciju Fiatovih traktora nastavlja New Holland, FiatAgri je ostao u simbolu lista na zaštitnom znaku, a Ford s plavom bojom traktora.

Dr. sc. Viktor Jejčič

STORY ABOUT TRACTOR FROM COVER PAGE

FIAT 702

In the beginnings of the tractor development the greatest contribution was made by the English-American, German and Italian "tractor schools". By 1918, Italy, which today is considered one of the leading manufacturers of machinery and equipment for agriculture, did not have a tractor industry, similar to Germany or the UK. Even in these countries, intensive development and production of tractors began after the First World War. At that time, various US types of tractors were used in Italy, which mainly came as US military aid during the WWI (International, Mogul, Titan, Fordson, etc.) to facilitate food production. One of the first involved in the tractor production in Italy was the legendary company FIAT, which advocated the diversity of its production - "to be present on land, in water and in the air" was the idea of the factory founders. The aim was mass-driven motorization of Italy at an affordable price. In 1918, during the final phase of the WWI in Europe, in Italy due to the need for intensive food production, was introduced Fiat Tractor Model 702. The tractor solved the problem of lack of labour force in agriculture needed for cultivation of large areas for food production. After extensive testing, on 14th August 1918, Fiat presented to Italian authorities the Model 702 in ploughing. At that presentation the tractor showed best performance, far ahead of all rivals, and in 1919 it was chosen to equip Italian agriculture with tractors.

It is interesting that Fiat, unlike other Italian manufacturers, which were built-in hot-bulb fired engines, chose its path of development based on tractors with four-stroke gasoline engines. In designing Model 702 were used some design elements of the legendary tractor Fordson (self-supporting structure of the tractor without the chassis, where the engine, gearbox and rear axle of steel castings were supporting structure of the entire tractor). Model 702 was more suitable for work in hilly areas, present in the European conditions of agricultural production, as well as for tillage of heavy soils due to greater engine power. Fordson was more suitable for flat surfaces with prevailing lighter soil types. The serial production of Fiat's Model 702 began in 1919. The four-cylinder, liquid cooled, petrol engine developed 30 HP at 800 rpm. The weight of the tractor was 2.700 kg and it was equipped with a non-synchronous transmission with three gears to move forward and one back. Based on the wheeled model, the version of the crawler tractor has also been developed. In 1932 the market was introduced with the Model 700 C (C according to the Italian word cingoli - caterpillar) with a 30 HP engine, while the Model 702 C was equipped with engines of 28-35 HP. Model 702 has paved the way for the successful introduction of many following tractor models. Production of the Model 702 was very successful until 1927 when it was replaced by a more modern model 700, which with modifications stayed in production until 1950. In the 1970s, FiatTrattori was the leading European tractor manufacturer and in 1991 it purchased the American Ford Tractor, which had previously acquired the harvester producer New Holland. Today the tradition of Fiat tractors continues with New Holland, FiatAgri remained in the symbol of a leaf on the trademark, and Ford with blue colour of tractor.

Viktor Jejčič, Ph.D

PREDGOVOR

Poštovane kolegice i kolege,
Poštovani čitatelji,

Simpozij Aktualni zadaci mehanizacije poljoprivrede ove je godine održan 47. puta, u godini kada Agronomski fakultet Sveučilišta u Zagrebu, jednako kao i Zavod za mehanizaciju poljoprivrede kao organizator Simpozija, obilježavaju znamenitu obljetnicu – 100 godina postojanja, znanstveno-istraživačkog rada i prenošenja znanja novim generacijama. Dugu tradiciju Simpozij može zahvaliti predanom radu uglavnom malog organizacijskog tima, znanstvenom doprinosu autora i recenzenata, te sponzorima i kolegama mehanizatorima diljem svijeta. Suorganizatori ovogodišnjeg Simpozija od strane međunarodnih strukovnih udruga su CIGR (Commission of Agricultural and Biosystems Engineering), EurAgEng (European Network for Advanced Engineering in Agriculture and Environment) i AAAE (Asian Association for Agricultural Engineering). Znanstveni značaj ATAE Simpozija vrednovan je uvrštavanjem u citatne baze, od 1997. godine se radovi objavljeni u Zborniku nalaze u bazama Clarivate Analytics: Web of Science Core Collection - Conference Proceedings Citation Indeks i CAB International - Agricultural Engineering Abstracts.

Ovogodišnji Zbornika radova sadrži 57 radova autora iz 10 zemalja, među kojima se nalaze po jedan (1) iz Češke i Estonije, po dva (2) rada iz Bugarske i Litve, četiri (4) iz Njemačke, po pet (5) iz Italije, Slovenije i Srbije, dvanaest (12) iz Hrvatske i dvadeset (20) radova iz Rumunjske. Pristup elektroničkom izdanju Zbornika je besplatan na web adresi http://atae.agr.hr/proceedings.htm.

Ovom prilikom najavljujem promjenu u dinamici održavanja ATAE Simpozija, idući će se održati 2021. godine s namjerom zadržavanja takvog dvogodišnjeg ciklusa. S ciljem kontinuiranog podizanja kvalitete Simpozija i bolje povezanosti poljoprivredne tehnike s drugim područjima agronomije započeli smo suradnju s CASEE (The ICA Regional Network for Central and South Eastern Europe). U godinama između ATAE Simpozija, autori će svoja postignuća moći prezentirati na „mehanizatorskoj“ sekciji u sklopu CASEE konferencije.

Kako bi sudionicima ATAE Simpozija približili mogućnost publiciranja radova i izvan Zbornika, znanstveni odbor Simpozija će autore najkvalitetnijih prezentacija pozvati da svoje radove prijave za specijalno izdanje znanstvenog časopisa „Die Bodenkultur“ posvećeno poljoprivrednoj tehnici.

Zahvaljujem svim autorima, recenzentima te kolegama iz organizacijskog i znanstvenog odbora, koji su svojim predanim radom omogućili održavanje ovogodišnjeg Simpozija. U ime organizatora zahvaljujem i sponzorima, Ministarstvu znanosti i obrazovanja Republike Hrvatske, Zakladi Hrvatske akademije znanosti i umjetnosti te tvrtki INA MAZIVA d.o.o.

Zagreb, ožujak 2019. Igor Kovačev, urednik

PREFACE

Dear Colleagues,
Dear readers,

Symposium Actual tasks on agricultural engineering this year was held for the 47th year, when the Faculty of Agriculture, University of Zagreb, as well as the Department of Agricultural Engineering as the organizer of the Symposium, celebrated notable anniversary: 100 years of existence, scientific and research work and transfer of knowledge to new generations of students. Its long tradition the Symposium can thank to devoted work of usually small organizing team, the scientific contribution of authors and reviewers, as well as sponsors and colleagues around the world. International professional associations as co-organizers of this year's Symposium are CIGR (Commission of Agricultural and Biosystems Engineering), EurAgEng (European Network for Advanced Engineering in Agriculture and Environment) and AAAE (Asian Association for Agricultural Engineering). The scientific significance of the ATAE Symposium is evaluated by the fact that the papers from the Proceedings have been indexed since 1997 into databases: Clarivate Analytics: Web of Science Core Collection - Conference Proceedings Citation Index and CAB International - Agricultural Engineering Abstracts. This year's Proceedings includes 57 articles by authors from 10 countries: Bulgaria 2, Croatia 12, Czech Republic 1, Estonia 1, Germany 4, Italy 5, Lithuania 2, Romania 20, Serbia 5 and Slovenia 5. Access to the web edition of the Proceedings is free at the website http://atae.agr.hr/proceedings.htm.

On this occasion, let me announce a change in the dynamics of the ATAE Symposium, the next will take place in 2021, with the intention of continuing such a two-year cycle. With the aim of continually raising the quality of the Symposium and better integration of agricultural engineering to other areas of agriculture, we started cooperation with CASEE (The ICA Regional Network for Central and South Eastern Europe). In the years between ATAE Symposia, the authors will be able to present their achievements at the AgEng section within the CASEE conference.

To open up a possibility for ATAE participants to publish their papers outside of the Proceedings, the Scientific Committee of the ATAE will invite authors of the best presentations to submit their manuscripts for a special edition of the scientific journal "Die Bodenkultur" dedicated to agricultural engineering.

I would like to thank all authors, reviewers and especially members of the Organising and Scientific Committee for their efforts which made this conference possible. ATAE organisers also acknowledge the continuous financial support from the Ministry of Science and Education of the Republic of Croatia, The Foundation of the Croatian Academy of Sciences and Arts and the INA MAZIVA company.

Zagreb, March 2019 Igor Kovačev, editor

SADRŽAJ – CONTENTS

47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Stručni izvještaj
Expert report

HIGHLIGHTS OF 28TH CLUB OF BOLOGNA MEETING

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Peter SCHULZE LAMMERS[4]

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SUMMARY

Club of Bologna, world task force on strategies for development of agricultural mechanization, at 28th annual meeting in Bologna, during its agenda, three important sessions were presented: 1st Remote machinery repair, maintenance and assistance, 2nd Agricultural machinery new technologies: challenges and limits for users, 3rd Specific mechanization: machines for horticulture. Besides Sessions, agenda comprised: Giuseppe Pellizzi Prize 2018 Award Ceremony, Report of Study Group and Programme of activities for 2019.

Keywords: *Club of Bologna, remote machinery repair, maintenance and assistance, agricultural engineering strategy, machines for horticulture*

INTRODUCTION

Club of Bologna (CoB), a world task-force on the strategies for the development of agricultural mechanization belongs, for sure, to the worldwide most important organizations in the field of agricultural and biosystems engineering. It was founded 1989 as a free and nonprofit organization, supported by Italian agricultural and earth moving machinery manufacturers association *FederUnacoma*. CoB gathers members from 31 countries and has 93 full members. Common, and most significant, CoB's activity is annual members' meetings, held alternatively in Bologna, during exhibition EIMA, and Hannover, during *Agritechnica*.

REMOTE MACHINERY REPAIR, MAINTENANCE AND ASSISTANCE

First presentation *"Product Services in the digital age (Industrie 4.0)"* was given by *E. Westkämper*, former head of Fraunhofer Inst. Manufacturing Engineering& Automation in Germany. The presentation was mainly focused on the future challenges for machine manufacturers in service and support. Future fields of action ranges from the state of the art in pure technical workshop services to web-based consulting services and finally to remote operations such as process diagnostics, process monitoring, automatic process optimization and thus up to automatic online operations. Main resume puts a focus on demands and trends of future development. All participants in the ICT framework have be involved "from cradle to grave", from resource deliverer to residue maintainers (including machinery producer and after consumer sector). Consequently, tools for life cycle assessment have to be implemented in ICT.

The main challenge for the machine manufacturer within the scope of digitization are the expansion of the product horizon from pure machine production to applied production processes in which the machines are used both regionally and in the global environment of goods and information flows. The next stages will be focused: Implementation of remote production via real-time communication. Meeting security requirements and challenges to create and secure trust. The increasing demand for Big Data Management must be adequately met in order to take account of the rapid development of sensor technologies (frequency in msec, more than 200 basic technologies available) and the need for technologies for data analysis. Big data management and artificial intelligence" have already become a key technology for the future, as a lot of data has to be retrieved from very complex systems and processes. The future research challenge must include the analysis and modelling of processes as crucial needs for future development (including high importance). To this end, the evaluation of process simulation and the development of "feedback loops and artificial intelligence" needs a learning environment of technical systems.

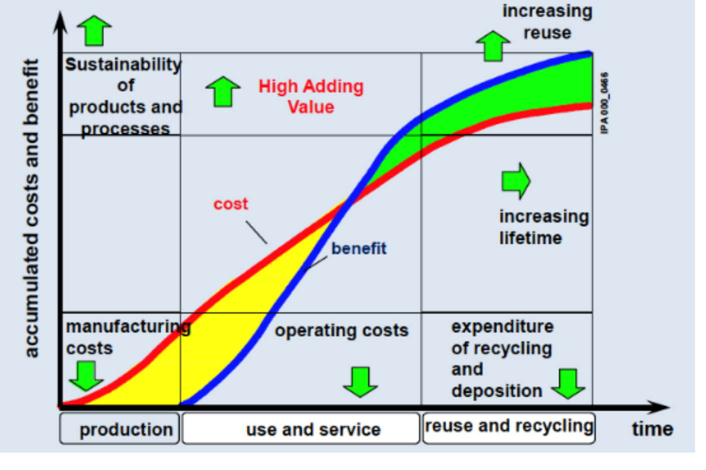

Figure 1 Sustainability of Manufacturing (Westkämper, 2018)
http://www.clubofbologna.org/ew/ew_proceedings/2018%20_S1.1_PPTX_Westkmper.pdf

In terms of costs and benefits, the manufacturing and operating costs for the use and maintenance of machines as well as the costs for recycling and deposit must be reduced. Increasing the service life is a challenge to achieve higher sustainability of products and processes and last but not least a higher added value and increased reuse.

Final statement: “The transformation of “Industrie 4.0” is a clear revolution, which will change the management and will have winner and looser in all sectors. It requires new qualification of employees, new methods of economic control and changeable structures of organisation.”

F. Protano from CNH Industrial, responsible for Precision Solutions and Telematics Product Management showed an inside into the strategy for *“The Farm Data Ecosystem”*.

She presented definitions of Agriculture 1.0 up to 4.0 and what can be understood by digital farming (Figure 2).

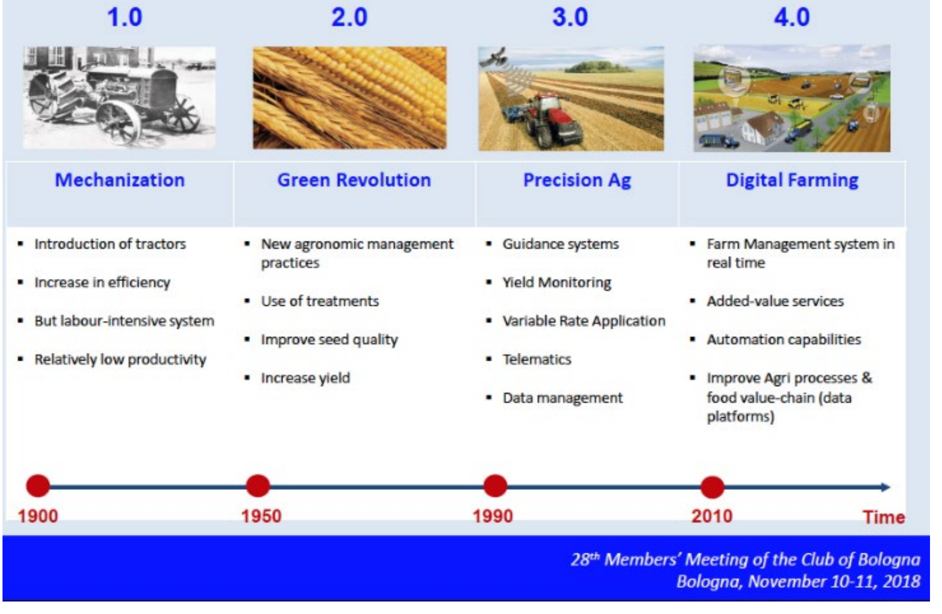

Figure 2 The agricultural Evolution (Protano, Vandecaveye, 2018)
http://www.clubofbologna.org/ew/ew_proceedings/2018_S1.2_PPTX_PROTANO_VANDECAVEYE.pdf

A clear focus was given on opportunities for Equipment Manufacturers and related strategies for operational organization between customer, dealer and manufacturer. Especially future possibilities regarding innovations in telematics connections (bi-directional communication for high density and transmission speed of online data between partners) and new infrastructures for e.g. pro-active intervention, to improve the customer service quality and the products and processes for the manufacture. “But the ultimate goal is to build the perfect vehicle.” Using the combine harvester as an example (equipped with automatic steering solutions and various crop sensors, a modem on board, which allows the vehicle to be monitored in real time), the possibilities of future developments and their advantages from the different perspectives of machine manufacturers, dealers and end customers were presented. The CNHI Agricutural Control Room, a central control room and web-based communication node between machines and all stakeholders, was presented to implement networked communication between machines, users and experts from different backgrounds online (Figure 3.)

Figure 3 The Control Room Concept (Protano, Vandecaveye, 2018)
http://www.clubofbologna.org/ew/ew_proceedings/2018_S1.2_PPTX_PROTANO_VANDECAVEYE.pdf

Several examples were given how the stored data can be used for many services from optimization of farm processes up to food traceability and documentation duties. The operational details (e.g. machine information from CAN-bus to technical support including expert knowledge online from abroad) were presented exemplary. The possibilities for an improved efficiency of the production processes were presented. For example, how to achieve proactive troubleshooting of machines in action and thus reduced repair cases and repair times or to obtain practice-relevant information for the successive further development of machines for "the next generation". "To conclude, a data-driven approach is nowadays a major factor of competitive advantage for enterprises, and especially a support for remote maintenance applications."

M. Pier (Grimme) demonstrated in his presentation *"InnoServPro: Innovative Service Products for individual and availability-oriented business models in capital goods industry"* the technical details from sensor technology to telecommunication structures in order to demonstrate the possibilities and benefits of smart farming technologies used by premium partner contractors using the example of potato harvesters. Main topic was "After sales management". To achieve an innovative service three main goals were defined: First the development of customized, availability-oriented business models; Second the development and integration of smart components with the ability to communicate; Third a design and configuration of an information management platform to provide and exchange service relevant data. Beginning with the sensor technology using the example of a sensor which detects the load limits at the conveyer belt chains of the potato harvester (by analyzing "the process of the elongation of the conveyer belt chains in test bench trials. Results showed that the elongation increased slowly with the applied stress, and can be predicted."), the entire data transfer (from signal post processing to a prediction of the conveyer belt conditions) and telecommunication system including a predictive maintenance were presented followed by the stepwise development of a business model between manufacturer and contractor. It was pointed out very clearly that "manufacturers of industrial goods integrate several components from different component suppliers into their specific machines". A central cloud platform is obligatory due to the interconnection of component suppliers up to the machine user for cross-company data exchange (Figure 4).

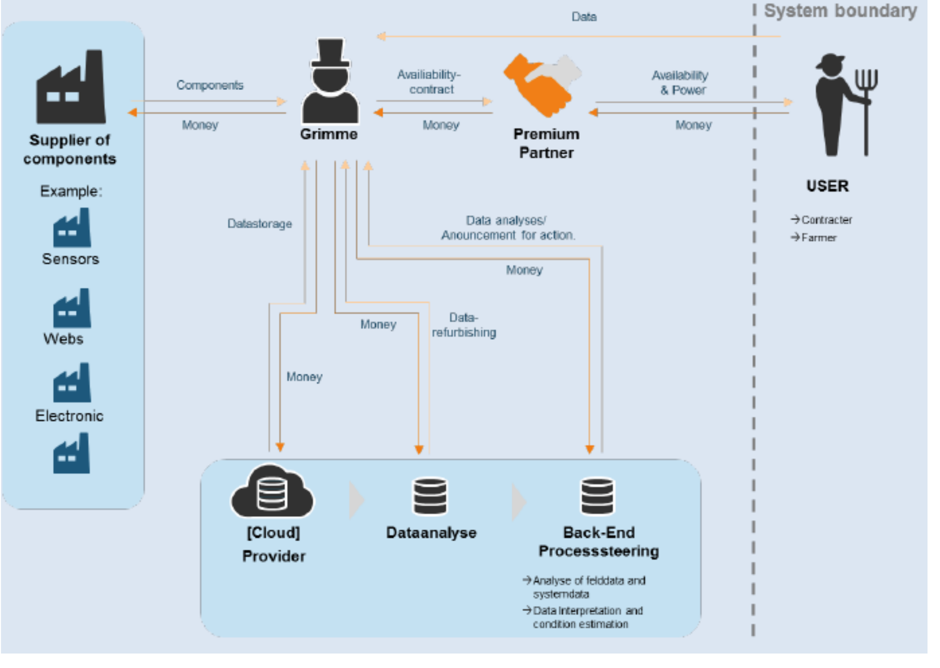

Figure 4 Value network map (Pier, 2018)
http://www.clubofbologna.org/ew/ew_proceedings/2018_S1.3_PPTX_PIER_rid.pdf

User, contractor, manufacture and component supplier are connected in a network to increase machine and process efficiency continuously.

For the future global logistic networks will be build predicting the frequency of maintenance by intelligent interfaces of machines.

AGRICULTURAL MACHINERY, NEW TECHNOLOGIES AND LIMITS FOR USERS

H. Auernhammer gave a short introduction for the Session 2., reminding audience on at Club of Bologna annual meeting during Agritechnica fair in Hanover 2017 introduced term 4.0 Agriculture.

Section started with presentation of *B. Pichlmaier* related to *trends and new technologies for agriculture and agricultural machinery.* Actual aspects of expected future development, based on complex principles of sustainability were discussed and commented. He tackled issues of machinery power and weight growth, aimed to contribute reduction of operational costs. It was concluded that the growth reached limit. Fig. 5 presented tractor operational costs as a function of engine power, and fig. 6. the same for application of future autonomous, driverless, solutions.

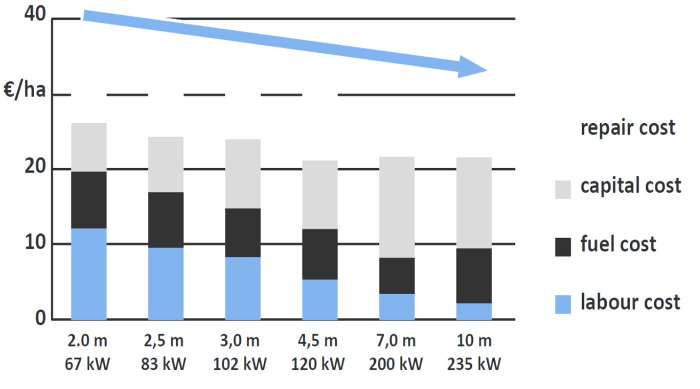

Figure 5 Operational costs versa tractor power

According to fig. 5. the power growth over 120 kW does not result in reduction of operational cost per hectare. Regarding autonomous vehicles, whose introduction is expected in the future, no labor costs, small units will have lower overall costs per hectare. This motivated author to express motto for future development: multitude instead of magnitude. Author elaborated and presented few other aspects of future technologies, like advanced controlled environment agriculture (greenhouses), robots, smart machines, new fuels (e.g. electricity) and information visualization. Very interesting, intelligent and usable presentation was finished with few messages.

Two most significant are:

- Sustainable productivity is the fundamental objective for farming. Support fresh thinking for a truly circular agricultural economy.
- Evaluate paradigm shifts: Machinery → Agronomy; Magnitude → Multitude; Complexity → Simplicity.

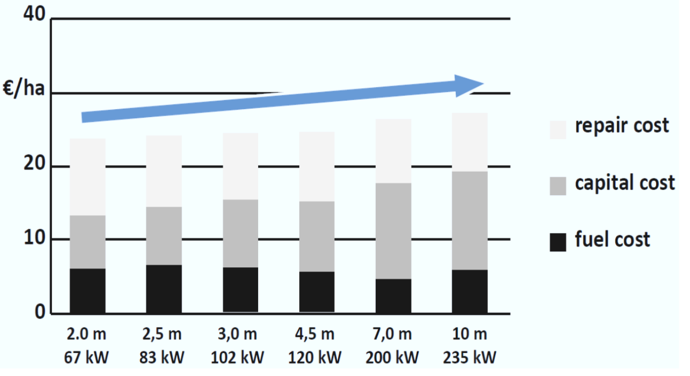

Figure 6 Operational costs versa power for autonomous, driverless, tractors

M. Shulman informed about *European Associations of Agricultural (family) Farms Copa and Cooperatives –Cogeca.* These two entities are, since merged in 1962, the biggest and most active lobby organizations in Brussels. Organization appreciates idea of "Smart Village" and is ready to accept digitization, “big-data”, robotics, biotechnology, smart farming, etc., but this should be on a level to provide concrete solutions and ensure full security. In this regard EU Code of Conduct on agricultural data sharing by contractual arrangement should be usable tool. The final message of the presentation was: Innovation needs to provide concrete solutions and all farmers need to access latest technology in order to respond to dynamic markets and maintain high quality of agricultural products!

This was followed by untypical presentation of advanced farmer *J. Bosch,* who demonstrated his and other *farmer's experiences with new technologies in agriculture,* mostly related to application of IT and digitalization. He mentioned advantages of IT, but some problems as well. Most significant are those related to putting systems into operation and fighting with malfunctions. To overcome mentioned is needed between less than hour, till few months, including engagement of sellers' team. It was also mentioned the problem of coupling tractors and implements by using different stages of ISOBUS. That means, full commercial maturity of compatibility of ISOBUS is still in front of us. However, it was concluded that introduction of IT and digitalization already support agriculture, and future expectations are unlimited. Section was finalized by presentation on status in P.R. China, given by *M. Yang.* This was overview of current development and future plans, but was more like political declaration, with less concrete achievements and future outlooks.

SPECIFIC MECHANIZATION: MACHINES FOR HORTICULTURE

The future of horticulture mechanisation, by prof. Silvana Nicole, Univ. of Turine

Author emphasize several basic characteristics and future challenges of horticulture production such as: 1. High costs and low productivity, 2. Internal and external business risks, 3. Maintain product performance and quality control, 4. Threat from emerging economies with larger and cheaper labor and 5. Various risks in managing work health and safety. Besides previous, Prof. Nicole pointed out that future horticulture production needs Intelligent sensing systems, robotics and precision agriculture automation as means to reduce production costs due to increase of productivity. Robots in horticulture are useful in nurseries and greenhouses, parks and golf courses, in the field for monitoring, serve as mechanical aids, allow high level of mechanization and can be real machines, help during post-harvest practices for picking and harvesting, grading and sorting, and packing. Harvesting fruits and vegetables proves to be a difficult problem to automate, but several companies are up to the challenge. According to prof. Nicole opinion by interconnecting crops, tools and vehicles to smart devices and sensors, farmers will soon be able to increase productivity saving money and conserving natural resources by making the right decision at the right time based on data.

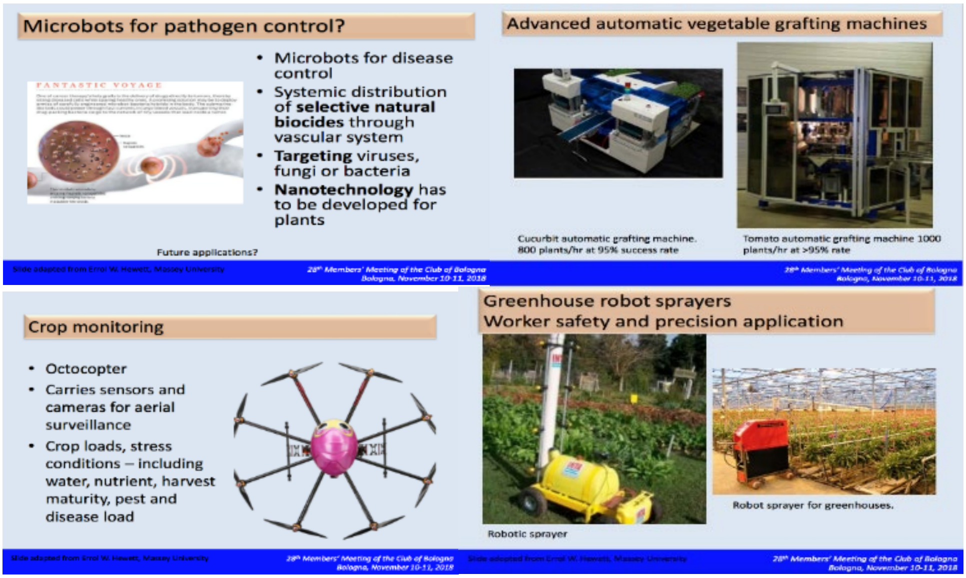

Figure 7 Pathogen monitor and control by micro robots, advanced automatic vegetable grafting machines, crops monitoring by drones and greenhouse robot sprayers (S. Nicole)

Horticulture mechanization and automation in open-field: state of the art and future perspective, by prof. Danilo Monarca from Univ. Tuscia

The author describes the machines for the production in open field, starting from the sowing and transplanting machinery and their most recent innovations (transplanters, mulchers, combined machines). After a short description of some machines for pesticide application and weed control, ample space was given to the harvesters. The distinction between product for the fresh market and for the processing industry is fundamental. For the product destined directly to the table, the use of manual and only partially facilitated harvesting yards is still very widespread (asparagus, artichoke, cauliflower), while for the productions destined for industry, harvesting operations

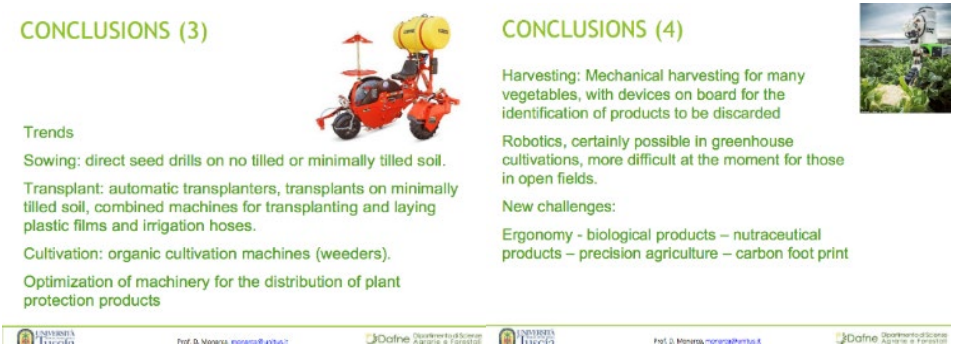

Figure 8 Final conclusions of future development and using smart machines in open field horticulture production (D. Monarca)

Automation and robotics in the protected environment, current development and challenges for the future, by Jochen Hemming, Vageningen University

The modern consumer demands guaranteed and constant quality. Moreover, there are intensified hygiene, food safety and traceability demands. Automated production and quality assessment systems can contribute to fulfill these demands. It is proven that the use of more technology in protected cultivation results in more yield, better product quality, and much higher resource efficiency. Many highly automated systems are already applied in commercial greenhouses. This includes logistics and autonomous transport of plants and harvested product in the greenhouse, spraying robots, machine vision based sorting systems for pot-plants and cut-flowers and robotic cutting, planting and grafting machines. Actual research focus on automated crop scouting (e.g. insect and disease detection), phenotyping (e.g. monitoring and predicting fruit setting) and robotic harvesting (e.g. of tomatoes, sweet pepper, strawberries). Still more research is needed to make such systems performing fast, simple and safe to use in practice. The current developments in high-tech horticulture are supported by the worldwide rapid improvements in computer hardware, software and artificial intelligence.

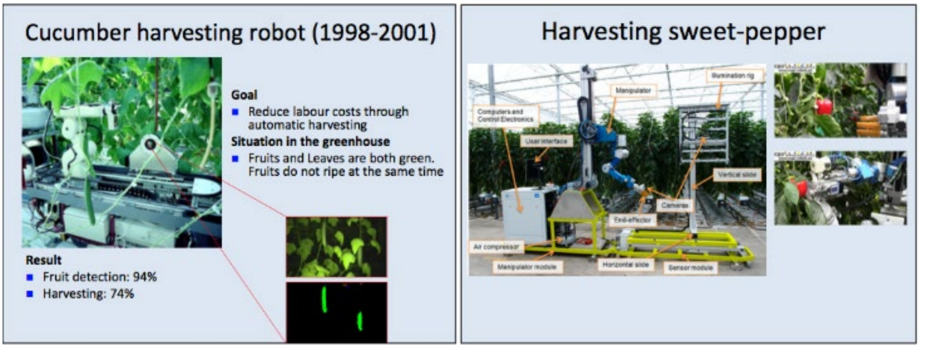

Figure 9 Some research achievements in harvesting (J. Hemming)

Equipment innovations in postharvest handling and minimally processing of fresh fruit and vegetables, by Giancarlo Colelli (University of Foggia – Italy)

Fresh fruit and vegetables are constituted by living tissues which carry on metabolic processes related to ripening and senescence. They are important for human diet as they represent an important source for bioactive compounds. Postharvest handling of these products is aimed to conditioning (cooling, grading and packaging) and to storing and/or shipping to more or less distant markets. Minimally processing is aimed to trim, wash, and cut into 100% usable product that is then packaged to offer high nutrition, convenience and value while still maintaining freshness. Despite available measures for maintaining quality of raw and processed material, degradation due to minimally processing is unavoidable, also considering that peeling, trimming and/or cutting operations are often present. In addition, other operations as washing and drying are known to cause mechanical stresses and loss of sugars and nutrients. However, the extent to which quality is compromised depends on the produce and on the processing conditions, including equipment and their operational settings.

Figure 10 Group photo of Club of Bologna members at 28th meeting, November 2018.

NOTE: All presentations and written papers are free available at web address: https://www.clubofbologna.org/en/meetings-proceedings.php

47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

ON THE CURRENT STATE OF AGRICULTURAL ROBOTICS IN CROP FARMING CHANCES AND RISKS

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ABSTRACT

For decades, labour shortage in agriculture has been met by clout increase through heavy machinery, creating environmental problems. Latest automation technology offers additional opportunities for a more sustainable land use. Therefore, new information and communication technology can be merged into Cyber Physical Systems providing the basis for agricultural robotics.

A widely discussed concept is swarm farming, where many small robots work and organize autonomously. The human operator is left with planning, surveillance and emergency management chores. This work examines the current state of agricultural robotics in the market and identifies chances and threats the technology poses to the work environment of farmers.

Robots can improve the efficiency of crop farming and help mitigate negative environmental impacts of heavier farm machinery. Low-input robots offer special potential, as they can perform tasks that originally required the precision of human body work. A combined approach of small robots and middle-sized tractors, working together in swarm configuration will foster the scalability of the resulting system, but also requires more complex surveillance- , management- and data infrastructure systems. Robots in agriculture can mitigate physical loads and stress of monotonous work, but the required level of skill, education and always-alert-times will rise. On the other hand, these changes in technology will create new, well paid jobs for educated experts in rural areas.

Keywords: *Digitization, Smart Farming, Swarm Robotics, Field Robots, Data Management*

INTRODUCTION

Agriculture must produce food, feed and fibre for up to 10 billion people by 2025. Simultaneously agriculture faces severe and increasing labour shortage. Within the last decades, the agricultural technology path has therefore solely developed through clout increase and heavy power vehicles. Since the last disruptive innovation of the self-driving tractor and mobile combustion engine combines in the early twentieth century, farming operations stayed the same, reaching their maximum capacity. Further, labour shortage in the agricultural sector urges the need of additional automation in the field. New ideas of farm management need to be developed. Throughout this process, information and communication technology must be merged into new Cyber Physical Systems (CPS). Such systems have been introduced by several institutions already (Herlitzius, 2017). As the adoption of these smart systems increases, the optimization, regulation and control of machines, logistics, quality control and traceability is made possible. That opens the fields for robots, that have been hindered so far by diverse environmental conditions in agricultural landscapes and production systems. Furthermore, Blockchain technology is on the rise to revolutionize information sharing in agricultural value chains. For a successful connection of information sharing systems to agricultural robotics, still, new communication networks must be established in rural areas (Fitzek, 2018). Pedersen et. al. (2008) already discussed the current state of Field-Robots, preparing the ground for a discussion on the potential of self-communicating machines. In the future, Robotics, will change agricultural practices on both small- and large-scale scenarios (Minßen et al., 2015), earthbound as well as airborne (Scherer et al., 2017).

The potential of robotic farming can be put into practice by fully automating conventional heavy agricultural machinery and by arranging machine-to-machine communication of self-managed, autonomous small vehicles. A widely discussed idea is the concept of swarm farming with small vehicles working together in the field, organizing themselves, with the only remaining human task of surveillance and emergency management.

Aim of this research, is to display the current state of agricultural robotics in crop farming, including innovations that are “in the pipeline” already. This work shall further identify chances and risks and help to predict future developments in the crop production value chain. Based on the technological possibilities at hand, changes in the work environment shall be analyzed from a farmer’s perspective.

MATERIALS AND METHODS

Starting from an overview of businesses and use-cases of agricultural robotics available at present, a thorough literature review is carried out. Further use-cases and possible evolvements of agricultural robotics in the future (mid-term and long-term) are identified. Furthermore, an own classification system of agricultural robotics is applied (Figure 1). The robotic solutions are categorized into airborne and earthbound solutions. In the next step the interaction towards telemetry- and data-management Systems is discussed. Finally, the way robotics influence external stakeholders and the human decision-making unit (farmer) by interaction over these systems is evaluated. In the end, the findings are discussed regarding impacts the changes in technology will have on the farmers profession and what chances and opportunities may arise in the future.

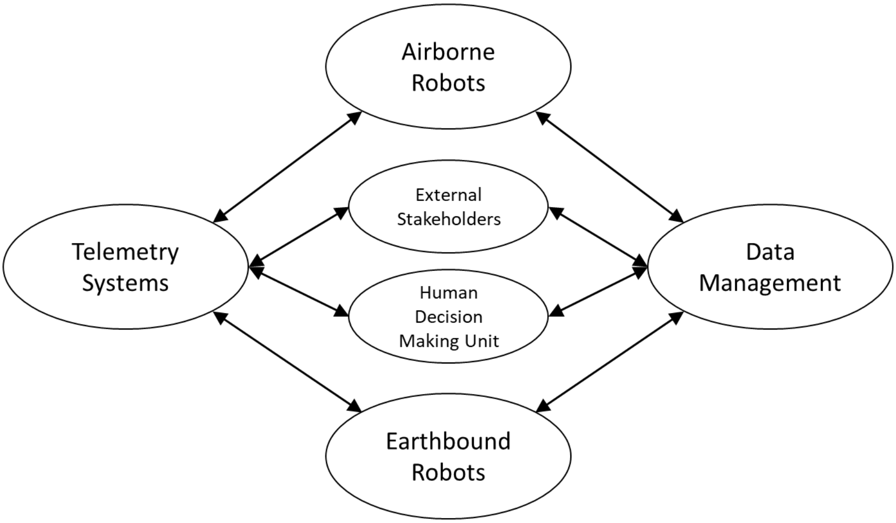

Figure 1 Categorization of Agricultural Robotics and the interaction of such categories towards external stakeholders

RESULTS AND DISCUSSION

Throughout the research, 228 companies and their robotic solutions regarding agriculture have been reviewed. Out of these, 49 companies do have robots that are in the market at present already. 137 Companies do have technology, that is very probably going to hit the market mid-term and 42 companies do have robotic solutions applicable for agriculture in the pipeline long-term.

Figure 2 shows, that there is already a significant number of robotic solutions for agriculture on the market. In the mid-term, up to three times as many may follow. For the long term, there are some innovations in the pipeline already, that can make a big impact in the field of agricultural robotics, but of course the amount of solutions available in the long-term is impossible to entirely predict.

The further categorization of the found solutions is shown in Figure 3. In absolute numbers, the earthbound robots play the most important role. Airborne robotic systems like unmanned aerial vehicles (UAVs) for mapping, surveillance or precision farming chores like spraying or fertilizing special cultures (e.g. vineyards) are available as well and expected to rise further in the midterm. The last two categories are the data-management and telemetry solutions. Interpretation of these numbers must be done cautiously, as the borders between these two categories can be blurry. As data-management solutions are on a strong rise at present and in the mid-term, their long-term developments are hard to predict. The same goes for telemetry solutions, that may have their strongest rise for agricultural robotics in the mid-term, judged by the number of companies having solutions in the pipeline already. However, after further review, the data-management and telemetry solutions should have been merged into one category, as they often form the joint basis for a robotic system being successful in the market. That’s why their importance should not be underestimated.

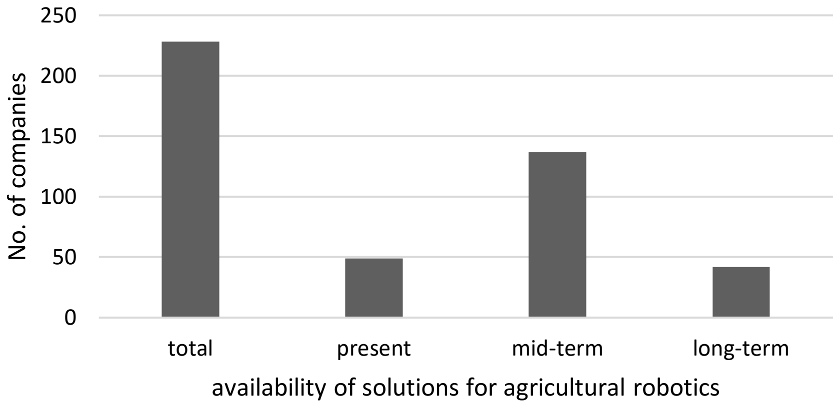

Figure 2 Availability of solutions for agricultural robotics on a timely horizon

From a more general point of view, Figure 3 shows, that the field of agricultural robotics is on the rise mid-term. Earthbound robots, the use of drones and the telemetry and data-management systems, going hand in hand with this hardware, will become more and more common in agricultural practice in the next few years. As a result, farmers must get used to the presence of this technology in their working lives. For the long-term, the development is hard to predict, but the fact, that there are thus many innovations in the pipeline already, that are supported by public relations and marketing measures, speaks for an ongoing trend.

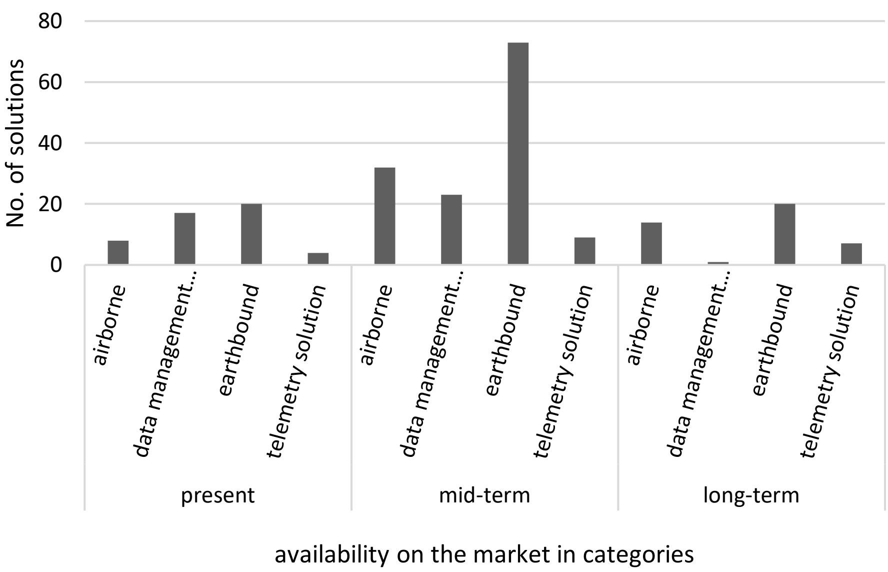

Figure 3 Availability of solutions for agricultural robotics in categories

Regarding the standalone earthbound robots that are on the market already, there are eight major approaches that can be identified. They are shown in Figure 4 in conjunction with their relative frequencies in the dataset of earthbound robots, that are already available today (at least as prototypes for proof of concepts). The most common application for robots in the dataset is a weeding robot, followed by implement carriers, that are versatile platforms for multiple tasks in crop farming. Next in frequency are sensing platforms and pickers, that rely heavily on sensor technology and image evaluation processes. Finally, Sprayers and combinations from sprayers and weeders are of importance, as well as platforms for special crops like for example asparagus or hop, that differ massively in construction from the other categories and each other. An important observation regarding this dataset is, that most of the earthbound robots are small and light, matching the expectations of agricultural robotics in public perception. Others, like some sprayers and especially the implement carriers are bigger in size and weight and can be compared to small or medium sized conventional tractors in size and weight. Concerning that a cropping system consists of many different machines and different tasks, a single agricultural robot can only partly automate the system. Therefore, it is very likely, that on future robot farms, different robots will perform different tasks in a cropping system and must communicate and work together with the help of telemetry data exchange and smart data-management and decision-support systems.

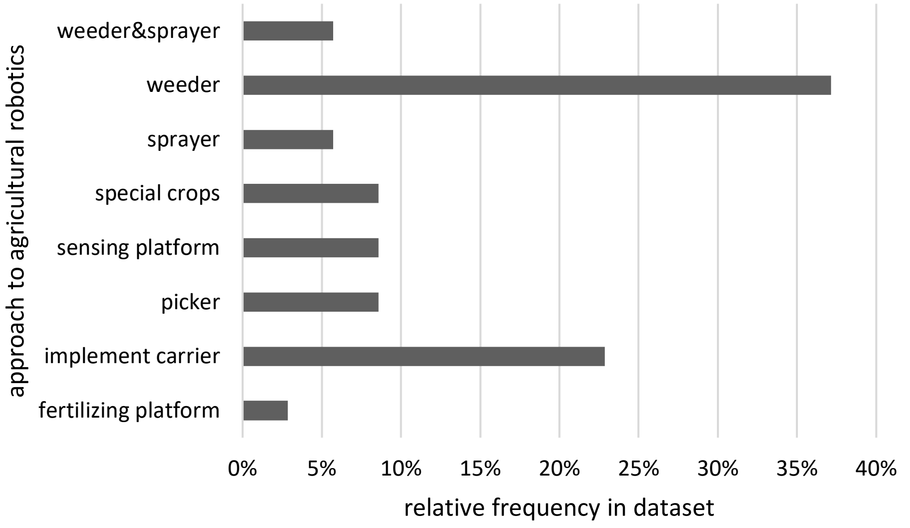

Figure 4 Earthbound robots for agriculture, available at present (at least as POC prototype), with relative frequencies in the dataset

The smaller robots, in general, are more suitable for tasks like weeding, seeding, sensing or spraying. Some of them will have significant impacts on the work environment of farmers, as they can, to a certain degree, substitute human labour in tasks like picking fruits or harvesting special crops, that required many human workers in the past (Calderone, 2014). There are tasks like tillage however, that require the bigger implement carriers. It is likely, that in robot farming systems of the future, small and medium sized machines will work cooperatively. From a farmer's perspective, not only is there a need for self-organizing robot swarms of small machines that handle one single task, but more diverse systems, with many different agricultural robots, working on different tasks, are needed. That requires single robots of different kinds to communicate with each other and the farmer. Therefore, the importance of farm management information systems and new approaches for machine-to-machine (M2M) and human-to-machine (H2M) communication will keep on rising. Nonetheless, the farmer must always have the possibility to gain direct control over any machine as a last-resort fall back solution (Griepentrog, 2017). The combined approach of small and big autonomous machines can help to maximize the benefits, the use of robots in agricultural systems offers. Achievable benefits are for example a higher precision of work, the mitigation of soil compaction, driver relief, avoidance of accidents and optimal usage of machine capacities (Eder, 2016). They stand against the risks of the technology, like for example loss of autonomy in decision making, polarization of work, higher complexity of work or the increase of stress due to permanent availability of the farmer (Zecha, 2018). But the transfer of technology, originally developed for other applications than agriculture, brings great opportunities as well. The attraction of skilled workers and young graduates to the agricultural sector is of utmost importance. Also new jobs can be created in rural areas, offering these professionals work and mitigating the adverse effects of urbanization (Duckett et al., 2018)

CONCLUSIONS

Agricultural robots improve the efficiency of crop farming and help mitigate negative environmental impacts of bigger farm machinery. Low-input robots offer special potential, as they can perform tasks in the field that originally required the precision of human body work.

There are several concepts for agricultural robots in the market already. The most common of which are weeding machines or concepts for multi-use implement carriers. A big increase in offerings and adoption is to be expected for the near future.

A combination of two approaches, conventional automation of heavy farming machinery and swarm robotics, or an integration of both into one system of middle-sized tractors that are part of swarm farming will foster scalability of the agricultural robot systems.

Therefore, the development of telemetry-solutions, data-infrastructure, management- and decision-support systems must go hand in hand with hardware development for successful adoption in agriculture.

Regarding the impact on the work environments of farmers, the socio-economic risks of robotic farming remain uncertain and even rise the question of redundancy of the human farmer as such. With his experience and expertise being outcompeted by smart systems, artificial intelligence and rapidly extending knowledge backed by Big Agricultural Data, the required level of skill, education and always-alert-times will rise. On the other hand, robots in agriculture can improve the quality of work, or mitigate physical strains, exposure to dangerous work environments and stress of monotonous work. Further, they offer the big opportunity to create new, well paid jobs for educated experts in rural areas.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Pregledni rad
Review paper

PARNI LOKOMOBIL U HRVATSKOJ POLJOPRIVREDI S NAGLASKOM NA 19. STOLJEĆE

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SAŽETAK

Razvoj lokomobila kao prijenosnog parnog stroja započinje 1840-tih godina u Engleskoj i u poljoprivredi se koristio više od 100 godina, 1920-tih godina počinje gubiti na značaju uvođenjem traktora s motorom s unutarnjim izgaranjem. U početku se najviše koristio za pogon vršalica, a kasnije i za obradu tla pomoću vitla i čeličnog užeta. Procesi industrijalizacije i modernizacije poljoprivrede u Hrvatskoj su započeli kasnije i odvijali su se sporije u odnosu na zapadnoeuropske države. Hrvatske zemlje su do 1918. godine bila u sastavu Austro-Ugarske monarhije, gdje su Hrvatska i Slavonija bile zaseban politički teritorij sa Saborom i banom. Druga agrarna kriza koja je zahvatila Europu između 1870. i 1895. godine je potaknula velika poljoprivredna gospodarstva u Hrvatskoj i Slavoniji na uvođenje parnih strojeva radi racionalizacije biljne proizvodnje, no dio gospodarstva s ekstenzivnim ratarstvom nije bio financijski u mogućnosti provesti modernizaciju. Na poljoprivrednim gospodarstvima u Hrvatskoj i Slavoniji je 1895. godine bilo ukupno 1.211 strojeva i gospodarskog oruđa na paru, od kojih su 451 bili lokomobili. Slavonija kao poljoprivredno najrazvijenije područje i glavna žitnica se isticala s 1.041 strojem i gospodarskim oruđem na paru (85,96%), od kojih su 381 bili lokomobili (84,48%). Lokomobili su bili najzastupljeniji na gospodarstvima s površinom od 575,5 ha (1.000 jutara) i više, njih ukupno 212, od kojih je 107 bilo u Virovitičkoj županiji. Prof. Raimond Fantoni, utemeljitelj Zavoda za mehanizaciju poljoprivrede Agronomskog fakulteta Sveučilišta u Zagrebu, proveo je 1920-tih godina ispitivanja kvalitete oranja s lokomobilom, mehanizmom za mijenjanje brzina i plugom vučenim čeličnim užetom. Obrada tla s parnim plugom je na imanju Belje u Baranji bila dominantna do 1956. godine i primjenjivala se sve do proljeća 1958. godine.

***Ključne riječi:** lokomobil, prijenosni parni stroj, parni plug, Hrvatska i Slavonija, industrijalizacija poljoprivrede*

UVOD

Potkraj 18. stoljeća u Engleskoj počinje korištenje parnog stroja u poljoprivredi, vodećoj gospodarskoj grani tog vremena. U početku su to bili stacionarni strojevi za pogon vršalica, preveliki i preskupi za korištenje na poljoprivrednim gospodarstvima prosječne veličine. Razvojem polustacionarnih i pokretnih parnih strojeva počinje njihova intenzivnija primjena u poljoprivredi. Produktivnost rada u poljoprivredi je između 1816. i 1861. godine porasla za 78%, i daljnji razvoj poljoprivrede će sve više ovisiti o industriji strojeva i umjetnih gnojiva što će voditi „industrijalizaciji poljoprivrede“ (Defilippis, 2005). Proces industrijalizacije i izgradnja prometnica kao osnova za razvoj i modernizaciju poljoprivrede u Hrvatskoj počinju kasnije i odvijaju se sporije u odnosu na razvijene zemlje zapadne Europe. U drugoj polovici 19. stoljeća Hrvatska je bila dominantno seljačka zemlja, prema M. Zoričiću u Hrvatskoj i Slavoniji je 1890. godine od poljoprivrede živjelo 84,64%, a u Dalmaciji 86,12% stanovništva. Nakon ukidanja feudalnih odnosa 1848. godine i uvođenja procesa zemljišnog rasterećenja trebalo je nekoliko desetljeća za konsolidaciju i modernizaciju poljoprivrede. Primjena parnih strojeva je osjetno zaostajala i industrijska revolucija u Hrvatskoj započinje tek sredinom 19. st., a veći zamah dobiva u razdoblju od 1850. do 1875. godine. Nakon sklapanja Austro-ugarske nagodbe 1867. godine otvaraju se mogućnosti intenzivnije provedbe industrijalizacije, obilnijom ponudom kapitala, izgradnjom modernih prometnica, jačanjem i širenjem urbanih središta (Vranješ-Šoljan, 1998). Prvi parni stroj u ovom dijelu Europe nabavljen je 1833. godine za tvornicu papira Smith & Meynier u Rijeci (Grgurić, 2007) i pušten u pogon 1835. godine. U početnoj fazi industrijalizacije najzastupljeniji su parni mlinovi, a osobito jača drvno-prerađivačka industrija i prerada šećerne repe. Do 1854. godine je zabilježeno svega petnaest parnih strojeva i glavnina industrijskih pogona utemeljuje se tijekom šezdesetih i na početku sedamdesetih godina (Galović, 2000). Prema Hrvatskoj tehničkoj enciklopediji do 1864. godine u Hrvatskoj je bilo 39 parnih strojeva s ukupnom snagom od 518,5 kW (696 KS), polovica ih se rabila na poljoprivrednim gospodarstvima i u tvornicama prehrambenih proizvoda.

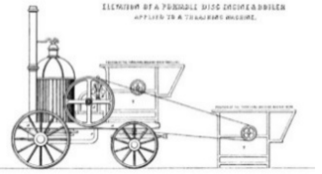
Za unapređenje poljoprivrede bila je neophodna izgradnja kopnenih i vodenih prometnica koje bi omogućile proširenje tržišta i bolje iskorištenje postojećeg poljoprivrednog potencijala. Poljoprivredna gospodarstva su svoje proizvode dopremali cestom do tržišta ili do željezničkih stanica odnosno riječnih pristaništa (Jelinović, 1986). Prva željeznička pruga izgrađena je 1860. godine u Međimurju, a zatim 1862. godine slijedi željeznička pruga Sisak-Zagreb-Zidani Most, prva u ondašnjoj Kraljevini Hrvatske i Slavonije. Razvoj prometnica je potaknuo modernizaciju hrvatske poljoprivrede i uvođenje parnih strojeva na poljoprivredna gospodarstva u šezdesetim i sedamdesetim godinama 19. stoljeća. Do 1867. godine Hrvatske zemlje su bile u sastavu Habsburške Monarhije, a zatim do 1918. godine u Austro-Ugarskoj Monarhiji. Istra s Kvarnerom je bila pod upravom Austrije, a Kraljevina Hrvatska i Slavonija je bila bez Baranje, Međimurja i Rijeke s okolicom koji su bile pod upravom Ugarske. Trojedna kraljevina je bio političko-pravni naziv za Kraljevinu Hrvatsku, Dalmaciju i Slavoniju kao jedinstveno državno i političko tijelo. Tadašnja Hrvatska i Slavonija je površinom prekrivala oko 67% današnje Hrvatske ne računajući istočni dio Srijema koji od 1918. godine pripada Srbiji. Srijemska županija s gradom Zemunom je prema Statističkom godišnjaku I. iz 1905. godine imala površinu od 6.866 km^2 i prema Hrvatskoj enciklopediji danas je 2.454 km^2 (oko 35%) u Hrvatskoj, u Vukovarsko-srijemskoj županiji, a 4.360 km^2 (oko 65%) u Srbiji, u Vojvodini. U radu su korišteni statistički podaci iz prvog Popisa gospodarstva i stoke od 31. prosinca 1895. godine koji su naknadno detaljnije obrađeni u

Statističkom godišnjaku Kraljevine Hrvatske i Slavonije I. iz 1905. godine. Uz zastupljenost lokomobila prema tadašnjim županijama prikazana je i zastupljenost parnih plugova koji su predstavljali složeniju primjenu lokomobila.

LOKOMOBIL

Lokomobil (lat. *locus:* mjesto + mobilis - pokretan) je pokretni ili nepokretni parni uređaj koji se sastojao od stapnog parnog stroja i parnog kotla spojenih u jednu cjelinu, a služio je za pogon radnih strojeva. U hrvatskoj poljoprivredi je bilo uvriježeno za lokomobil smatrati parni stroj na kotačima koji je bio vučen zapregom ili samokretan, kako ga i opisuju u tadašnjoj domaćoj literaturi (Fantoni, 1929a; Šah i Kišpatić, 1882). Koristili su se za pogon drugih radnih strojeva preko remenice (najčešće vršalica), zatim za vuču oruđa za obradu tla s čeličnim užetom preko vitla, pogon pumpi za vodu itd. Parni strojevi koji su se koristili za vuču plugova s čeličnim užetom pomoću vitla nazivali su se i lokomotive, odnosno parne lokomotive ako su bile samokretne (Fantoni, 1929a). Lokomobilski parni stroj stacionarnog postrojenja koji se ne kreće zove se polulokomobil (Serdar, 1986) odnosno koji nema kotače i postavljen je stalno na jednom mjestu, zove se i polustabilni parni stroj (Fantoni, 1929a).

Razvoj lokomobila kao pokretnog parnog stroja s kotačima započeo je u Engleskoj oko 1840. godine. Prvo javno predstavljanje pokretnog parnog stroja za pogon vršalice bilo je na Izložbi poljoprivrednih oruđa, priključaka i strojeva 1841. godine u Liverpool-u, organiziranoj od Royal Agricultural Society of England - RASE (Parkes et al., 1843). Robert i James Allen Ransome iz Ipswich-a su predstavili parni stroj i kotao snage od 3,7 kW (5 KS) postavljene na okvir s kotačima. Na farmi pored Liverpool-a je ispitivan učinak i kvaliteta rada vršalica pogonjenih ručno ili Ransome-ovim prijenosnim parnim strojem. Utvrđeno je da za 23 minute i 30 sekundi rada parni stroj ima isti učinak kao i 24 do 25 osoba u vršidbi, s time da bi kod duljeg rada s ručnim pogonom bio potreban odmor ili smjena ljudi (Parkes, 1841). Na Izložbi 1842. godine u Bristol-u (RASE) prikazan je Ransome-ov samokretni parni stroj na četiri kotača s platformom dovoljne površine za transport vršalice s farme na farmu (slika 1a), mogao se kretati po cesti brzinom od 6,4 do 9,7 km h^{-1} (Parkes et al., 1842).



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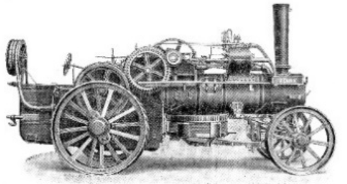


b

Slika 1 a Ransome-ov samokretni parni stroj s vršalicama, jedna u transportu i druga u radu, **1 b** lokomobil s vitlom (izvor: Ritchie, 1849; Černý, 1926)

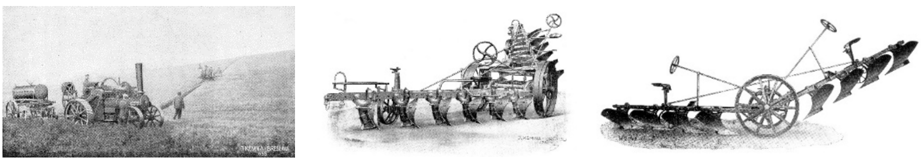
Figure 1 a Ransome's selfpropeled portable steam engine with threshing machines, in transport and in work, **1 b** selfpropeled steam engine (locomobile) with winch (winding drum) (source: Ritchie, 1849; Černý, 1926)

Svrha samokretnog lokomobila nije bila vuča oruđa preko polja ili transport tereta po cesti, nego jednostavnije premještanje pogonskog stroja s farme na farmu korištenjem vlastitog pogona umjesto životinjske vuče (zaprege). Lokomobili su se prvenstveno koristili za pogon radnih strojeva i imali su veliku masu te nisu bili prikladni za kretanje preko polja zajedno s plugom. Za oranje se koristio sustav vuče oruđa s čeličnim užetom pomoću vitla na lokomobilu koji je stajao na rubu polja. Daljnjim razvojem se povećava snaga parnog stroja, povećavaju se tlakovi u parnom kotlu i uvode se pregrijači pare u dimnoj komori. Lokomobili s 10,3 kW (14 KS) nisu mogli ostvariti dovoljnu vučnu silu za oranje na težim tlima na dubini od 36,9 cm i počeli su se proizvoditi modeli sa snagom od 14,7 do 18,4 kW (20-25 KS) (G.l. br. 8, 1870). Kasnije izvedbe lokomobila (parnih lokomotiva) koji su se koristili za oranje imali su efektivnu snagu od oko 36,8 kW (50 KS) do oko 147,1 kW (200 KS), odnosno do oko 220,6 kW (300 KS) prolazne maksimalne snage (Fantoni, 1954). Za rad s lokomobilom bilo je potrebno od 4 do 5 osoba i bila je prisutna opasnost od samozapaljenja zbog iskrenja iz dimne komore ili od eksplozije parnog kotla.

Obrada tla s lokomobilom se primjenjivala na velikim posjedima u Europi i SAD-u, no počela je gubiti na značaju iza I. svjetskog rata. Do 1920-tih godina je prevladavala proizvodnja lokomobila, a zatim se postepeno smanjivala (Jejčič, 2010).

OBRADA TLA S PARNIM PLUGOM

U 19. stoljeću se razvija obrada tla s parnim strojem i nastaje termin parni plug s obzirom na vrstu pogonskog odnosno vučnog stroja. Jedan ili dva parna stroja (lokomobil) stajala su uz rub parcele i vukli plug s čeličnim užetom pomoću vitla (slika 2a) ili je parni stroj (poljoprivredna parna lokomotiva) vukao priključni plug s kojim se kretao preko polja. Priključni plugovi su se manje koristili jer se parni stroj teško kretao po lakšem tlu zbog velike mase, sabijao je tlo i trošio je dodatnu snagu za vlastito kretanje. U početku su se gotovo redovito koristili parni plugovi vučeni čeličnim užetom s jednim ili dva lokomobila koji su bili samokretni ili vučeni zapregom.



a b

Slika 2 a Oranje s parnim plugom (izvor: Černý, 1926), **2 b** dvokrilni, balansni plug (izvor: Černý, 1926; Fantoni, 1929a)

Figure 2 a Steam ploughing (source: Černý, 1926), **2 b** balance plough (source: Černý, 1926; Fantoni, 1929a)

Razvoj

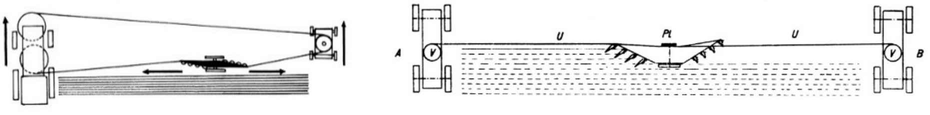
Zamisao korištenja užeta i mehaničke snage za vuču pluga krtičnjaka nastaje u Engleskoj, prvi ju je razvio Richard Lumbert oko 1800. godine, a najraniji patent za vuču ratila užetom s parnim strojem je iz 1810. godine od Major Pratt-a (Partridge, 1973). Prvi potencijalno praktičan i isplativ postupak vuče pluga krtičnjaka s vitlom i užetom je razvio John Fowler (Engleska) 1850-tih godina. Godine 1854. uspješno predstavlja vuču pluga krtičnjaka s lokomobilom od 4,4 kW (6 KS) na RASE izložbi u Lincoln-u. Nakon dvije godine predstavlja sustav za obradu tla s dvokrilnim odnosno balansnim plugom s lokomobilom proizvođača Ransomes, Sims and Jefferies Limited iz Ipswich-a. Prema katalogu iz 1860. godine samokretni lokomobil je imao snagu od 7,4 kW (10 KS), i od oruđa se navode plug za četiri brazde, kultivator, drljača i podrivač. Fowler je 1856. godine patentirao sustav oranja s dva samokretna lokomobila bez kola za usidrenje, a 1863. godine ga predstavlja na RASE izložbi u Worcester-u. Za oranje se koristio dvokrilni plug premetnjak, tzv. balansni plug (slika 2b) koji je bio vučen čeličnim užetom dužine od 450 do 600 m. Parni plugovi se od 1867. godine u velikoj mjeri koriste i u Francuskoj i Njemačkoj te u prekomorskim zemljama, a preko 300 ih je oralo u egipatskom Ponilju (G.l. br. 8, 1870). Pojavljuju se i tzv. „putujući orači“ koji su lokomobile i parne plugove prevozili od sela do sela i obavljali ugovorena oranja (G.l. br. 25, 1871).

Princip rada

Za oranje s jednim lokomobilom bila su potrebna kola za usidrenje s koloturom postavljena uz rub parcele nasuprot lokomobila i između njih se vukao plug s čeličnim užetom (slika 3a). Lokomobil i kola za usidrenje su se pomicali prema naprijed uz rubove parcele nakon prohoda pluga. Moglo se koristiti i više kola za usidrenje s koloturom i tada je lokomobil mogao biti postavljen na uglu parcele a plug se vukao između kola za usidrenje koja su se postepeno uz rubove parcele primicala prema lokomobilu.

Parni plugovi su se najviše koristili s dva lokomobila postavljenim jedan nasuprot drugog uz rubove parcele (slika 3b). Okretanjem vitla na jednom lokomobilu uže se namatalo i vuklo plug, a na drugom lokomobilu na suprotnoj strani parcele se čelično uže automatski odmatalo s vitla. Radna brzina oranja s dva lokomobila je bila od 6 do 9 km h^{-1} na većim dubinama. Samokretni lokomobili su se sami bez vuče sa zapregom postepeno pomicali uz rub parcele nakon prohoda pluga.

Lokomobil se koristio i za vuču kultivatora, brana, strojeva za vađenje repe itd., i često se s plugom istovremeno vuklo i drugo oruđe, npr. valjak. Oranje s lokomobilom se isplatilo samo na velikim površinama približno pravilnog oblika, osim toga morale su postojati prilazne ceste do parcela zbog velike mase lokomobila.



a b

Slika 3 Sheme parnog oranja: **3 a** lokomobil i kola za usidrenje (izvor: Partridge, 1973), **3 b** dva lokomobila (izvor: Fantoni, 1954)

Figure 3 Steam ploughing schemes: **3 a** one portable steam engine/locomobile and portable anchor (source: Partridge, 1973), **3 b** double-engine system with two portable steam engines/locomobiles (source: Fantoni, 1954)

LOKOMOBIL U HRVATSKOJ POLJOPRIVREDI U MONARHIJAMA

Nakon ukidanja kmetstva u Hrvatskoj 1848. godine pojavljuje se problem nedostatka sezonske radne snage i iznosa nadnice u poljoprivredi (G.l. br. 44, 1856). Kao jedno od rješenja predlaže se uvođenje poljoprivrednih strojeva, npr.: sječkarice za slamu, mlatnice za žito, ruljače za kukuruz (G.l. br. 45, 1856). U Gospodarskom listu br. 24. iz 1857. godine se navodi: *„Za našu zemlju strojevi potrebni su, to suvišno bilo bi dokazivati; mi imamo mnogo zemljah malo rukah i skupih težakah“*. Razlozi za sporo uvođenje i rjeđu upotrebu parnih strojeva u hrvatskoj poljoprivredi bili su: nepoznanica i bojazan korištenja strojeva koji su bili novina, njihova velika nabavna cijena i troškovi rada, upitna iskoristivost odnosno isplativost kupnje stroja velike snage s obzirom na obim poslova, zatim nedostatak stručnih osoba koje bi njime rukovale kao i dostupnost servisiranja i popravljanja stroja (G.l. br. 47, 1859).

Sredinom 19. stoljeća u Hrvatskoj su se za lokomobil koristili i izrazi „parno kretalo“ i „parokret“ (G.l. br. 25, 1858; G.l. br. 29, 1861). Godine 1882. izdan je niz knjiga pod imenom „Novovjeki izumi u znanosti, obrtu i umjetnosti“ autora Mije Kišpetića i Ivana Šaha. Bio je to prvi znanstveno-tehnički bestseler napisan na hrvatskome jeziku. U prvoj knjizi „Novovjeki izumi“ autor Ivan Šah u poglavlju Lokomobil navodi: *„Trebao je parostroj, koji bi mogao prenašati na razna mjesta bez velikih neprilika, da mu on jednom ore, žanje, sije polje, da mu drugi put grabi i vuče vodu .... On stoji na kotačih, te nije osobito težak, tako da ga jedan ili dva konja mogu i po lošijoj cesti lahko odvući na opredieljeno mjesto.“*

Nabava parnog stroja kao što je lokomobil bila je isplativa za velike posjednike ili za više srednjih i manjih posjednika kroz udruge ili društva. U početku su jedino u Engleskoj a zatim i u sjevernoj Njemačkoj postojali kontraktori koji su svoje usluge s parnim strojevima nudili poljoprivrednim gospodarstvima (G.l. br. 47, 1859). U Hrvatskoj je bio problem što posjednici nisu imali dovoljno gotovine za kupovinu skupih strojeva, a u početku nije bilo mogućnosti kreditiranja, također nije postojala domaća proizvodnja parnih strojeva koji bi bili niže nabavne cijene. U početku je u Monarhiji cijena parnog pluga, lokomobila i kola za usidrenje bila dvostruko veća od cijene u Engleskoj i kamata je iznosila od 10 do 20%, dok je u Engleskoj kamata iznosila samo od 2 do 4% i postizali su se veći prinosi uz bolju cijenu pšenice (G.l. br. 29, 1861). Hrvatsko-slavonsko gospodarsko društvo je osnovano 1841. godine kao strukovno društvo s ciljem razvoja i unapređenja poljoprivrede, a od 1910. godine je omogućavalo povoljniju nabavu i velikih strojeva poput lokomobila uz „najveći mogući popust i najpovoljniju otplatu od 3 do 6 godina“ (G.l. br. 19, 1910).

Počeci

Na imanju Belje u Baranji provodila se preobrazba veleposjedničke ekonomike pod upravom nadvojvode Albrechta od 1847. godine. Sredinom 19. stoljeća u pogonu su bila četiri parna stroja od kojih je jedan je radio u Čemincu, drugi u pustari Kneževo, treći u Villanyu za destiliranje vinske žeste, a od 1858. godine parni stroj snage od 5,9 kW (8 KS) pogoni vršalicu. Iste godine je u Habsburškoj Monarhiji u Ugarskoj ispitivana vršalica koju je pogonio lokomobil od 6,6 kW (9 KS) i za 30 minuta se ovršilo 285 snopova pšenice s oko 770 kg zrna, a za 12 sati 17.500 kg zrna (G.l. br. 25, 1858). Za posluživanje lokomobila bilo je potrebno dvoje ljudi, a za vršalicu 12 ljudi. Prvi parom pogonjen plug u Habsburškoj Monarhiji je bio predstavljen u lipnju 1861. godine s desne strane Dunava u blizini tadašnjeg Požuna (današnja Bratislava). Primijenjen je Fowler-ov sustav oranja sa samokretnim lokomobilom s kotvom ili sidrom, te plugom s 6 brazdi radnog zahvata od 122 cm. Postignut je učinak od 0,58 h^{-1} na dubini od 13 cm, a sustav je posluživalo 10 osoba uključujući i 2 osobe za nalijevanje i dovoz vode kolima sa zapregom (G.l. br. 29, 1861). Nakon uspješnog predstavljanja parnog pluga donesen je prijedlog o osnivanju društva za uvođenje parnih strojeva u gospodarstvo i imenovan je njegov odbor.

Tada snažni lokomobili od 5,9 do 8,8 kW (8-12 KS) su bili preskupi i prejaki za manje zahtjevne radove, te su se izrađivali i jeftiniji lokomobili od 1,5 do 2,2 kW (2-3 KS) koji su imali niže troškove rada, prvenstveno manju potrošnju goriva. Nisu mogli raditi cijeli dan, ali su investicijski bili isplativi jer su se mogli koristiti 8 mjeseci godišnje za pogon: vršalica, strojeva za rezanje sječke i korijena, žrvnja za zrno i uljani trop, pumpi za vodu i za piljenje drva (G.l. br.47, 1859).

Izgradnjom željezničke pruge omogućeno je i organiziranje Prve dalmatinsko-hrvatsko-slavonske gospodarske izložbe 1864. godine u Zagrebu koja je predstavila gospodarsko i kulturno stanje ondašnje „trojedne kraljevine“. Sudjelovali su i izlagači iz ostalih dijelova Habsburške Monarhije, a pod XIV. Podrazredom bilo je izloženo „*gospodarstveno orudje i strojevi, kola, štrcaljke, pjeneznice itd.*“. Najistaknutiji je bio lokomobil snage 5,9 kW (8 KS) proizvođača Clayton Shutlworth & Co. iz Lincolna iz Engleske s podružnicom u Beču koji je izložio i vršalicu, razne strojeve i oruđa (katalog 1864).

Od 1870. godine

U tadašnjoj Monarhiji nadvojvoda Albrecht je prvi naručio parne plugove s lokomobilima za svoja imanja u Baranji (G.l. br. 8, 1870) i prvo oranje parnim strojem u Hrvatskoj je bilo 1870. godine na veleposjedu Belje. Naručena su dva kompleta Flower-ovog sustava oranja s dva lokomobila, ukupno dva parna pluga i četiri lokomobila koji su bili namijenjeni za oranje površina za uzgoj kukuruza i šećerne repe. Na Belju je 1880. godine bilo 7 kompleta sustava za oranje s dva lokomobila koji su obrađivali 12.234 ha, od čega je 8 lokomobila bilo snage od 14,7 kW (20 KS) i 6 lokomobila snage od 10,3 kW (14 KS) (Musa, 1986). Koristili su se i za pogon vršalica, runilica, kao i za pogon pumpi za potrebe odvodnje, radi prebacivanja vode iz kanala u kanal (G.l. br. 17, 1896).

Na Belju se vodila evidencija prosječnog dnevnog i satnog učinka oranja s parnim plugom i u razdoblju od 1872. do 1900. godine učinak se postepeno povećavao. Počevši od 1872. i zaključno s 1900. godinom dnevni učinak za oranje na 30 cm dubine je iznosio od 4,30 ha do 8,21 ha, a satni učinak od 0,31 ha do 0,59 ha. Za plitko oranje na 15 cm dubine dnevni učinak je iznosio od 5,93 ha do 9,48 ha, a satni učinak od 0,42 ha do 0,68 ha. Obrada tla s parnim plugom je na Belju bila dominantna do 1956. godine i prvenstveno se koristila za oranje, drljanje i tanjuranje. Parni plugovi su ostali u radu sve do proljeća 1958. godine, a prema procjeni tadašnjih stručnjaka usjevi su bili bolji gdje se oralo parnim strojem naspram oranih zapregom. Oranje se izvodilo kvalitetno bez sabijanja tla, osim toga strojevi su bili dugovječni u radu (50 i više godina) i snažniji u odnosu na tadašnje traktore (Musa, 1986).

Druga agrarna kriza zahvatila je Europu između 1873. i 1895. godine, nastala je zbog pritjecanja velikih količina jeftinog žita na europsko tržište iz SAD-a, Kanade, Indije, Rusije i Ukrajine. Najviše su stradali veliki posjedi s ekstenzivnom proizvodnjom žitarica, te da bi kompenzirali gubitke nastale zbog pada cijena glavnih žitarica uvodi se nova mehanizacija i smanjuje broj najamnih radnika te konjskih i volovskih zapreka kojima se dotad obrađivalo zemljište (Stipetić, 1986). U tom razdoblju posjed „Belje“ u Slavoniji unosi sve više parnih plugova, parnih vršalica i drugih strojeva (Stipetić, 1986). No, agrarna kriza je ipak zakočila razvojne tendencije velikog dijela slavonskih veleposjeda (Karaman, 1986).

Popis gospodarstava i stoke 1895. godine

Krajem 19. stoljeća Hrvatska i Slavonija se sastojala od osam županija, od kojih su Požeška, Virovitička i Srijemska županija bile u Slavoniji, poljoprivredno najrazvijenijoj regiji i glavnoj žitnici. Prema popisu gospodarstva i stoke od 31. prosinca 1895. godine, u svih osam županija se u poljoprivredi koristilo 1.211 strojeva na paru, to su bili pogonski i radni strojevi, kao i parni plugovi. Od toga: 451 lokomobil, 359 vršalica, 20 parnih plugova i 151 pod ostali strojevi na paru. U Slavoniji je na poljoprivrednim gospodarstvima bio ukupno

1.041 stroj na paru (85,96%), od toga 381 lokomobil (84,48%), 501 vršalica (85,06%), 15 parnih plugova (75,00%) i 144 ostalih parnih strojeva (95,36%). Prema navedenom vidljivo je da je Slavonija suvereno dominirala u korištenju parnih strojeva i parnog pluga u poljoprivredi. Prednjačile su Virovitička i Srijemska županija koje su ukupno imale 957 strojeva na paru (79,03%) od čega 347 lokomobila i 15 parnih plugova, a ostale županije su ih imale znatno manje ili ih nisu imale (tablica 2).

Tablica 1 Površina svih gospodarstva i broj gospodarstva s površinom od 575,5 ha (1.000 jutara) i više prema županijama (Popis gospodarstva i stoke od 31. prosinca 1895. i Statistički godišnjak Kraljevine Hrvatske i Slavonije I. 1905.)
Table 1 Area of the farms by counties and number of farms with 575,7 ha and over (Statistical data from 1895 and 1905)

Županija County	Površina gospodarstva / Area of the farms ('000 ha)						No. of farms with 575,5 ha and over
	Sva gospodarstva All farms			Gospodarstva s 575,5 ha i više Farms with 575,7 ha and over			
	ukupno total	oranica i vrt[1] arable land	šuma forest	ukupno total	oranica i vrt arable land	šuma forest	
Lika-Krbava	163	90	4	-	-	-	-
Modruš-Rijeka	250	100	57	48	0,3	45	6
Zagreb	497	233	121	75	13	44	44
Varaždin	221	90	72	35	9	20	30
Bjelovar-Križ	313	196	33	24	4	16	11
Požega	322	157	93	94	7	82	14
Virovitica	436	202	155	245	54	153	72
Srijem	481	337	43	81	25	40	32
Ukupno/Total	2.683	1.405	580	603	112	399	209[2]

[1] Ukupna površina oranica za Hrvatsku i Slavoniju je iznosila 1.350.507 ha (96,12%), a vrtova 54.554 ha (3,88%).
[1] Total area of arable land in Croatia and Slavonia was 1,350,507 ha (96,12%), and vegetable gardens 54,554 ha (3,88%)
[2] Ukupno je bilo 30 gospodarstva s površinom većom od 5.755 ha (10.000 jutara), 15 u Virovitičkoj, 5 u Požeškoj županiji i 10 u ostalim županijama
[2] Total of 30 farms larger than 5,755 ha (10,000 k.j.) existed, 15 in Virovitica county, 5 in Požega county, and 10 in other counties

Lokomobili su bili najzastupljeniji na velikim gospodarstvima s površinom od 575,5 ha (1.000 jutara) i više, dok su parni plugovi bili najzastupljeniji na gospodarstvima s površinom od 11,5 do 57,5 ha (20-100 jutara) i to u Srijemskoj županiji (tablica 2). Može se pretpostaviti da su ta gospodarstva bila udružena s drugim gospodarstvima ili su nudila uslugu oranja drugim poljoprivrednicima. Velike površine oranica i veći broj velikih gospodarstava u županijama kao što su Virovitička i Srijemska (tablica 1) omogućavali su veća ulaganja u parne strojeve. Niz krupnih imanja u Slavoniji je raspolagalo s velikim šumskim kompleksima koji su često donosili veću dobit od poljoprivredne djelatnosti, što je sve do prvog svjetskog rata nepovoljno utjecalo na zainteresiranost slavonskih veleposjednika za daljnje unapređivanja vlastitih agrarnih privrednih jedinica (Karaman, 1986). Bez obzira na činjenicu da je slavonska zemljoposjednička aristokracija veći dio prihoda ostvarivala prodajom drvne sirovine parnim pilanama i drvnoprerađivačkim poduzećima, provela je modernizaciju i racionalizaciju poslovanja na poljoprivrednim gospodarstvima uvođenjem parnih strojeva. Može se pretpostaviti i da se dio profita iz šumskog kompleksa preusmjeravao i u modernizaciju poljoprivrede. U Virovitičkoj županiji su gospodarstva s površinom od 575,5 ha (1.000 jutara) i više imala ukupno 152.553 ha pod šumama, a u Požeškoj županiji 81.674 ha, što je zajedno iznosilo oko 40% od ukupnih površina pod šumama za sva gospodarstva (tablica 1).

Tablica 2 Broj lokomobila i parnih plugova prema županijama i površini gospodarstava u 1895. godini (Statistički godišnjak Kraljevine Hrvatske i Slavonije I. 1905.)
Table 2 Number of portable steam engines and steam ploughs by counties and farms area in 1895 (Statistical data from 1905)

Županija County	Br. No.	Površina gospodarstva / Farm size (ha)					Ukupno Total
		2,9 - 11,5	11,5 - 57,5	57,5 - 115,1	115,1 - 575,5	> 575,5	
		jutro (1 k.j. $\approx$ 0.5755 ha)					
		5 - 20	20 - 100	100 - 200	200 - 1000	> 1000	
Lika-Krbava	LM [1]	-	-	-	-	-	-
	PP	-	-	-	-	-	-
Modruš-Rijeka	LM	-	-	-	-	1	1
	PP	-	-	-	-	-	-
Zagreb	LM	-	-	-	7	17	24
	PP	-	-	-	-	-	-
Varaždin	LM	-	-	-	6	18	24
	PP	-	-	-	-	-	-
Bjelovar-Križevci	LM	1	9	1	4	6	21
	PP	1	2	-	2	-	5
Požega	LM	5	3	2	13	11	34
	PP	-	-	-	-	-	-
Virovitica	LM	1	10	17	34	107	169
	PP	-	-	-	-	1	1
Srijem	LM	8	48	37	33	52	178
	PP	-	11	-	-	3	14
Hrvatska i Slavonija	LM	15	70	57	97	212	451
	PP	1	13	-	2	4	20
Površina i broj gospodarstava u Hrvatskoj i Slavoniji / Size and number of farms in Croatia and Slavonia ('000 ha)							
Ukupno / Total		1.112	601	42	98	603	2.456
Oranica / Arable land		670	374	25	43	111	1.223
Šuma / Forest		81	46	7	29	399	562
Br. gosp./ No. of farms		192.656	33.433	550	380	209	227.228

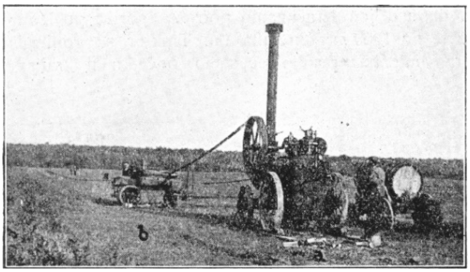
[1] LM – lokomobil, PP – parni plug / LM – locomobile, PP – steam plough

Vršidba žitarica strojevima u Hrvatskoj i Slavoniji 1918. godine

Prema izvještaju o uspjehu vršidbe u 1918. godini ukupno se koristilo 5.961 strojeva za vršidbu (Glavni izvještaj, 1918), i ovršeno je 304.664 t žitarica (pšenica, raž, ječam i zob). Pogon s parnim strojem je imalo 2.174 strojeva za vršidbu (36,47% od svih vršalica), i oko 96% ih se koristilo u tadašnjoj Slavoniji. Motor s unutarnjim izgaranjem je pogonio 618 strojeva za vršidbu (10,37% od svih vršalica). Zanimljivo je napomenuti da se u Fantonijevoj knjizi Gospodarsko strojarstvo (1929a) navode i motorni lokomobili s motorom s unutarnjim izgaranjem umjesto parnog stroja i kotla, a „Motori i lokomobil za petrolej, benzin, špirit i plin. Bez pogibelji od vatre i eksplozije!“ se počinje oglašavati u Gospodarskom listu od 1900. godine (br. 13). U prvim desetljećima 20. stoljeća zavisno od snage lokomobila i dimenzije bubnja učinak vršalica je iznosio od 430 do 1.700 kg zrna pšenice u 1 h; za efektivnu snagu od 3,7 do 19,9 kW (5-27 KS), dužinu bubnja od 760 do 1.530 mm i promjer bubnja od 500 do 610 mm (Fantoni, 1929a).

PRIMJENA LOKOMOBILA U ISPITIVANJIMA ZAVODA ZA OPĆE I GOSPODARSKO STROJARSTVO

Današnji Zavod za mehanizaciju poljoprivrede osnovan je 1919. godine kao Zavod za opće i gospodarsko strojarstvo na Gospodarsko – šumarskom fakultetu Sveučilišta u Zagrebu i 1922. godine dobiva pravo ispitivanja gospodarskih strojeva i oruđa. Osnivač Zavoda, prof. Raimond Fantoni je 1926. godine na fakultetskom dobru u Maksimiru u Zagrebu proveo ispitivanje kvalitete oranja s lokomobilom koji je preko remenice pogonio mehanizam za mijenjanje brzina s vitlom kao zasebnim strojem (slika 4).



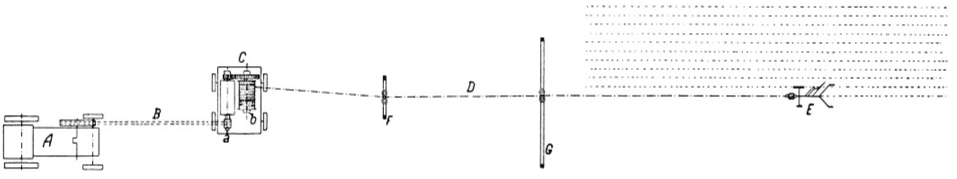
a

b

Slika 4 a Ispitivanje oranja iz 1926. godine s lokomobilom i plugom vučenim užetom preko mehanizma za mijenjanje brzina, **4 b** mehanizam za mijenjanje brzina
(izvor: Fantoni, 1929a i 1929b)

Figure 4 a Ploughing research with agricultural locomotive and haulage system with plough, steel cable and gearbox mechanism in 1926, **4 b** gearbox speed-change mechanism
(source: Fantoni, 1929a i 1929b)

Jednobrazdni plug s ručkama je vuklo čelično uže koje se namatalo na vitlo na mehanizmu za mijenjanje brzina (slika 5). Cilj istraživanja je bio utvrditi utjecaj brzine kretanja pluga na kvalitetu oranja, na izvršeni rad (utrošak snage) te kod koje je brzine oranje najpovoljnije. Donesen je zaključak da se za tlo na kojem su izvedeni pokusi i za oblik korištenog pluga, kod iste dubine oranja i za istu površinu troši manje rada u oranju s volovima koji oru brzinom od oko 1,6 km h^{-1}, nego s konjima koji oru brzinom od oko 2,5 km h^{-1}, a kvaliteta oranja je ista. Zatim, da se kod oranja strojnim plugom bolje ore pri većim brzinama, jače se sitni i rahli tlo. Na kraju rada Fantoni R. (1929a) u zaključku navodi: „da je u prilikama, u kojima su provedeni pokusi, optimum oranja brzinama između 4,9 i 6,2 km na sat".



Slika 5 Shema ispitivanja oranja iz 1926. godine, A - lokomobil, B - remen, C - mehanizam za mijenjanje brzine na kolima, b - vitlo, F - uređaj za pravilno namatanje užeta na vitlo, D - čelično uže, G - uređaj za vuču pluga u pravcu i E - plug (izvor: Fantoni, 1929a)
Figure 5 Ploughing research scheme in 1926, A – portable steam engine/agricultural locomotive, B – belt, C – gearbox speed-change mechanism on the waggon, b – winch, F – device for proper winding of a steel cable to a winch, D – steel cable, G – device for keeping ploughing in the direction and E – plough (source: Fantoni, 1929a)

Radovi s rezultatima istraživanja su objavljeni u vanjskim časopisima (Fantoni, 1927a, 1927b i 1934), u knjizi Gospodarsko strojarstvo (Fantoni, 1929a) i u prvoj Spomenici fakultetskog savjeta 1919. - 1929. (Fantoni, 1929b).

LOKOMOBIL SREDINOM 20. STOLJEĆA

Prestanku korištenja lokomobila u europskoj poljoprivredi sredinom prošlog stoljeća pridonijela je isporuka traktora iz SAD-a kao poslijeratna pomoć, povećanje broja žitnih kombajna, nestašica ugljena iza rata itd., ipak su se još neko vrijeme zadržali u cestogradnji (Jejčič, 2010). Nakon II. svjetskog rata su se još neko vrijeme koristili za pogon vršalica žita i oranje, a u nekim zemljama i do 1970-tih godina. Na imanju Belje je uloga parnih strojeva u osnovnoj obradi tla bila dominantna sve do 1956. godine i koristili su se do proljeća 1958. godine, godišnje se s lokomobilima oralo prosječno 8.400 ha, uz drljanje i tanjuranje (Musa, 1986). Za sustav oranja s dva lokomobila bilo je potrebno od 8 do 12 osoba, ovisno o udaljenosti od mjesta opskrbe vodom i gorivom. Na svakom lokomobilu su bila po dva ložača, zatim dvije osobe za upravljanje plugom, te od jedne do dvije osobe za dovoz vode i isto toliko za dovoz goriva. Radni dan osoblja na lokomobilu je započinjao od 2 ili 3 sata ujutro radi loženja i postizanja radnog tlaka pare za što je trebalo od 1,5 do 2 sata, i onda je moglo započeti oranje koje je trajalo sve do 18 ili do 20 sati. Lokomobil od 110,3 kW (150 KS) je mogao postići učinak u oranju od 2,27 ha h^{-1}, na dubini od 24 cm pri specifičnom otporu tla od 0,6 kg cm^{-2}, s korisnim učinkom oranja od 0,9 (računajući okretanja na uvratinama) i korisnim koeficijentom prijenosa snage na vitlo od 0,85 (Fantoni, 1954). Prema procjeni tadašnjih stručnjaka na Belju oranje se izvodilo kvalitetno bez sabijanja tla, osim toga strojevi su bili dugovječni u radu (50 i više godina) i snažniji u odnosu na tadašnje traktore (Musa, 1986).

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Sredinom 19. stoljeća počinje intenzivnija industrijalizacija poljoprivrede razvojem lokomobila, odnosno mobilnih parnih strojeva na kotačima koji su pogonili radne strojeve i koristili se za obradu tla. Obrada tla s parnim plugom se koristila na velikim posjedima i počela je gubiti na značaju 1920-tih godina što je uzrokovalo postepeno smanjenje proizvodnje lokomobila. U Hrvatskoj su procesi industrijalizacije i modernizacije poljoprivrede počeli kasnije i odvijali su se sporije u odnosu na zapadnoeuropske zemlje. Izgradnja kopnenih i vodenih prometnica, spajanje s postojećom željezničkom prugom Beč-Trst, jačanje i širenje urbanih središta, kao i početak druge agrarne krize potakli su 1870-tih godina uvođenje parnih strojeva na velikim poljoprivrednim gospodarstvima u Hrvatskoj i Slavoniji. U tadašnjoj Slavoniji kao poljoprivrednoj regiji i glavnoj žitnica bio je 1041 stroj na paru, što je iznosilo 85,96% od svih strojeva na paru koji su se koristili na gospodarstvima prema Popisu iz 1895. godine. Udio u lokomobilima je iznosio 84,48%, što također potvrđuje prevlast Slavonije u korištenju strojeva i oruđa na paru u poljoprivredi tadašnje Hrvatske i Slavonije. Virovitička županija je imala najviše velikih gospodarstva s površinom od 575,5 ha (1.000 jutara) i više, na kojima je bilo 107 lokomobila, a 15 gospodarstva je imalo površinu veću od 5.755 ha (10.000 jutara). U svih osam županija na velikim poljoprivrednim gospodarstvima s 575,5 ha (1.000 jutara) i više bilo je ukupno 212 lokomobila, a 50,48% (107 lokomobila) ih je bilo u Virovitičkoj županiji. Veleposjedi u Slavoniji su raspolagali s velikim površinama pod šumama koje su često donosile veću dobit od poljoprivrede, što je sve do prvog svjetskog rata nepovoljno utjecalo na daljnju modernizaciju velikih poljoprivrednih gospodarstva. Lokomobil se na Gospodarsko – šumarskom fakultetu Sveučilišta u Zagrebu koristio i u znanstvenoistraživačkoj djelatnosti. Prof. R. Fantoni je 1926. godine na pokušalištu Maksimir proveo pokuse s ciljem utvrđivanja utjecaja brzine gibanja pluga na kvalitetu oranja. Ispitivanja su izvedena s lokomobilom, mehanizmom za mijenjanje brzina i plugom vučenim užetom, te je utvrđeno da se kod oranja strojnim plugom bolje ore pri većim brzinama, jače se sitni i rahli tlo. Optimalne brzine oranja su iznosile između 4,9 i 6,2 $km h^{-1}$ s obzirom na stupanj rahlosti tla i uloženi rad. Lokomobil se u poljoprivredi zadržao još do sredine 20. stoljeća, uglavnom za pogon vršalica žita. Glavni razlog prestanka korištenja lokomobila je bila sve veća dominacija traktora s motorom s unutarnjim izgaranjem, a kasnije i sve raširenija primjena kombajna. Obrada tla s parnim plugom se na imanju Belju koristila do 1958. godine.

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STEAM LOCOMOBILE IN CROATIAN AGRICULTURE WITH A STRESS ON 19TH CENTURY

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ABSTRACT

The development of locomobile as a portable steam engine began in the 1840s in England and it has been in use in agriculture for over 100 years. In the 1920s it began to lose importance with the introduction of tractors powered by internal combustion engines. At first, it was mainly used to propel threshers, and later in soil tillage by means of winding drum and steel cable. The processes of industrialization and modernization of agriculture in Croatia began later and unfolded slower compared to West European countries. Croatian lands were until 1918 part of the Austro-Hungarian monarchy, within which Croatia and Slavonia were a separate territory with parliament and governor (ban). The second agrarian crisis which hit Europe between 1870 and 1895 stimulated large agrarian estates in Croatia and Slavonia to introduce steam machines for the purpose of rationalization of plant production, but there was also part of the economy with extensive agriculture which was not financially capable of carrying out this modernization. On agrarian estates in Croatia and Slavonia in 1895 there was a total of 1211 machines and agricultural tillage tools powered by steam, of which 451 were locomobiles. Slavonia as the most developed agrarian area and the main source of wheat headed this trend with 1041 engines and agricultural tillage tools powered by steam (85.96%) of which number 381 were locomobiles (84.48%). Locomobiles were mostly represented on estates with an area of 575.5 ha (1000 acres) and larger. They accounted for 212 of such machines, 107 of which were in the Virovitica County. Prof. Raimond Fantoni, the founder of the Department for Agricultural Engineering at the Faculty of Agriculture of the University of Zagreb, began in the 1920s to test the quality of tillage with locomobiles, gearbox mechanism and plough pulled by steel cable. Steam ploughing was a dominant technology on the Belje estate in Baranja until 1956 and was applied until spring of 1958.

Keywords: *locomobile, transportable steam machine, steam plough, Croatia and Slavonia, industrialization of agriculture*

47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

ELECTRIFICATION OF MOUNTED IMPLEMENTS - CONCEPTS OF TRACTION ASSISTANCE

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ABSTRACT

Electrification is a futuristic agricultural technology. Some tractor manufacturers offer electrical generators on their tractors. Transferring traction power into electrical energy is still a novel concept in agriculture; however, the technology can be realized. Although electrical assistance of trailer axles is available, mounted implements with traction assistance are not available yet.

We present, test, and analyze new concepts for electrical traction support. Possible scenarios are tested and analyzed. With the intent to maximize the variety of possible operation modes, ultimately to enable agricultural implements using electrical assistance to achieve high market penetration and to be a worthwhile investment for farmers.

The results of our work show that traction support between crop rows is possible. Our work has also led to new agriculture methods using mounted implements in untilled soil. Considering the space needed for the crop rows, the driving unit is formed without spaces between the traction elements. For a wide range of row spacing, no damage to crops will occur. Mounted implements are usefully applied several times a year for different purposes, according to concepts presented herein.

We also examined the feasibility of supplementary features. For example, in addition to a system height adjustment while operating, we added a soil-reworking function: Depending on the prevailing soil conditions, it is possible to generate positive slippage on the soil surface and, thus, actively shift the uppermost soil layer.

The concept of electrification of mounted implements is just a starting point for further developments. It will promote the general use of electrical support in agriculture.

Keywords: *Electrification, mounted implements, concept study, traction assistance*

INTRODUCTION

Liquid manure and fermentation residues of biogas are important suppliers of nutrients in present-day agriculture. Because, penetrate the soil immediately during application, nutrient losses and ammonia emissions can be avoided. In addition, microbial biomass is rises with soil tillage using a grubber (Murugan et al. 2014). For tilling loamy soils and clay, either a high draft force is needed for the grubber, as investigated by Ranjbarian et al. (2017) for different tillage implements, or the upper soil layer has to be cut first (Middelton 1821). Chen (et al. 2013) worked on a design for slurry-injection tools that would prevent high draft force before a prototype mounted implement was built. Laguee (1991) presented a semi-liquid manure spreader/injector; however, he also had considered draft force. Slurry penetration into loamy soils and clay is unusual; however, with electrification of mounted implements, it is possible to develop traction units intended to reduce the required draft forces for these soils and clay. These developments allow multiple uses of such slurry-application units.

Concepts presented here are preparatory for the construction of different models and functional configurations. First, we must consider all the requirements and needs of every possible agricultural crop. The *status quo* is not the only reason for such considerations. Since electrification is a futuristic technology, we have to evaluate the potential of this new class of implements. We expect the electrification of mounted implements to accelerate developments in agriculture.

Some tractor manufacturers already offer electrical generators on their tractors. By using concepts such as transferring electrical energy to apply traction to draft force, novel designs in agricultural technology can be realized. Although electrical assistance for trailer axles is already available - there are new studies such as those about electrification of tractors (Ueka et al. 2013) or about combinations of tractor and mounted implements (Tetzlaff, 2015).

MATERIALS AND METHODS

All the concept studies were created with Autodesk Software. The application-unit toolset generally specifies that a traction unit is in front of a slurry grubber unit and that both of them are in front of the resealing unit. These defaults were applied to all the following concept levels during our investigation. We used an electric motor in the first traction unit to provide better traction on unloosened soil. After the traction unit passed over the soil surface, the grubber unit cut into the soil for liquid-manure application, and then we resealed the soil to prevent ammonium emissions and water losses.

Basic design and dimensions of the mounted implement

The traction unit has a width of three meters. This is necessary so that a folding mechanism can extend the working width to six meters. For each tree-meter-wide component of the traction roller, only one electric motor is needed. The total weight should not exceed three tons. Otherwise, problems could occur when the implement is mounted to a slurry trailer, for which it is designed. The traction roller is the heaviest component. Therefore, it has to be placed nearby the mounting point of the implement.

Specification and layout of the traction roller for maximum traction power reduction

The aim of this concept study is to achieve a traction power reduction of 40% up to 50%. Comparing the values given in Heyde (1971) for different soil types and moisture grades, tires are not a good choice to be mounted on the traction roller. Preferably, we will choose elements like a spike tooth roller. Thus, the expected values of 0.7 up to 0.8 presented by Heyde (1971) as maximum for driving force values on soils with caterpillar track might be reached.

We divided the overall concept into several levels involving successive considerations and/or steps, as follows.

Concept Level 1: As a first step, construction choices are considered in view of having an agricultural crop already growing in the field. An optimal contact between soil surface and traction element is important for the traction unit to allow safe and effective traction force. The second consideration is customized construction, if a standing crop is in the field, as the agriculture crop has to be protected. The traction elements should run between the plants and account for row spacing. For this purpose, we researched prior-published information on usual row distances for agricultural crops. We also focus on newer crops and renewable resources.

Concept Level 2: We stipulated that the results from Concept Level 1 should be interchangeable and convertible. For this purpose, we expand construction considerations further based on outcomes from Concept Level 1.

Concept Level 3: After configuring the basic layout of electrified mounted implements, we present potential new features based on requirements of the agricultural crops. We considered the use of the new electrified application units several times a year and sought to maximize a variety of effective methods for use in agriculture.

RESULTS AND DISCUSSION

Concept Level 1

This first model uses a continuous roller that can work in the field even without a standing crop. Figure 1 shows the possible construction of the mounted implement. Exemplary, we use a spike-tooth-roller design in the graphics.

In a field without a growing crop, the electrified traction roller can be constructed uniformly. The whole soil surface can be used for generating traction with the electrified element. After the traction roller is used, the manure unit passes with the application grubber. This unit opens up the soil and applies the fertilizer to the defined penetration depth. Finally, a third tool unit reseals the soil. Having a single roller as the traction element can mean very cost-effective construction. Having more rollers traverse the whole soil surface can increase soil moisture because of the higher surface traffic (Altikat et al., 2018).

When a standing crop is in the field, to prevent damage to the agriculture crop, we have to separate the single traction roller into multiple traction elements that run between the planted rows. Consequently, the contact area of the traction elements with the soil surface is smaller.

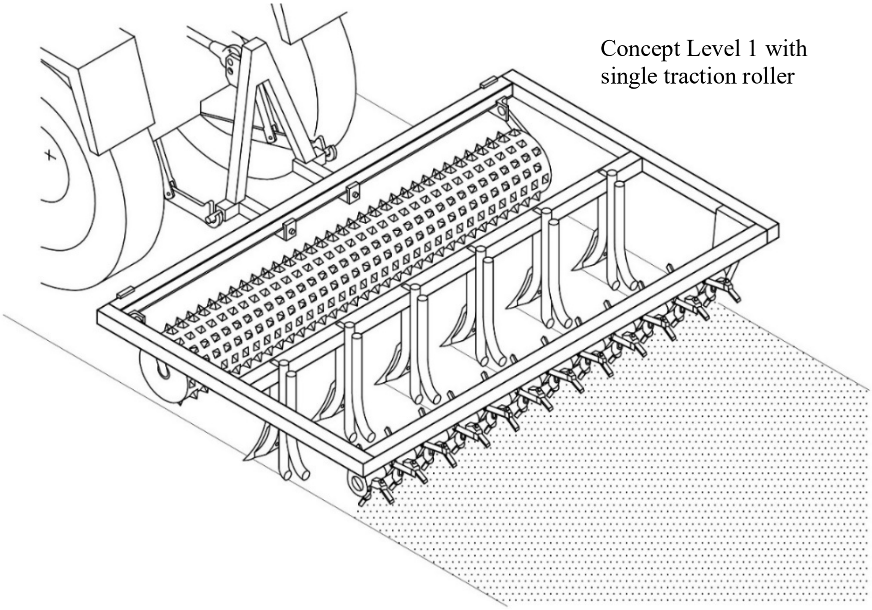

Figure 1 Application unit in field without standing crop
(Traction element is single roller covering whole working width)

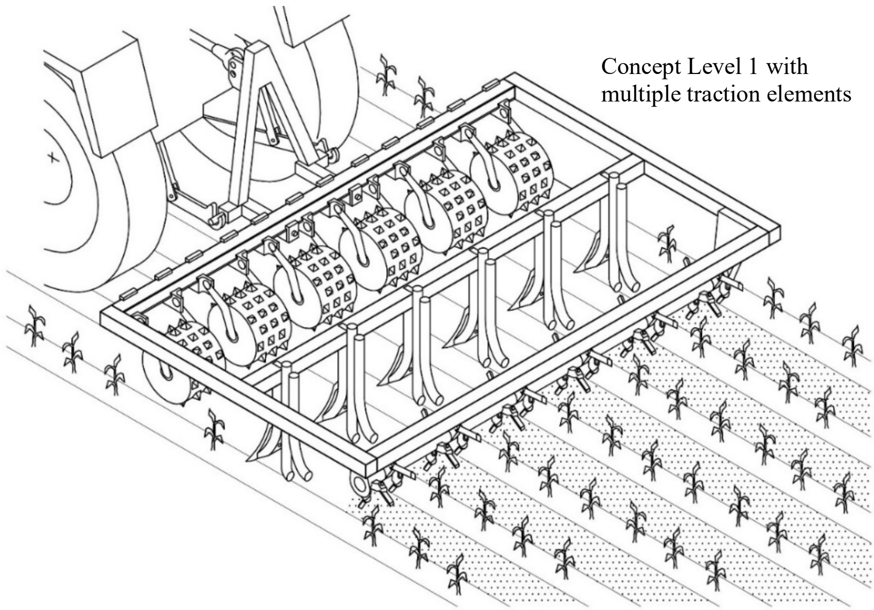

Figure 2 Traction roller segmented several times
(Traction takes place only at row spacing of agricultural crop)

The traction elements` bearing surface is smaller. The slurry can only be applied between the plants in the evenly spaced rows. Another consideration is standing-crop height, as it is easy to imagine that the axis of the traction elements could streak and damage the plants. Until the later stages of plant growth, the electrified mounted implement can be used several times to apply manure to the soil. For multiple traction elements to be fixed on an axle, much more money is needed to construct the prototype and generate the final design.

Table 1 Row spacing for construction of multiple traction elements.

Crop	Minimum row spacing (cm)	Maximum row spacing (cm)
maize	37.5	75
winter rape	37.5	50
beet	45	50
potato	75	90
corn	20	25
millet	30	75

In most agricultural settings, maize is cultivated with a row spacing of 75 cm. For prototype construction, this width could be a good choice for the traction elements. To use electrified mounted implements for corn, the small row spacing reduces the traction area between rows of the standing crop. In addition, we have to consider that new plant breeding may lead to crops with different optimum row spacing. Therefore, we need to consider existing and potential crops in the design for prototype construction. For example, millet is not a focus of agriculture in industrialized nations; however, in the face of climate change and global warming, millet could gain importance for plant breeders and farmers. With the ability to stop plant growth under drought conditions and restart growth as conditions improve, millet is able to handle climatic difficulties much more easily than many other crops.

Concept Level 2

The requirement of just simple tools to convert the electrified traction unit from a single full-width roller to multiple elements on continuous axle is important. Figure 3 shows such changeable.

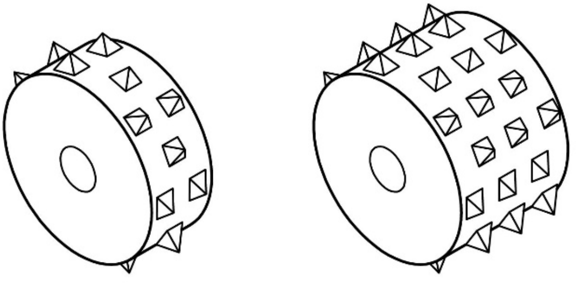

Figure 3 Two possible widths of traction elements

Dividing the continuous roller (Concept Level 1) into smaller elements, we can exchange the one large roller for several smaller elements to be combined and mounted on axis. Thus, in theory, many different roller widths and distances between the elements are possible. The structure of the traction unit can be changed in both directions - in the continuous roller (by adding more and smaller elements) as well as in the segmented traction elements (by adding small elements until the traction element accommodates row-spacing width). This design flexibility allows the entire tool combination to be adapted to different ground and crop conditions. If changeability is made an integral part of the design of the application unit, several structures for the assembly on the traction axle can be tested and considered. Figure 4 shows further structural elements.

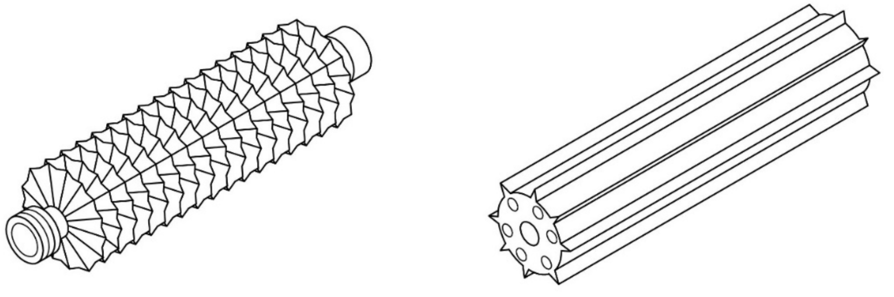

Figure 4 Two possible structural elements for traction unit, each of which can consist of multiple smaller design segments

For the replacement of the traction elements, the electric unit and the electric motor should not have to be completely disassembled. For making a quick exchange of the structural elements, it is advantageous if they are designed as half-shell elements. One person can disassemble these half-shells easily, separate them, or put them together again in a different order. A continuous electrified axis that connects all elements is required.

Figure 5 shows a single traction element. The vertical lines on both sides of the elements represent the possible separation range of the half-shell elements. Simple assembly can be done by machine-screw mounting in two sides of every half-shell.

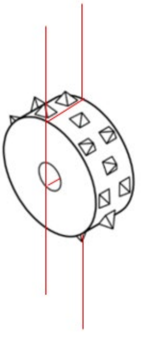

Figure 5 Half shells with vertical lines through traction element

Concept Level 3

After introducing new concepts of electrified traction tools on mounted implements (Concept Level 1), we can test the feasibility of adding further functions (presented below).

Aspect 1: Active high adjustment

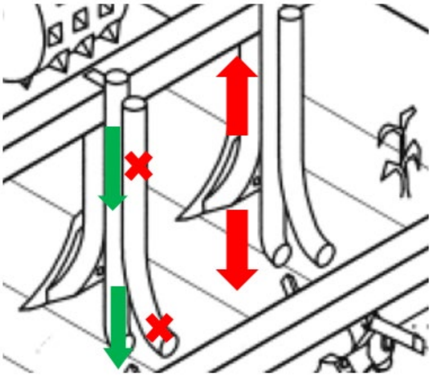

Figure 6 Manure application unit with two slurry pipes for different row spacing

In Figure 6, the manure grubber on the right side shows the possible height adjustment of the application unit (to accommodate different slurry penetration depths of the whole system) and two fertilizer tubes (to provide two single-slurry working depths). Each pipe can be closed or opened individually. This configuration offers a form of dosing system for slurry application. The expected working depth can be up to 0.25 meters.

Aspect 2: Positive slippage system

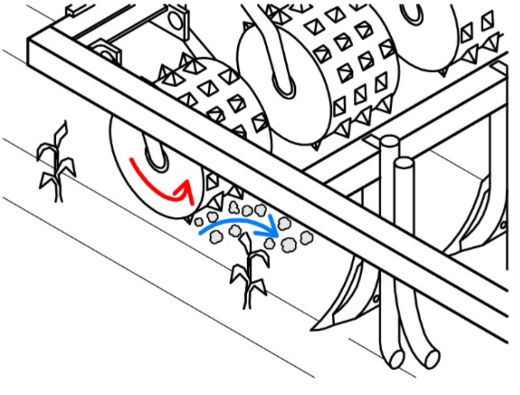

Figure 7 Traction elements with variable rotation speed between the row spacing in standing crops

The traction elements as shown in Figure 7 can operate at a higher rotation than necessary for the driving speed. This creates positive slippage on the soil surface and may loosen soil particles. Moving the upper soil layer, weed control can be applied between the standing crop plants. The left arrow (pointing upward) represents the higher speed on the elements and the right arrow (pointing downward) represents loosened soil, which is redeposited toward the rear.

To visualize this new feature, we plan to make a virtual slippage test as described by Yin and Lu (2010). For calculating the balance between tractor and implement, we intent to use several computer-based models as described by Battiato and Diserens (2017). A next step also might be a test scenario running on a software platform as shown by Lee et al. (2016) or a mathematical calculation as presented by Janulevicius et al. (2018).

CONCLUSIONS

The presented concept study for electrified implements mounted on farm equipment evaluates new modes of operation for agriculture. Using the example of fertilizer application, the working scenarios are flexible and reliable. The further development of such electrified devices will also lead to changes in crop cultivation, including making other crops practicable. In addition, the modular design of the tool combination makes it possible to adapt the agricultural system quickly in the field. Without a changeability of traction elements, the whole machinery design would be easier; however, the disadvantages would predominate. The upcoming field trails will show whether we receive the expected traction power reduction.

ACKNOWLEDGMENTS

My thanks go to Prof. Dr. Dr. Bernhardt and his support for the project KombiWKZ. As well, I would like to thank the partners on the Technical University of Dresden for the support. The Federal Ministry of Food and Agriculture fund the KombiWKZ project. The project carrier BLE also provides support.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

IMPACT OF REDUCED TILLAGE ON SPRING OIL SEED RAPE, WINTER WHEAT, MAIZE AND SPRING BARLEY PRODUCTION IN LITHUANIA

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ABSTRACT

Climate and soil conditions strongly effects impact of reduced tillage systems on productivity of agricultural crops. Plenty scientific investigations conclude that the most positive effect of tillage reduction was found in warm arid climate conditions.

A long-term stationary field experiment (30 years) was performed at the Experimental Station of the Aleksandras Stulginskis University (ASU, 54°52' N, 23°49' E) on silty light loam Endohypogleyic-Eutric Planosol and in semi humid (about 650 mm annual precipitation rate) subarctic climate (annual average temperature 6.5-7.2° C) conditions. Sugar beet, maize and faba bean crops were investigated.

Five different primary tillage systems were tested: conventional (22–25 cm) and shallow ploughing (12–15 cm) with a mouldboard plough, chiselling (25-30 cm), disking (10-12 cm) and no-till.

According to the results of investigations, long-term reduced tillage mainly had no significant effect of crop productivity. No-till system slightly decreased crop productivity because of problems with seed germination in untilled stubble of winter wheat. However, differences were weak and mostly insignificant. We *found negative correlations between stubble coverage and germination rate and germination rate and productivity parameters.*

Keywords: *long-term tillage, productivity, spring rape, winter wheat, maize, spring barley.*

INTRODUCTION

In agricultural crop production, a very high proportion of the total labour and energy costs are used for tillage and sowing operations. Seed emergence, crop growing conditions, yield and its quality indicators are dependent on the quality of performance of these operations. In recent years in agriculture, it has become increasingly important to produce low-cost, high-quality produce able to compete on the global markets. As a result, one of the ways to decrease agricultural production costs is simplification of production technological processes through the application minimum (reduced) soil tillage systems. It has been evidenced that reduced tillage intensity results in greater conservation of soil, which is the main means of agricultural production (Telles et al., 2018; Chaghazardi et al., 2016).

With the application of reduced pre-sowing tillage, the soil structure is subject to lesser damage, the microorganism activity becomes more intensive, post-harvest residues are mixed in the upper soil layer, which prevents them from being stratified. Moreover, reduced tillage requires less fuel and labour input. In the soils exposed to wind and water erosion, reduced tillage or even direct drilling into undisturbed soil is a good protection against these undesirable factors (Latifmanesh et al., 2018; Zhang et al., 2018; Jodaugienė, 2002). D. Šimanskaitė (2007) has reported that the productivity of direct-drilled winter wheat and maize was the same as that in the soil ploughed at a usual depth. Noticeable differences or even contradictory or ambiguous findings are often observed among the results of reduced tillage investigations carried out in Lithuania and other countries. The data of other researchers evidenced that with the application of reduced tillage crop productivity declined (Cannell, Hawes, 1994; Diaz-Zortia, 2000). The effect depends on specific soil and climate conditions, amount of plant residues, peculiarities of design of implements and other factors.

Considerable know-how on the feasibility of direct drilling into undisturbed soil, especially under drier climate conditions, has been accrued in foreign countries. However, direct drilling into undisturbed soil under wetter Lithuania's climate conditions has hardly been studied before. The shift to reduced tillage, and especially to direct drilling into undisturbed soil, poses quite a few problems and requires more knowledge about soil and crop properties (Bogužas et al., 2010).

The study was aimed to establish the effects of different long-term autumn tillage on agrocenoses when applying intensive technologies and crop rotation.

MATERIAL AND METHODS

The long-term (since 1988) stationary field experiment has been performed at Aleksandras Stulginskis University, Experimental Station (54º52′ N, 23º49′ E). Research objects were agrocenoses of spring oilseed rape (*Brassica napus* L.), winter wheat (*Triticum aestivum* L.), maize (*Zea mays* L.) and spring barley (*Hordeum vulgare* L.). The soil of the experimental field is *Endohypogleyic-Eutric Planosol – PLe-gln-w* (WRB 2014). The depth of the ploughing layer is 23–27 cm. Soil texture – loam on heavy loam. The upper part of the plough layer (0–15 cm) contained: pH_{KCL} – 6.6–7.0, available phosphorus – 131.1–206.7 mg kg^{-1}, available potassium – 72.0–126.9 mg kg^{-1} (Romaneckas et al., 2015).

Prof. dr. A. Stancevičius was the initiator and leader of the experiment. At that time the experiment was conducted in the six-course crop rotation. Since 2001, the experiment has been modified by prof. dr. V. Bogužas by introducing direct drilling treatment and four-course crop rotation. The experiment is being continued. Five primary (autumn) tillage methods were investigated:

1. Deep conventional ploughing at 22–25 cm depth (DP) (control treatment);
2. Shallow ploughing at 12–15 cm depth (SP);
3. Deep cultivation at 23–25 cm depth (DC);
4. Shallow cultivation-discing at 12–15 cm depth (SC);
5. No tillage (direct sowing) (NT).

Crop rotation was used: spring rape – winter wheat – maize – spring barley. Experiment design: 4 replications, 20 plots per crop, randomised distribution. The *brutto* size of plots was 126 m^2 (14 x 9 m), and the netto size was 70 m^2 (10 x 7 m).

Tillage practice in the experiment is presented in Table 1. Before a sowing, the soil was shallowly cultivated with a cultivator Laumetris KLG-3.6), fertilizers were distributed with a fertilizer spreader AMAZONE-ZA-M-1201. The crops were sown with Väderstad Rapid 300C Super XL sowing machine. Weeds control was performed by spraying with a sprayer AMAZONE UF-901. Crops were harvested with a small plot combine harvester "Wintersteiger Delta" (Avižienytė et al., 2013). Organic fertilizers and legumes were not applied (Derpsch et al., 2014).

Table 1 Primary tillage practice in the experiment, 2010-2012

Tillage system	Stubble tillage	Primary tillage	Equipment	Depth of tillage (cm)
Deep ploughing (DP)	Yes	Inversion	Mouldboard plough Gamega PP-3-43 with semi-helical mouldboards	22–25
Shallow ploughing (SP)	Yes	Inversion	The same as DP	12–15
Deep cultivation (DC)	Yes	Non-inversion	Chisel cultivator Kverneland CLC	23–25
Shallow cultivation (SC)	Yes, twice	No	Disc harrow Väderstad CARRIER 300	12–15
No tillage (NT)	No	No	None	0

Crop emergence and crop stand density (1st assessment) were assessed in 10 spots of a record plot in 1 m row. Emergence of cereals and oilseed rape was estimated 3 and 10 days after beginning of emergence and for maize – 3 and 25 days.

Crop stand productivity was determined by estimating oilseed rape and maize stand density (2nd assessment), productivity indicators (for spring rape: seed yield, 1000 seed weight; for winter wheat: productive stems number, grain yield, 1000 grain weight; for maize: kernel yield, 1000 kernel weight; for spring barley: productive stems number, grain yield, 1000 grain weight). Crop stand density (for spring rape and maize) and productive stems number (for cereals) were evaluated in 10 spots per plot in 0.06 m^2 area (for spring rape) or 1 m longitudinal row (for cereals and maize). Cereal and spring rape productivity was estimated by mechanical harvesting. Maize samples were collected manually.

Quality indicators of crops were established at the Agrochemical Research Laboratory of Lithuanian Research Centre for Agriculture and Forestry. Cereal and maize grain protein content was determined according to directive 72/199/EEC, rapeseed fat content – according to 71/393/EEB.

Tests data was statistically analyzed by ANOVA. Significant differences between treatments and the control treatment (deep conventional ploughing) were marked in the following way: * – differences are significant at the 95% probability level ($P<0.05$), or ** – differences are significant at the 99% probability level ($P<0.01$).

In Lithuania, climate is subarctic transitional maritime-continental with wet winters and moderate summers. Annual mean (last 59 years) precipitation rate in experimental site is 625.5 mm. In 2010 and 2011, crop vegetation was warmer and more humid than usual average of many years. The humidity of 2012 was similar with 2010 and 2011 but temperatures were nearly the average.

RESULTS AND DISCUSSION

In our previous investigations in the same experiment plots, we did not find significant influence of different tillage practice on sugar beet productivity (Romaneckas et al., 2006; Romaneckas et al., 2009). Similarly, in 2010-2012, different tillage practices did not have any significant influence on spring rape crop density and seed oil content, and for seed yield and 1000 seed masses (Table 2).

Table 2 The impact of different primary soil tillage on spring rape stand density, seed yield and quality parameters, the data averaged over 2010–2012

Soil tillage	Crop density at the end of vegetation m^{-2}	Seed yield t ha^{-1}	1000 seed weight g	Seed fat content (%)
DP	131.5	1.29	4.14	42.67
SP	136.8	1.26	4.11	42.67
DC	124.9	1.25	3.82	42.20
SC	128.2	1.35	4.02	42.01
NT	89.1*	1.47	3.93	42.00

Notes: * - significantly different at *P≤0.05* from the control treatment (DP) within rows. Abbreviations as in Table 1.

The correlation-regression analysis of the research data showed that the yield of spring rapeseed seeds largely depended on the crop density at the beginning and the end of vegetation (r = 0.606*; 0.533*), the 1000 seed weight – on crop density at the end of vegetation (r = 0.612*), and the fat content of seeds - on weed incidence (r_{number} = 0,846**; $r_{biomass}$ = 0.780**).

The effect of different primary tillage on winter wheat grain yield, 1000 grain mass and protein content were not significant. However, in NT plots, grains had by the 5.1% more protein that in DP plots (Table 3).

Table 3 The impact of different primary soil tillage on winter wheat stand density, grain yield and quality parameters, the data averaged over 2010–2012

Soil tillage	Crop density at the end of vegetation m^{-2}	Grain yield t ha^{-1}	1000 grain weight g	Grain protein content (%)
DP	356.6	7.33	40.01	9.77
SP	355.6	6.83	37.49	9.85
DC	366.5	6.48	40.15	10.07
SC	359.3	6.69	39.46	10.16
NT	328.2	7.36	41.63	10.34

Abbreviations as in Table 1. *P*>0.05

The winter wheat seed yield was partly dependent on the soil structure stability ((r = 0.563*), the photosynthetic active radiation (PAR) conditions (r = 0.671**); the 1000 seed weight - on the soil's physical and chemical properties ($r_{agregate\ stability}$ = 0.579*; r_{pH} = 0.721*; r_{P2O5} = 0.713*; (r_{K2O} = 0.785**) and weed number (r = –0.561*); grain protein content - on the soil chemical composition (r_{pH} = 0.748*; r_{P2O5} = 0.861**; r_{K2O} = 0.872**).

Different tillage practice has not significant influence on maize productivity and quality parameters (Table 4). All indices have the highest value in DP plots.

The kernel yield of maize and the mass of 1000 seeds partly depended on the density of crop (r = 0.725**; 0.904**) and weed number (r = –0.917**; –0.965**); and the protein content in the seeds was affected by the soil structure stability (r = –0.888**) and the PAR conditions (r = 0.797**).

Table 4 The impact of different primary soil tillage on maize stand density, productivity and quality parameters, the data averaged over 2010–2012

Soil tillage	Crop density at the end of vegetation m^{-2}	Kernel yield t ha^{-1}	1000 kernel weight g	Kernel protein content (%)
DP	8.3	7.68	210.09	6.46
SP	7.3	7.13	206.68	6.46
DC	7.5	6.93	188.19	6.68
SC	7.6	7.21	204.86	6.83
NT	7.8	7.29	214.91	6.61

Abbreviations as in Table 1. *P*>0.05

In the NT plots, the number of productive stems for spring barley was modestly on average 0.7% higher, and grain yield was 6.0% lower, 1000 seed mass, essentially 9% higher compared to the control; incidentally 8.2% lower grain protein content was observed in SC plots (Table 5).

Table 5 The impact of different primary soil tillage on spring barley stand density, grain yield and quality parameters, the data averaged over 2010–2012

Soil tillage	Crop density at the end of vegetation m^{-2}	Grain yield t ha^{-1}	1000 grain weight g	Grain protein content (%)
DP	342.8	4.96	46.09	11.11
SP	347.5	4.93	47.79	10.61
DC	333.1	5.04	48.00	10.26
SC	332.1	5.10	47.87	10.20
NT	311.1	4.66	50.25*	10.24

Abbreviations as in Table 1. P>0.05

Grain yield of spring barley mostly depended on soil structure stability (r = 0.698**) and amount of phosphorus (r = 0,851**), stand density (r = 0.648*), weed number (r = –0.788**) and protein content – on mentioned indices and PAR conditions (r = 0.673**).

CONCLUSION

Generally, in almost all cases, different primary tillage generally did not have any significant impact on the seed yield, 1000 seed weight and seed quality parameters of the crops tested. Significantly higher 1000 seed weight for spring barley was evidenced in the NT plots. Due to high amount of pre-crop residues on the soil surface in NT plots, sowing quality was worse than in tilled plots. That decreased crop stand density, but mainly insignificantly.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

THE IMPACT OF DIFFERENT SECONDARY TILLAGE ON QUALITY AND YIELD OF CARROT CROP (*DAUCUS CAROTA* L.)

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ABSTRACT

The field trial was carried out trying to establish the effect of soil tillage on the quality and yield of carrot (Daucus carota L.) on loamy soil with stones in the soil layer. Early spring carrot variety Bilbo was used in the trial. Two types of soil cultivation machines were compared in order to prepare ridges with no stones for carrot production and harvesting. The first machine was rottary harrow which is used only for the cultivation and mixing of the soil aggregates in the upper soil layer (15-20 cm). The second machine was rottary cultivator with tines, which crush the soil aggregates in small pieces, while stones and larger soil aggregates are placed in lower soil layers. In such a manner the ridges are made of small soil aggreagets without stones and larger soil aggregates in them. The carot seeding and other agricultural operations were applied according to good agriculture practice. When the rotary harrow was used the ridges contained 20.5% of stones larger than 2 mm, while when using rotary cultivator with tines only 9.1% of stones remained in ridges. The average germination was 73.3%, the total yield reached 64.8 t ha^{-1} of which 32.6 t ha^{-1} (50.3 %) were labeled as extra grade, when the rottary harrow was used. The carrots were in general distorted 7,1° from the head to the nib of the carrot. The soil cultivation using the rottary cultivator with tines resulted with the average germination of 91 % with the total yield of 75.6 t ha^{-1}, of which 49.5 t ha^{-1} (65.5 %) were labeled as extra grade. The carrots, in this case, had curvature of 5.2°.

Keywords: *rotary cultivator, rotary harrow, carrot, quality, yield.*

INTRODUCTION

Cultivated carrot (*Daucus carota* L.) is biennial plant, developing roots of different shapes in the first year and in the second year it develops flowers and seeds later (Osvald and Kogoj Osvald, 2005). The enlargement of the upper part of the root begins, when 70 % of leaves mass is formed. The roots are used for human nutrition, when technological ripeness is achieved (Lešić et al., 2004).

When growing carrot roots push the soil upwards, so the good soil preparation is necessary for high and quality yield. The deep soil ploughing of 25 to 30 cm is needed for the growing of early carrot cultivars in the autumn. It is even better that lower soil layers are loosened using subsoil loosener just before ploughing. For later carrot seeding for autumn or winter harvest, the soil is cultivated in the spring, however it depends on soil condition and the previous crop (Lešić et al., 2004).

The soil should be suitable for cultivation, so that there are no compacted soil layers, which can cause significant root deformations (Strandberg and White, 1979). Carrot is usually sown on ridges, which are prepared before seeding. Seeding of carrrot on the ridges contributes to better soil aeration and lower percentage of greening upper parts of roots. Seeding layer of the ridge should be good leveled and fine structured, which is required for equal seeding depth. The soil should be consolidated, so that capillary connection with ground water is not disturbed (Bajec, 1994). It is also useful to use rollers after the seeding is done, which enables equal germination (Černe et al., 1989). Evers et al. (1997) reported that the total and marketable yields were larger in flat land and narrow ridge than in the broad- and compacted broad ridges at higher plant densities.

The aim of the trial is to establish how different secondary tillage helps to better quality of market yield and to find out the difference between total yield and yield of »extra class«. The carrots from extra claas yield should be of excellent quality and washed, with no surface defects, so that they not influence the quality, durability, and look in the packing box. The carrot roots should be smooth, fresh, regular shapes, without slots, mechanical damage and cracks and without damage because of frost. Green or violet root tops are not allowed.

We assumed that intensive secondary soil cultivation will contribute to higher and more uniform yield. We hypothesize that when using rotary cultivator with tines the percentage of market yield will be higher and better quality in comparison with the use of rotary harrow for secondary soil preparation.

MATERIALS AND METHODS

The field trial was designed in the spring of 2016 on stony soil in Drnovo, Slovenia (46,2° N; 14,6° E). The soil is shallow to medium deep with low field water capacity (31 – 80 mm) (Atlas okolja, 2017). In the autumn of 2015 the trial plot was subsoiled to the depth of 50 cm with the subsoiler. Then the trial plot was ploughed so that plant residues were incorporated using 5 furrow reversible plough, Lemken Variopal 8. The ploughing depth was from 25 to 30 cm and the speed ranged from 7 to 8 km/h. For the soil leveling hydraulically folding leveling bar 9 m width was used in the spring of 2016. The field was fertilised after the leveling of the soil and just before secondary tillage was done. Bogballe L2W plus fertilisier spreader was used with 18 m spreading width and calibration weighing system which is operated from the tractor cab. The hopper capacity was 2000 kg.

In the trial two types of machines for secondary tillage were used just before seeding of carrots. The first machine was rotary harrow Ranger Celli P 500 with tooth roller (Figure 1). The rotary harrow was hidraulically foldable with working width of 5 m and mass of 2100 kg. The maximal tractor power is 154 kW and the recommended power is 118 kW. The measures of the knives are 90 x 12 x 285 mm.

Figure 1 Rotary harrow Celli ranger P500 (Celli, 2008)

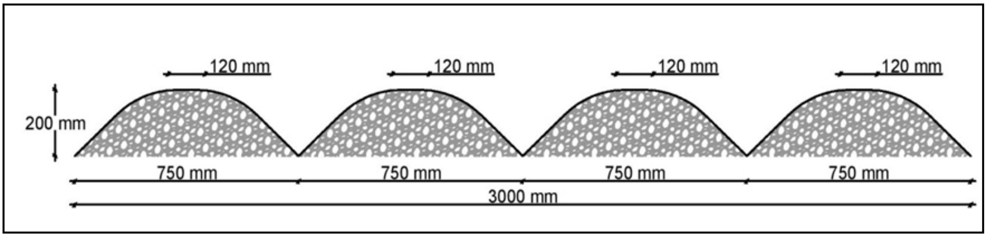

Figure 2 Ridges after the cultivation with rotary harrow

The second machine used in the trial was rotary ridging cultivator with tines Baselier UKFB 300, which crushes larger soil particles due to high rotor speed and separates stones from the soil particles (Figure 3). Stones are placed below the seeding layer, while fine soil is sieved through the special fork and it is used for the ridge formation (Figure 4). Rotor is driven by two cardan shafts in the centre of the machine, its rotational speed is 248 min^{-1}. 80 tines are fastened to the rotor with the working width of 3000 mm. The recommended tractor power is 125 kW, while the maximal is 191 kW. Mass of the machine is 2200 kg, its lenght 220 cm, width 348 cm and height 140 cm. Ridging bodies and the seeding machine could be attached to the rotary ridging cultivator (Baselier, 2017). The size of the individual trial unit was 3,0 ha.

Figure 3 Rotary ridging cultivator Baselier UKFB 300

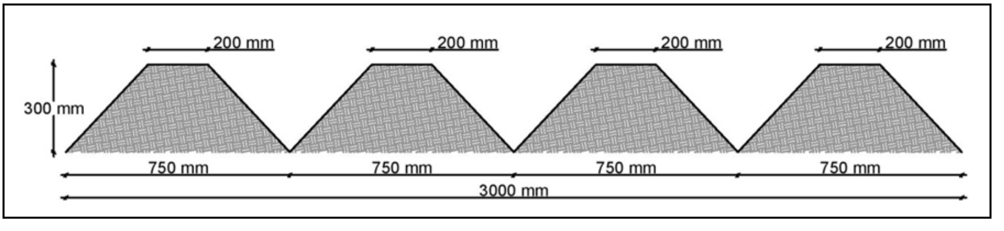

Figure 4 Ridges after the cultivation with rotary ridging cultivator

In the trial unit where the rotary harrow was used ridges were formed by the special ridging machine in the front part of the tracor. In this way 3 ridges were formed with the row width of 75 cm (Figure 2). Behind the ridging body was the leveling bar for the ridge leveling. The ridge height was 20 cm, while the righe top width reached 12 cm. At the same time the carrot seeding was carried out using seeding machine at the back part of the tractor.

The carrot seeding on the ridges was performed by the 4 row vacuum seeding machine Agricola Italiana SN-2-130 (Figure 5). The seed quantity was 1.330.000 seeds per hectare and the intra row distance was 1 cm. The seeding speed ranged between 5 to 8 km h^{-1}. The hybrid Bilbo was used in the trial. It is cylindrical shape with sharp top, its length is 20 cm and diameter of 2 to 3 cm.

Tractor Fendt GT with attached sprayer Rau with 2000 l tank and working width of 18 m was used for the chemical control of carrot.

Figure 5 Carrot seeding on ridges using pneumatic seeding machine

At the beginnig of July 2016 the soil samples were taken from the ridges, where the rotary harrow and also rotary ridging cultivator was used. On each treatment three random samples were taken. For two weeks soil samples were dried on 40 °C. Then the samples were crushed and stones were removed. Stones were sieved through sieves with meshes of 25 mm, 10 mm, 5 mm and 2 mm. Later on the mass and volume of stones of different fractions was measured. Soil texture was determined by standard procedure using texture triangle for the American texture classification (SIST ISO 11277, 2011; Soil survey, 1992).

Carrots were sampled at the stage of technological maturity at the beginnig of August 2016. From individual treatment sample carrots were randomly taken on 20 spots. Each sample was taken from 1 m long ridge, which coresponds the area of 0.75 m^2. Samples were placed to cooling room with air temperature of 1 to 2°C and relative humiditiy of 80 to 90 %. 39 to 98 carrots were in the individual sample. First the mass of individual carrot, its length and diameter were measured. Later on curvature of carrots were measured with the caliper in such a way that the deviation of carrot nib from the straight line was determined. From these data the angle was calculated, which represented curvature of carrots. Carrots of iregular shapes were eliminated from our analysis.

RESULTS AND DISCUSSION

Results of volume percentage of stones in the ridges show significant differences between ridges cultivated with rotary ridging cultivator and ridges cultivated with rotary harrow (Figure 6). 9.1 % of stones, larger than 2 mm, were found in ridges where rotary cultivator with tines was used. On the other hand there was 20.5 % of stones in ridges, larger than 2 mm, when rotary harrow was used, which was significantly higher in comparison with ridges cultivated with rotary ridging cultivator. When cultivation was done using rotary harrow there was 4.3 % of stones in the ridges, larger than 25 mm, which was significantly higher as by the use of rotary ridging cultivator with tines where no stones in ridges appeared. By the use of rotary ridging cultivator with tines 4.4 % of stones, with the size of 10 to 25 mm, appeared in the ridges while 9 % by the use of rotary harrow. The difference was significant.

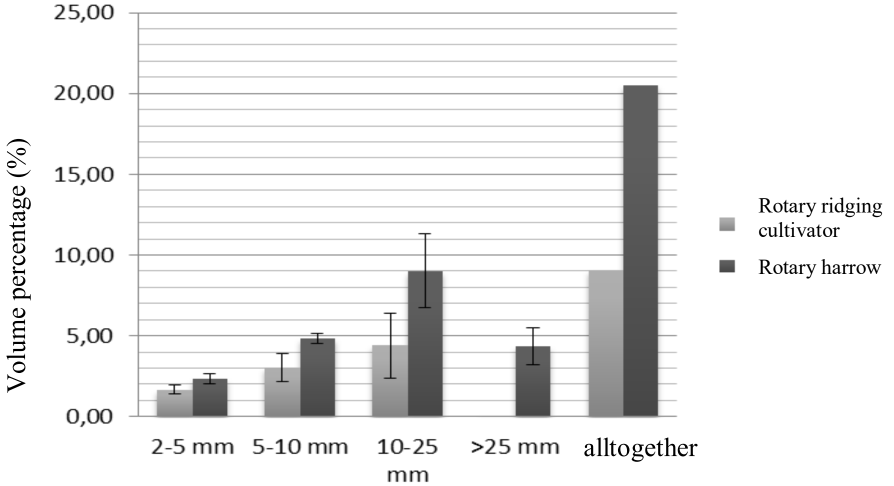

Figure 6 Volume percentage of stones in the ridges

There was 3 % of stones, with the size of 5 to 10 mm, when rotary ridging cultivator was used and 4.8 % by the use of rotary harrow. Also in this case the difference was significant. No significant differences occured between two machines by the stone size of 2 to 5 mm (2 %).

Soil texture was loam according to American soil texture classification and the soil belongs to middle heavy soil.

More intensive soil cultivation with the rotary ridging cultivator resulted also on significantly higher carrot yield of 75.6 ton ha^{-1}, while by the use of rotary harrow it reached only 64.8 tons ha^{-1} (Table 1). Mean germination was significantly higher (91 %), when rotary ridging cultivator was used, compared to 73.3 % by the use of rotary harrow. Higher seed germination by the use of rotary ridging cultivator resulted on higher crop density, on larger mass, length and diameter of one carrot. Mass of one carrot amounted 62.5 g by the use of rotary ridging cultivator and 69 g by the use of rotary harrow.

The lenght of carrots from the trial units cultivated with rotary ridging cultivator (153.1 mm) was higher than from the trial units cultivated with rotary harrow (151.9 mm). The carrot diameter amounted 26.9 mm by the rotary ridging cultivator and 28.8 mm by the rotary harrow. The difference was significant. The curvature of carrot was significantly lower (5.2°) in ridges formed with rotary ridging cultivator compared to ridges formed with rotary harrow (7.1°).

The carrots which do not fulfill demands for »extra« class, were removed from the yield. For the inclusion of carrots in the »extra« class it is necessary that mass of individual carrot is in the range between 30 g and 150 g. The carrot diameter should not be less than 20 mm and should not exceed 45 mm. The carrot curvature should not exceed 10°.

Table 1 Morphological properties of carrot

Treatment	Yield (t ha^{-1})	Mass (g)	Length (mm)	Diameter (mm)	Curvature (°)	Germination (%)
Rotary ridging cultivator	75.7 ± 2.5 a*	62.5 ± 3.8 a	153.1 ± 3.5 a	26.9 ± 0.7 a	5.2 ± 0.4 a	91.0 ± 2.0 a
Rotary harrow	64.8 ± 5.2 b	69.0 ± 5.1 a	152.0 ± 8.7 a	28.8 ± 1.1 b	7.1 ± 1.1 b	73.3 ± 6.2 b

* Different letters in the same column represent significant difference at $p < 0.05$.

Considering all the requirements for extra class, the yield was smaller and the differences between two types of soil cultivation machinery became greater. The extra class yield was significantly higher (49.5 t ha^{-1}) by the use of rotaty ridging cultivator and only 32.6 t ha^{-1} by the use of rotary harrow (Table 2). There were no large differences between two soil cultivation machinery regarding mass, length, diameter and curvature of carrots from extra class.

Table 2 Morphological properties of carrots from extra class

Treatment	Yield (t ha^{-1})	Mass (g)	Length (mm)	Diameter (mm)	Curvature (°)
Rotary ridging cultivator	49.5 ± 4.5 a*	66.6 ± 2.2 a	154.2 ± 5.4 a	26.5 ± 0.5 a	3.6 ± 0.2 a
Rotary harrow	32.6 ± 7.3 b	70.9 ± 9.4 a	151.7 ± 6.9 a	28.0 ± 1.4 a	4.5 ± 0.1 b

* Different letters in the same column represent significant difference at $p < 0.05$.

The curvature of carrots from extra class was significantly lower (3.6°), when rotary ridging cultivator was used compared to 4.5° by the use of rotary harrow. Because of curvature 23.3 % of carrots was removed from extra class, when rotary harrow was used and only 12.7 % by the use of rotary ridging cultivator (Table 3). The difference was significant.

Table 3 Percentage of removed carrots from extra class

Treatment	Percentage of removed carrots because of				
	mass (%)	length (%)	diameter (%)	curvature (%)	deformation (%)
Rotary ridging cultivator	4.3 ± 1.5 a*	4.8 ± 4.6 a	3.5 ± 1.4 a	12.7 ± 3.2 a	7.0 ± 2.9 a
Rotary harrow	7.9 ± 0.9 b	6.5 ± 4.3 a	4.8 ± 1.5 a	23.3 ± 4.3 b	7.1 ± 4.5 a

* Different letters in the same column represent significant difference at $p < 0.05$.

There is a lack of research lately regarding machinery for ridge formation and their influence on the amount of stones in the ridges and yield parameters. Ponjičan et al. (2012) compared flat and ridge cultivation and their influence on the soil physical properties and carrot root physical characteristics and yield. They found out that carrot roots grown under ridge cultivation were morphologically more uniform and resulted in lower values of variation coefficient of carrot root dimensions and yields which further significantly influenced the estimation of market quality and overall carrot root price, in comparison to flat cultivation. Their results are not directly comparable to ours. In our research similar conclusions were made in the ridges with less stone amount, which were formed with rotary ridging cultivator. In these ridges higher yield and usually better morfological properties (germination, curvature) were obtained in comparison with ridges formed with rotary harrow, which contained higher percentage of stones. Blazewicz-Wozniak et al. (2015) reported that carrot emergence was the highest, when carrots were sown on ridges in comparison with flat cultivation. Hovewer their results are not comparable with ours, while in our research we did not compare ridge cultivation with flat cultivation. Also their research was to determine the influence of cover crops and tillage techniques on carrot emergence and growth, which was completely different as our research. Similar research was done by Gruszecki et al. (2015), who studied the effect of sowing perennial ryegrass, white clover and their mixture between carrot ridges in order to reduce growth of weeds and increase yield. Hovewer they found decrease of total and marketable yield using these methods.

CONCLUSIONS

By the secondary soil tillage using rotary harrow was 20.5 % of stones in ridges, where carrots will grow. When using rotary ridging cultivator only 9.1 % of stones remained in ridges.

Total carrot yield amounted 64.8 t ha^{-1} and 32.6 t ha^{-1} was the yield from extra class (50.6 %), when rotary harrow was used. However when rotary ridging cultivator was used the total yield amounted 75.7 t ha^{-1} and 49.5 t ha^{-1} was from extra class (65.5 %).

We found out that the curvature of carrots was 7.1° by the use of rotary harrow and only 5.2° by the use of rotary ridging cultivator.

Because of carrot curvature 23.3 % of carrots was removed from extra class when rotary harrow was used and only 12.7 % when rotary ridging cultivator was used.

The secondary tillage mostly influenced carrot germination, which was 73.3 % by the use of rotary harrow and 91 % when rotary ridging cultivator was used.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

STRUCTURAL AND MODAL ANALYSIS OF THE SUBSOILER EQUIPMENT TO PREPARE THE GERMINATIVE BED

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National Institute of Research - Development for Machines and Installations designed to Agriculture and Food Industry - INMA BUCHAREST

SUMMARY

This article presents the way to obtain the structural model for elementary linear-elastic static analysis of subsoiler equipment to prepare the germinative bed. Also, to prove the functionality of the obtained structural model, structural analysis results for the linear elastic static test are presented. These results are useful for estimating the safety factor and for assessing the behaviour in major overstress situations at the main part of the machine. Structure dynamics is a very broad discipline that uses a huge arsenal of theoretical and experimental methods to solve a fundamental problem of structures: the dynamic response to variable tasks over time. Vibrations and especially vibration in resonance modes are problems that occur frequently in large structures. Because large structures with large numbers of components can't be optimally engineered for resonant regimes, it is often done to resolve structures or improve them by using modal analysis of the mathematical models of these structures. The usefulness of this analysis is particularly evident in the testing phase and even in the first stages of operation, when it is necessary to improve the working regime of a product of the type analysed. The main results of the static linear-elastic structural analysis are: the values of the reactions in the holders, vector field distribution of the relative - resultant displacement in the structure, tensor fields' distribution of the specific deformation and the Cauchy stress tensor in the same structure. Also, an important result for the structure safety is the distribution of the safety factor. The analysis of the equipment's own spectrum, allows the proper identification of the main frequencies on which a resonant working regime can occur.

Keywords: *static analysis, von Mises Stress, fundamental frequency, safety factor*

INTRODUCTION

Optimal design or improvement of a complex mechanical structure are activities that are currently carried out in the work of advanced companies working in the field of mechanical and other types structures. Designing an optimal product (at least from some points of view) or optimizing existing products requires complex working tools that are nowadays integrated into CAD-CAE complex programs. The workflow in the CAD - CAE complex is often fragmented, due to the great workload and complex knowledge it requires. For these reasons, in general, the CAD model (Fig.1) may come from suppliers who don't have the qualification to do the structural analysis and vice versa. CAE models are used by structuralists who don't have all the engineering knowledge needed to create manufacturing drawings. Moreover, it is known that, in order to make manufacturing drawings, in CAD drawings some gaps are left to be filled by weld seams or other techniques. Such a CAD model is not functional from the point of view of structural analysis. Another problem that generates difficulties in obtaining CAD models is that CAD model providers can use an older and less performing design software, while the team performing structural analysis needs the CAD model appropriate to another program. Global concerns in most of the directions that our research addresses are very common (Arjun and Narendra, 2017; Gheorghe et al., 2016; Gheorghe et al., 2018; Biris et al., 2016; Gheorghita et al., 2018).

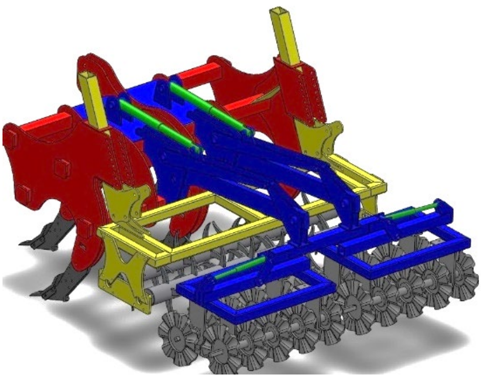


Figure 1 CAD model of the structure in the usual form for SolidWorks 2018 program

MATERIALS AND METHODS

Fixing conditions (Structure bearing)

The structure is borne in three points by the tractor attachment system, (Fig. 2). The attachment to the tractor is (exaggeratedly) made by inserting (cancelling all degrees of freedom on the contact surfaces between the tractor and subsoiler attachment elements) grip are not taken into account.

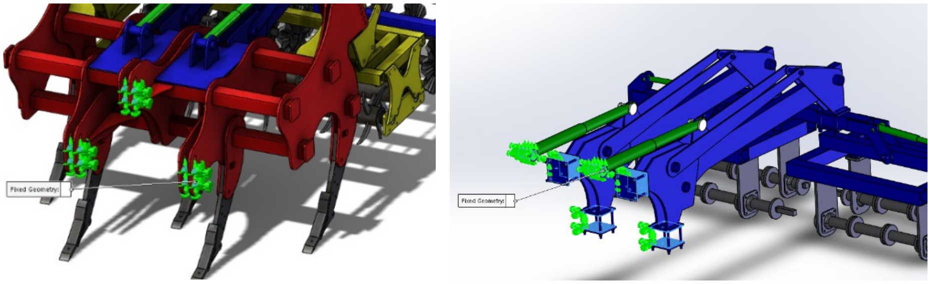


Figure 2 Structure bearing

Structure loading

In this article, we study the response of the structure only for the normal maximum workload. The total force applied to the projection of working parts on the normal plane to the travel direction was calculated using the method of (Letosnev, 1959; Krasnicenko, 1964; Sandru et al., 1983).

$$F_0 = ka_0b_0 + \varepsilon a_1b_1;\quad F_1 = ka_1b_1 + \varepsilon a_1b_1v^2;\quad F_2 = ka_2b_2 + \varepsilon a_2b_2v^2$$
$$F_{2o} = F_2 \sin\alpha\,;\quad F_{2v} = F_2\cos\alpha \tag{1}$$

where the sizes with index 0 correspond to the chisel type working parts, and those with index 1 correspond to the working parts holders (corresponding to the working depth, up to the working parts level). In (1) F_0 and F_1 are the resistance forces of the soil at the action of the two parts of the working body, a_0, b_0, respectively a_1, b_1 are the working depth and width of the working body's respective parts, while k_0, ε_0, respectively, k_1, ε_1, are soil specific resistances to deformation and soil resistance to deformation coefficients due to the working speed. The working speed has been denoted with v. In the example considered we used the following values: a_0=0.31 m^2, a_1=0.128 m, b_0=0.07 m, b_1=0.07 m, k0= 100000 Pa, k1= 20000 Pa. ε_1= ε_2= 2200 kg m^{-3}, v= 10 km h^{-1}. We have also considered a traction force, due to the discs, and to the fangs, calculated according to the formulas (1), with a_2=0.115, b_2=0.04 m, k_2=20000 Pa, ε_2=1000 k m^{-3}. We have also considered a 9-discs battery, and 18 fangs on the first roller with fangs with orientation angles α=15º. Forces (2) were applied to the structure according to the graphical representation in Fig. 3.

$$F_0 = 2538\,N;\quad F_1 = 1048\,N;\quad F_2 = 127{,}5\,N;\quad F_{2o} = 99\,N;\quad F_{2v} = 369\,N \tag{2}$$

Similar estimations of the interaction forces between the working bodies of the machines for soil tillage and the soil, as well as the experimental results, are mentioned in (Cardei et al., 2012; Nagy et al., 2011).

To perform linear-elastic static analysis, the global contact command was applied. This condition applied by the finite element analyser eliminates any kind of clearance, creating stress conditions corresponding to a more rigid structure than the real one. Thus, tensions will be higher than in reality, and relative displacements (deformations) are expected to have lower values than in reality. The discretization of the structure can be seen in Figure 4.

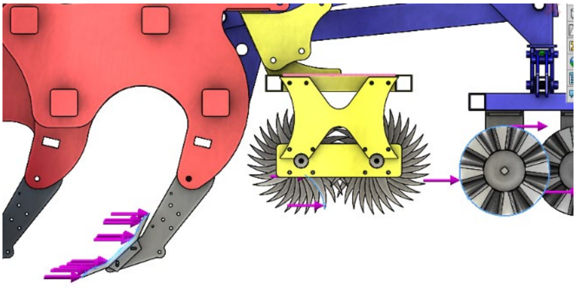


Figure 3 Loads application (forces)

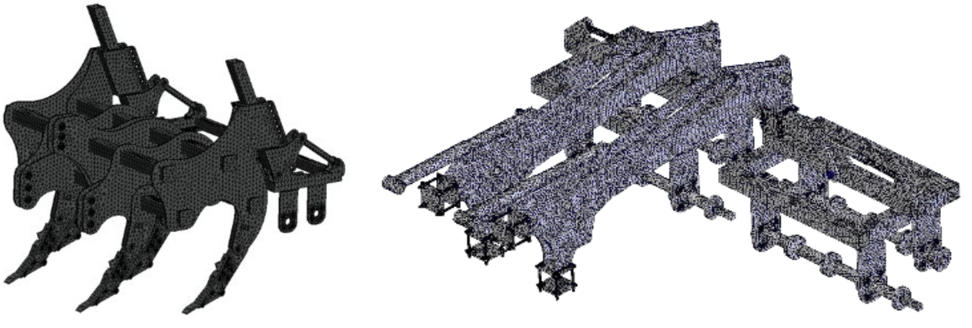


Figure 4 Structure discretization: Projection of finite elements on the structure border

The materials used for the components of the analysed structure are shown in Figure 5 together with the respective properties. For the pipes, S275JR was used, S355 was used for the plate parts and 16MnCr5 was used for the working parts.

Property	Value	Units
Elastic modulus	2.100000031e+011	N/m^2
Poisson's ratio	0.28	N/A
Shear modulus	7.9e+010	N/m^2
Mass density	7800	kg/m^3
Tensile strength	410000000	N/m^2
Compressive Strength in X		N/m^2
Yield strength	275000000	N/m^2
Thermal expansion coefficient	1.1e-005	/K
Thermal conductivity	14	W/(m·K)
Specific heat	440	J/(kg·K)
Material Damping Ratio		N/A

a) S75JR

Property	Value	Units
Elastic modulus	2.100000031e+011	N/m^2
Poisson's ratio	0.28	N/A
Shear modulus	7.9e+010	N/m^2
Mass density	7800	kg/m^3
Tensile strength	450000000	N/m^2
Compressive Strength in X		N/m^2
Yield strength	275000000	N/m^2
Thermal expansion coefficient	1.1e-005	/K
Thermal conductivity	14	W/(m·K)
Specific heat	440	J/(kg·K)

b) S355

Property	Value	Units
Elastic modulus	2.100000031e+011	N/m^2
Poisson's ratio	0.28	N/A
Shear modulus	7.9e+010	N/m^2
Mass density	7800	kg/m^3
Tensile strength	800000000	N/m^2
Compressive Strength in X		N/m^2
Yield strength	590593984	N/m^2
Thermal expansion coefficient	1.1e-005	/K
Thermal conductivity	14	W/(m·K)
Specific heat	440	J/(kg·K)

c) 16MnCr5

Figure 5 Material properties

RESULTS AND DISCUSSION

The main results of the static linear-elastic structural analysis are: the values of the reactions in the holders, vector field distribution of the relative - resultant displacement in the structure, tensor fields' distribution of the specific deformation and the Cauchy stress tensor in the same structure. Also, an important result for the structure safety is the distribution of the safety factor.

Table 1 shows the values of the resultant forces components, which are also found in the values of the reaction forces (in the three bearing areas).

Table 1 Resultant Forces

Components	X	Y	Z	Resultant
Reaction force, (N)	18524.9	-2189.9	0.008	18,653.9
Reaction Moment, (N·m)	0	0	0	0

The equipment was divided into two, for more efficient results and the power of the computer needed to run the analysis. Results will be presented separately.

Figure 6 graphically represents the distribution maps of the relative displacement field values on the structure border. It is noticed that the maximum value (about 1 mm) is located at the back of the structure. This maximum value can be exceeded if we consider the clearances of the structure and of the connection system between the scarifier and the tractor. Increasing the movement, in the conditions of the considered stress, admitting the clearances, contributes to the relaxation of the structure and consequently to the increase of the safety factor. However, exaggerated clearances generally lead to more or less premature wear.

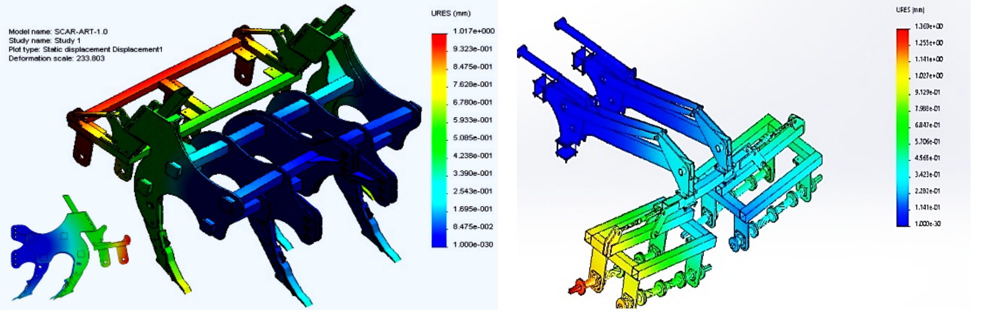


Figure 6 Distribution of the relative displacement field values resulting on the structure border

In figure 7, the distribution of the total specific deformation values is graphically represented by color map. The maximum stress area is also indicated in detail. Due to the fact that we are working in the elastic-linear field, the maximum tension will be located in the same area as the maximum specific deformation. The maximum equivalent tension is graphically indicated in the same way in Figure 8.

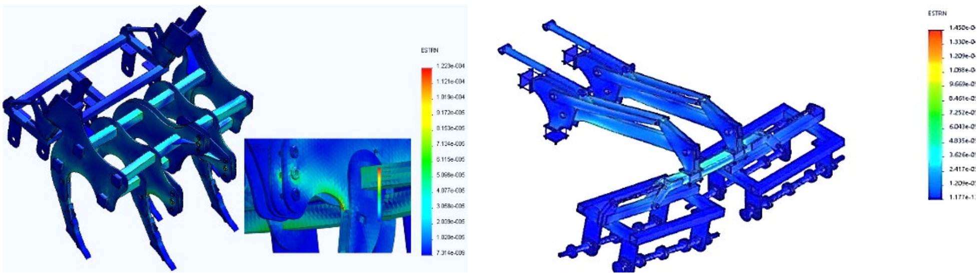


Figure 7 Field values distribution of the total specific deformation on the structure border

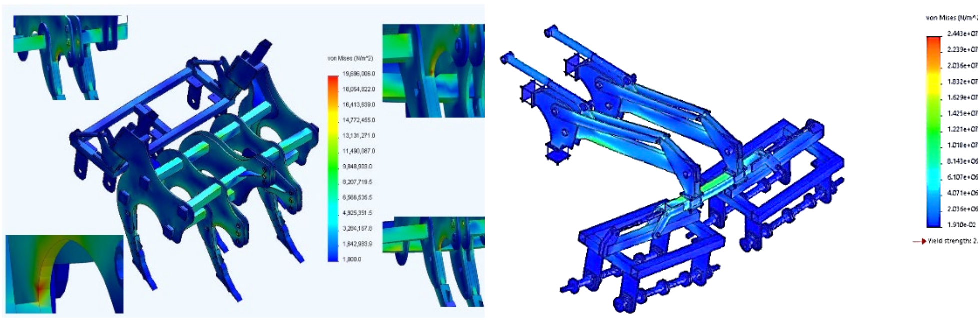


Figure 8 Representation of the equivalent tension distribution on the structure border

Finally, Figure 9 shows the graphical representation of the safety factor distribution in the structure.

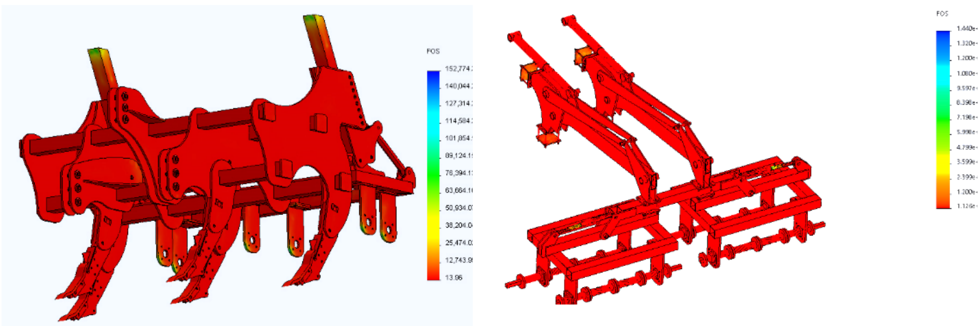


Figure 9 Field values distribution of the total specific deformation on the structure border

The results of second part of the article is about the modal analysis. This modal analysis was made only for the first three frequencies.

The result of calculating frequencies or modal analysis relies essentially in the list of a number of its own frequencies (in Hz) (pulsations, in rad/s and periods, in s), in ascending order, starting with the lowest (fundamental frequency). There are presented also the relative displacements on the directions and resultants in the structure, for each vibration mode, separately. Also, color maps of the field of relative displacements, on component or resultant, are presented.

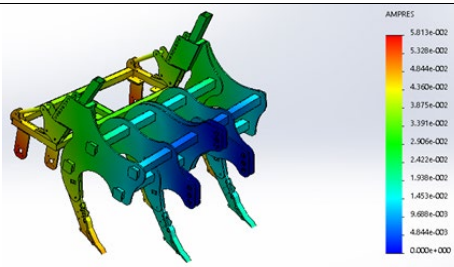
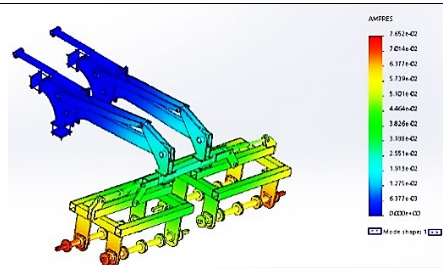
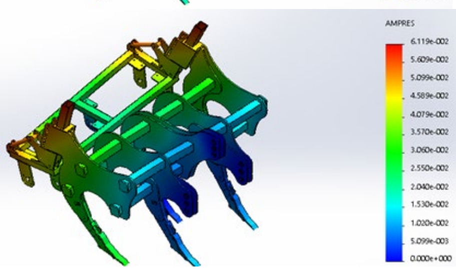
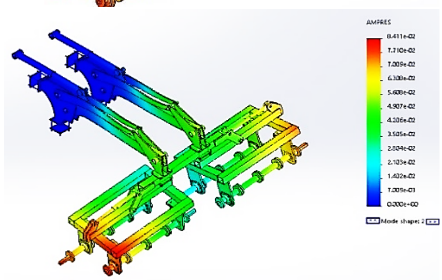
In Table 2, it is shown, from the SOLIDWORKS 2018 program report, which was used (the SIMULATION module) for making the frequency analysis, a list of the first three own frequencies, 20 frequencies have been calculated but only the first ones are important.

Table 2 Mass Participation (Normalized)

For the part of front		For the part of back	
Mode No.	Frequency (Hz)	Mode No.	Frequency (Hz)
1	11.836	1	5.6996
2	16.548	2	9.9854
3	20.833	3	11.076

Another way of showing these results appears in Table 3. Table 3 presents own frequencies and maps of the amplitudes on the deformed shape of the structure, in the vibration modes corresponding to the respective frequency. In Table 3, only two of the twenty calculated vibration modes are given, for reasons of fitting into a certain number of pages of an article.

Table 3 The first two amplitude maps on its surface

Mode No.	Maps of the amplitude on the deformed shape of the structure, (mm)	
	For the part of front	For the part of back
1		
2		

We tried to cover the frequency spectrum that could affect the tractor operator’s health, according to the standards (Bruel and Kjaer, 1989). Affecting the operator by the subsoiler own frequencies is also unlikely, as the periodic signals transmitted from the subsoiler to the tractor are weak in intensity also due to the coupling mode and attenuated in the tractor suspension system (including wheels for wheeled tractors). Concerns on the ergonomic line remain in place and receive new dimensions (Makoto et al., 1998).

CONCLUSIONS

The minimum safety coefficient value is 13.936, respectively 11.260. For agricultural machinery destined for tillage, the usual safety coefficient values are between 1.8 and 2.2. Therefore, this machine is either much oversized, or it works under much tougher conditions. The latter may appear either due to use under improper conditions or due to accidents (impact with hard rocks or roots in soil).

The results obtained and provided by modal analysis for mechanical structures are relatively few and their uses are accurate.

As it is known, the main result of the modal analysis is the set of calculated frequencies. In principle, we can ask the program to calculate an unlimited number of own frequencies. In fact, just the first few are useful. The most important is the fundamental frequency, which has the lowest value of the calculated ones. Most of the time, the list of own frequencies is used to avoid resonance working regimes and, in general, resonance phenomena that may occur under various circumstances.

For the structure analyzed in this paper, we limited the number of frequencies calculated to the first twenty. We considered that this way we cover all the basic frequencies that may occur in the equipment working process. The highest frequencies we had in view were those that usually come from the tractor engine (33-67 Hz), although through the coupling mode between the subsoiler and tractor, the transmission of these frequencies from the tractor to the subsoiler is highly unlikely to amplitude that is noticeable by the usual measurement and control equipment.

ACKNOWLEDGEMENT

This work was funded from the European Regional Development Fund through the Competitiveness Operational Program 2014-2020, contract no. 80 / 08.09.2016, within the project entiled “Rapid knowledge transfer and technical-scientific support in competitive technologies and competitive technologies in enterprises specific to bioeconomy and bioresuring production”.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

REZULTATI SJETVE KUKURUZA SIJAČICOM MATERMACC TWIN ROW–2 NA POKUŠALIŠTU „TENJA“

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SAŽETAK

U radu su prikazani rezultati prinosa zrna primjenom standardne i sjetve kukuruza u twin row tehnologiji na površinama pokušališta „Tenja“, (45°31'1,83" N 18°46'37,5" E) Osijek. Za sjetvu kukuruza u standardne redove na razmak od 70 cm korištena je PSK4 OLT sijačica, a za sjetvu u udvojene redove korištena je MaterMacc Twin Row-2 sijačica. U istraživanju bila su zasijana dva hibrida sjemenske kuće RWA, Chapalu (FAO 350) i Ferarixx (FAO 360). Prinos zrna kod hibrida Chapalu u standardnoj sjetvi iznosio je 13731 kg ha^{-1} sa standardnom devijacijom od 767,011 i koeficijentom varijacije od 5,59 %. Prinos zrna u sjetvi twin row tehnologijom iznosio je 14.501 kg ha^{-1} ili 5,61% više u odnosu na standardnu sjetvu. Povećanjem sjetvenog sklopa na 88.040 biljaka ha^{-1} utvrđen je prinos od 14.981 kg ha^{-1}. U standardnoj sjetvi prinos hibrida Ferarixx iznosio je 13.516 kg ha^{-1} sa standardnom devijacijom od 611,0 i koeficijentom varijacije od 4,52%. Prinos istog hibrida u sjetvi u udvojene redove iznosio je 14.570 kg ha^{-1} ili 7,79 % više u odnosu na standardnu sjetvu. Povećanjem sklopa kod hibrida Ferarixx na 88.395 biljaka ha^{-1} ostvaren je prinos od 15.056 kg ha^{-1}.

***Ključne riječi**: kukuruz, sjetva, twin row sijačica, prinos*

UVOD

Sjetva kukuruza na našem prostoru obavlja se na standardni razmak redova od 70 i 75 cm. U novije vrijeme provode se znanstvena istraživanja sjetve kukuruza u udvojene redove, poznate u svijetu kao twin row tehnologija. Ovisno o proizvođačima sijačica, udvojeni redovi zasijavaju se na razmak od 20, 22 ili 25 cm, a središnji razmak susjednih udvojenih redova iznosi 70 ili 75 cm tako da se berba može obaviti sa standardnim beračima za kukuruz. Prema literaturnim navodima izvođenje sjetve sa tzv. *"Twin-Row"* tehnologijom započeto je već početkom devedesetih godina u SAD-u kao težnja da se poveća prinos zrna s povećanjem sjetve većeg broja biljaka (sklopa) po proizvodnoj površini (ha). U RH s sjetvom u udvojene redove započeo je Čuljat (1986.). Prema navodima istog autora došlo je do znatnijeg povećanja prinosa u svim sjetvama od 6 do 18 %. U novije vrijeme rezultate dobivenih prinosa twin row sjetve u odnosu na standardnu sjetvu navode Banaj i sur. (2018). Tako autori navode da su ostvarili prinos zrna kod hibrida P0023 u standardnoj sjetvi od 12.882 kg ha^{-1} sa standardnom devijacijom od 631,012 i koeficijentom varijacije od 4,90 %. Prinos zrna hibrida kukuruza P0023 u sjetvi twin row tehnologiji iznosio je 13.477 kg ha^{-1} ili 4, 62 % više u odnosu na standardnu sjetvu.

U standardnoj sjetvi prinos hibrida P0412 iznosio je 12.605 kg ha^{-1}. Prinos hibrida P0412 u sjetvi u udvojene redove iznosio 5,83 % više u odnosu na standardnu sjetvu. Sjetvom hibrida „P0412" i hibrida „P0023" u standardnoj tehnologiji s razmakom redova od 70 cm i u twin row tehnologiji s razmakom udvojenih redova od 22 cm, navode Banaj i sur. (2017a.) da je hibrid *P0023* dao prinos u berbi 13.814 kg ha^{-1}.

Isti hibrid u twin row tehnologiji ostvario je prinos 10,35 % više u odnosu na standardnu sjetvu. Prinos zrna kod standardne sjetve hibrida *P0412* iznosio je 15.427 kg ha^{-1}. U sjetvi twin row tehnologijom prinos je iznosio 10,59 % više u odnosu na standardnu sjetvu. Rezultate prinosa u istraživanju hibrida sjemenske kuće *KWS*, hibrida iz FAO grupe 380 - *Kamparis* i hibrida iz FAO grupe 410 - *Balasco* navode Banaj i sur. (2017b.). Prinos hibrida *Kamparis* u standardnom načinu sjetve iznosio je 12.457 kg ha^{-1}, a u sjetvi twin row tehnologijom sa sklopom od 62.835 biljaka ha^{-1} iznosio je 13.712 kg ha^{-1} ili 10,07% više u odnosu na standardnu sjetvu. Kod hibrida *Balasco* zabilježeni prinos iznosio je 14.533 kg ha^{-1}, a sjetvom u twin row tehnologiji iznosio je 13.718 kg ha^{-1} ili 5,6 % manje u odnosu na standardnu sjetvu.

MATERIJAL I METODE

Sjetva dva hibrida kukuruza na površinama pokušališta „Tenja" obavljena je 19. travnja 2018. sijačicama *PSK4 OLT* i *MaterMacc Twin row-2.* U istraživanju su korišteni hibridi Chapalu *i Ferarixx* zasijani u standardnoj sjetvi s razmakom redova od 70 cm i u twin row sjetvi s razmakom udvojenih redova od 22 x 48 cm. Hibridi Chapalu i Ferarixx posijani su na teoretski sklop od 82.992 biljaka ha^{-1} u standardnoj sjetvi te na 84.435 i 97.767 biljaka ha^{-1} u twin row sjetvi. Na sjetvenoj površini predkultura je bila pšenica, a gnojidba kukuruza obavljena je sa 130 kg ha^{-1} N, 120 kg ha^{-1} P_2O_5 i 125 kg ha^{-1} K_2O. Osnovna i dopunska obrada tla bila je konvencionalna, a za zaštitu od korova korišten je herbicid *Adengo*. Ručna berba pokusne parcele kukuruza obavljena je 1. listopada 2018. godine berbom dva reda kukuruza u duljini od 20 m sa četiri ponavljanja. Za oba hibrida kukuruza određen je sklop biljaka po hektaru u vrijeme nicanja, razmak biljaka unutar reda nakon nicanja (cm), prinos (kg ha^{-1}) i vlaga zrna (%). Dobiveni podaci obrađeni su u *„SAS 9.4"* programu, odnosno određena je srednja vrijednost, standardna devijacija te koeficijent varijacije za sve vrijednosti. Odlike tla na lokaciji pokušališta „Tenja" prikazane su u Tablici 1.

Značajke klime sa meteorološke postaje Osijek Klisa aerodrom izmjerene za višegodišnji period (1981. - 2017.) u periodu vegetacije kukuruza (Tablici 2).

Tablica 1 Osnovna kemijska svojstva tla na pokušalište „Tenja“
Table 1 Basical agrochemical soil analysis on field „Tenja“

Pokušalište / experimental field „Tenja“ (45°31'1,83"N 18°46'37,5"E) (k. o. Tenja 1308 i 1309)	Dubina / Depth (cm)	AL-P_2O_5 (mg/100g)	AL-K_2O (mg/100g)	Humus / Humus content (%)
	0 - 30	15,58	24,29	3,71

Slika 1 Pokušalište „Tenja“ (izvor: Arkod)
Figure 1 Experimental field „Tenja“ (source: Arkod)

Tablica 2 Srednje mjesečne temperature zraka i ukupne godišnje količine oborina
Table 2 Mean air temperature and total monthly precipitation

Meteorološka postaja Osijek Klisa aerodrom (1981. - 2017.) Osijek meteo. station Klisa airport (1981 - 2017)							
Mjesec / Month	IV	V	VI	VII	VIII	IX	Suma
Količina oborina Total precipitation (mm)	48,4	77,9	77,9	58,2	60,1	52,6	375,1
Srednja temperatura zraka Mean air temperature (ºC)	12.1	17,3	20,6	22,5	21,7	17,1	18,55
2018. godina / year							
Količina oborina Total precipitation (mm)	25,1	77,6	102,9	89,2	45,6	106,1	446,5
Srednja temperatura zraka Mean air temperature (ºC)	17,0	20,6	21,7	22,5	24,4	17,9	20,68

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Utvrđene vrijednosti sklopa biljaka po ha u vrijeme nicanja, prinosa (kg) i vlage zrna za oba hibrida su prikazani u Tablicama 3. i 4. U standardnoj sjetvi sa sijačicom *PSK4 OLT* hibrid *Chapalu* u sklopu od 73.130 biljaka ha^{-1} nakon nicanja, ostvario je prinos od 13.731 kg ha^{-1} zrna s prosječnom vlažnošću od 28,30 %. Twin row sjetva sa ostvarenim sklopom od

74.905 biljaka ha^{-1} kod istog hibrida ostvarila je prinos od 14.501 kg ha^{-1} zrna s prosječnom vlažnošću 30,18 % što je 5,61% više u odnosu na standardnu sjetvu.

U sklopu od 88.040 biljaka ha^{-1} utvrđen je prinoss od 14.981 kg ha^{-1} zrna s prosječnom vlažnošću 30,35 %. Promatrajući srednje mjesečne temperature i količinu oborina za vrijeme vegetacije kukuruza na području Osijeka - Klisa aerodrom, vidljivo je kako su srednje mjesečne temperature u 2018. godini bile znatno više od višegodišnjeg prosjeka za to područje, kao i ukupna suma oborina koja je bila 71,4 mm (19.1% više od prosjeka) (Tablica 2.).

Tablica 3 Utvrđen broj biljaka unutar reda nakon nicanja kukuruza
Table 3 Number of plants and spacing inside rows after emergence

Hibrid / Hybrid	Sjetvena norma / Sowing rate (seeds/ha)	Broj biljaka ha^{-1} u vrijeme nicanja Number of plants per hectare after emergence				
		Xi	s.d.	C.V. (%)	Min	Max
Chapalu	Standardna – 82.992	73.130	3.666	5,01	68.870	77.390
	Twin row I – 84.435	74.905	4.832	6,45	68.160	79.520
	Twin row II – 97.757	88.040	2.592	2,94	85.200	90.880
Ferarixx	Standardna – 82.992	74.018	2.920	3,95	70.290	76.680
	Twinrow I – 84.435	75.970	3.380	4,45	72.420	79.520
	Twinrow II – 97.757	88.395	8.390	9,49	76.680	95.140

Tablica 4 Ostvareni prinosi zrna kukuruza (svedeno na vlagu od 14%) kod standardne i Twin row sjetve hibrida *Chapalu* i *Ferarixx* (Berba 1.10.2018.)
Table 4 Corn yield (calculated at 14% grain moisture) with standard and Twin row planting of hybrids *Chapalu* and *Ferarixx* (Harvest 1st October 2018.)

Hibrid / Hybrid	Sjetvena norma / Sowing rate (seeds/ha)	Prinos /Yield (kg ha^{-1})				
		Xi	s.d.	C.V. (%)	Min	Max
Chapalu	Standardna – 82.992	13.731	767	5,59	12.848	14.594
	Twin row I – 84.435	14.501	952	6,57	13.266	15.580
	Twin row II – 97.757	14.981	339	2,27	14.578	15.373
Ferarixx	Standardna – 82.992	13.516	611	4,52	12.740	14.178
	Twinrow I – 84.435	14.570	465	3,19	14.122	15.212
	Twinrow II – 97.757	15.056	1.146	7,62	13.638	16.422

Tablica 5 Vlaga zrna u vrijeme berbe
Table 5 Grain moisture in harvest

Hibrid / Hybrid	Sjetvena norma / Sowing rate (seeds/ha)	Vlaga zrna u vrijeme berbe / Grain moisture in harvest (%)				
		Xi	s.d.	C.V. (%)	Min	Max
Chapalu	Standardna – 82.992	28,30	1,257	4,44	27,20	30,10
	Twin row I – 84.435	30,18	1,575	5,22	28,10	31,80
	Twin row II – 97.757	30,35	1,752	5,77	28,30	32,00
Ferarixx	Standardna – 82.992	21,20	0,796	3,75	20,40	22,30
	Twinrow I – 84.435	22,43	0,334	1,49	21,90	22,80
	Twinrow II – 97.757	22,55	0,252	1,12	22,30	22,90

Standardnom sjetvom hibrida *Ferarixx* (74.018 biljaka ha^{-1} nakon nicanja) ostvaren je prinos od 13.516 kg ha^{-1} zrna s prosječnom vlagom od 21,20 %. Twin row sjetva istog hibrida sa sijačicom *MaterMacc Twin Row-2,* sa ostvarenim sklopom od 75.970 biljaka ha^{-1}, ostvarila je prinos od 14.570 kg ha^{-1} zrna s prosječnom vlagom od 22,43 %. Prinos zrna twin row sjetve hibrida *Ferarixx* bio je za 7,79 % veći u odnosu na prinos ostvaren u standardnoj sjetvi. Dobiveni rezultati slični su vrijednostima koje navodi autor Banaj i sur. (2017. a) od 10,35 % kod hibrida *P0023* na drugoj lokaciji istraživanja. Dobivene vrijednosti povećanja prinosa od 5,83 % kod hibrida *P0412* također su potvrđene od strane istih autora. Dobiveni rezultati istovjetni su podacima koje navodi Blandino i sur. (2013.) u Italiji. Jurković i sur. (2018.) također potvrđuju povećanje prinosa primjenom twin row sjetve od 3,56 do 7,66 %. Rezultate prinosa zrna ostvarenih u sjetvi kukuruza u udvojene redove u vegetacijskoj 2016. godini u bosanskoj Posavini, Bosna i Hercegovina, navode Jurković i sur. (2017.). Standardnom sjetvom hibrida *P0412* ostvaren je prinos od 15798 kg ha^{-1} u procijenjenom sklopu od 60.705 biljaka ha^{-1}. Sjetvom istog hibrida u udvojene redove ostvaren je prinos od 16.671 kg ha^{-1} ili 5,53 % više u odnosu na standardnu sjetvu. Nešto veći prinosi zrna zabilježen je u sjetvi twin row tehnologijom hibrida *BC525* od 13,95 % (16.613 kg ha^{-1}) više u odnosu na standardnu sjetvu (14.579 kg ha^{-1}) kod procijenjenog sklopa poniklih biljaka od 62.658 biljaka ha^{-1}. Tadić i sur. (2017.) navode rezultate prinosa zrna kukuruza ovisno o načinu sjetve uporabom podtlačne sijačice *PSK4 OLT* za standardni način sjetve i primjenom sijačice *MaterMacc TwinRow-2*. Hibrid „ZP 488“ ostvario je u standardnoj sjetvi prinos od 14.055 kg ha^{-1}, te 15.028 kg ha^{-1} u udvojenim redovima ili 6,48 % više od standardnog načina sjetve. Autori navode da je zabilježen prinos zrna kod hibrida „ZP 560“ u standardnom načinu sjetve od 14.394 kg ha^{-1}. Ostvareni prinos sjetvom u udvojene redove iznosio je 14.747 kg ha^{-1} ili 2,40 % više nego kod standardne sjetve. Kod sjetve hibrida *Os 403* Jurković i sur. (2018.) u razmak redova od 70 cm ostvaren je prinos zrna kukuruza od 15.153 kg ha^{-1}, a sjetvom u udvojene redove 15.693 kg ha^{-1} ili 3,56% više u odnosu na standardnu sjetvu.

Prinos hibrida *Os 378* u standardnoj sjetvi, kako navode autori iznosio je 13.426 kg ha^{-1}, a u sjetvi u udvojene redove iznosio je 14.455 kg ha^{-1} ili 7,66% više u odnosu na standardnu sjetvu. Blandino i sur. (2013.) proveli su ispitivanje twin row tehnologije u Italiji na 12 lokacija. Koristili su hibrid *DKC 6815*, FAO grupe 600, u sklopovima od 7,5 do 9,5 pa čak i 10 biljaka m^{-2}. Dobiveni rezultati ukazuju na povećanje prinosa na 8 lokacija u prosjeku za 5,5 %. Povećanje prinosa iznosilo je od 0,6 t ha^{-1} (+3,6 %) te 0,9 t ha^{-1} što je iznosilo povećanje prinosa za 6,2 %.

ZAKLJUČAK

Temeljem dobivenih rezultata mjerenih parametara tijekom jednogodišnjeg istraživanja kod oba hibrida, utvrđen je pozitivan učinak primjene twin row tehnologije u odnosu na standardnu sjetvu kukuruza.

- Temeljem meteoroloških podataka prvenstveno promatrajući srednje mjesečne temperature zraka i mjesečne količine oborina možemo zaključiti da je vegetacijska godina 2018. bila pogodna za proizvodnju kukuruza na pokušalištu “Tenja”
- U standardnoj sjetvi s pneumatskom sijačicom “PSK-4” tvrtke MIO OLT Osijek, hibrid *Chapalu* u sklopu od 73130 biljaka ha^{-1}nakon nicanja ostvario je prinos od 13731 kg ha^{-1} zrna s prosječnom vlažnošću od 28,30 %,
- Twin row sjetva sa ostvarenim sklopom od 74905 biljaka ha^{-1}kod istog hibrida polučila je prinos od 14501 kg ha^{-1} zrna s prosječnom vlažnošću od 30,18 % što čini povećanje u odnosu na standardnu sjetvu od 5,61 %.
- Standardnom sjetvom hibrida *Ferarixx* u sklopu od 74018 biljaka/ha nakon nicanja ostvaren je prinos od 13516 kg ha^{-1} zrna s prosječnom vlagom 21,20 %,
- Twin row sjetva istog hibrida s sijačicom MaterMacc “Twin Row-2” sa ostvarenim sklopom od 75970 biljaka ha^{-1} dobiven je prinos od 14570 kg ha^{-1} zrna s prosječnom vlagom od 22,43 % što predstavlja povećanje od 7,79 % u odnosu na standardnu sjetvu,
- Iako postignuti rezultati pokazuju da Twin row sjetva daje 5,61% i 7,73% veće prosječne prinose zrna od standardne sjetve, ovi rezultati nisu statistički potvrđeni odnosno nisu značajni te se predlaže nastavak postupka istraživanja.

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RESULTS OF CORN SOWING USING MATERMACC TWIN ROW–2 SOWING MACHINE ON EXPERIMENTAL FIELD „TENJA“

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SUMMARY

The paper presents the results of corn yield with application of standard and twin row seeding system on experimental field „Tenja“, Osijek (45°31'1.83"N and 18°46'37.5"E). Standard sowing was conducted with PSK4 OLT sowing machine with 70 cm row spacing, and for twin row sowing system, MaterMacc TwinRow – 2 sowing machines were used with double row spacing of 22 cm. For this investigation, two different corn hybrids are used: Chapalu (FAO 350) and Ferarixx (FAO 360). The yield of the Chapalu hybrid in standard sowing was 13,731 kg ha^{-1} with the standard deviation of 767.01 and the variation coefficient of 5.59%. The yield of the same hybrid in twin tow sowing system was 14,501 kg ha^{-1} or 5.61% more than the yield of standard sowing. With the increasing of seeding rate to 88,040 plants ha^{-1} the yield was 14,981 kg ha^{-1}. The yield of the Ferarixx hybrid in standard sowing was 13,516 kg ha^{-1} with the standard deviation of 611.00 and the variation coefficient of 4.52%. The yield of the same hybrid in twin tow sowing system was 14,570 kg ha^{-1} or 7.79% more than the yield of standard sowing. With the increasing of seeding rate to 88,395 plants ha^{-1} the yield was 15,056 kg ha^{-1}.

Keywords: *corn, sowing, twin row sowing machine, yield*

47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

SMANJENJE URODA PŠENICE NA UVRATINAMA USLIJED GAŽENJA

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SAŽETAK

Obavljanjem odgovarajućih agrotehničkih mjera u procesu proizvodnje poljoprivrednih kultura (pšenice), zbog brojnih prolaza mehanizacijom dolazi do gaženja tla. Na obiteljskim poljoprivrednim gospodarstvima u Srbiji tehnološki procesi proizvodnje poljoprivrednih kultura provode se pojedinačnim agrotehničkim mjerama. Počevši s rasipanjem gnojiva, višenamjenskim sustavom za obradu tla, zatim sjetvom, zaštitom, gnojidbom - prihranom, žetvom, transportom zrna i biljnih ostataka. Tako je u realizaciji tehnoloških operacija u proizvodnji biljnih kultura površina tla na parceli pregažena u 10 do 15 prohoda traktorskim i samohodnim sistemima. Velikim brojem prolaza mehanizacijom gazi se tlo po unutarnjem dijelu parcele, a osobito na uvratinama što negativno utječe na prinos kultiviranih usjeva i dovodi do fizičkog i mehaničkog poremećaja strukture tla.

Cilj istraživanja je bio ustanoviti razliku u prinosu, visini biljaka, duljini klasa, masi 1000 zrna i hektolitarskoj masi zrna pšenice u unutarnjem dijelu u odnosu na uvratine parcele.

U svrhu ovog rada postavljen je eksperiment sorte pšenice Pobeda na tri lokaliteta i praćena je visina uroda pšenice na unutarnjem dijelu-sredini i krajevima-uvratinama parcele na kojima je bilo izraženije zbijanje tla. Tijekom istraživanja, pored prinosa, određena je razlika u visini biljke, duljini klasa, mase 1000 zrna i nasipne (hektolitarske) mase zrna na sredini i uvratini parcele. Urod pšenice na unutarnjem dijelu parcele su na svim lokalitetima bili veći od 44% do 69,06% u usporedbi na urod na uvratinama. Prosječna visina biljke je veća od 4,76% do 13,75%, a duljine klase od 6,11% do 15,93% na unutarnjem dijelu u odnosu na uvratine parcele. Na unutarnjem dijelu parcele *mase 1000 zrna i nasipna masa manje su u odnosu na vrijednosti tih svojstava na uvratinama.*

Ključne riječi: *pšenica, uvratina, urod, visina biljaka, duljina klasa, masa 1000 zrna i hektolitarska-nasipna masa zrna.*

UVOD

Prema službenim podacima Republičkog zavoda za statistiku Srbije u proizvodnoj 2016/17. godini pšenica je uzgajana na površini od 556.115 ha sa prosječnim prinosom od 4,1 tha^{-1}. Na obiteljskim poljoprivrednim gospodarstvima u Srbiji tehnološki procesi proizvodnje poljoprivrednih kultura provode se pojedinačnim agrotehničkim mjerama. Počevši s rasipanjem gnojiva, višenamjenskim sustavom za obradu tla, zatim sjetvom, zaštitom, gnojidbom - prihranom, žetvom, transportom zrna i biljnih ostataka. Tako je u realizaciji tehnoloških operacija u proizvodnji biljnih kultura površina tla na parceli gažena u 10 do 15 prohoda traktorskim sistemima i samohodnim kombajnima. Izvođenjem odgovarajućih agrotehničkih mjera u procesu proizvodnje pšenice zbog brojnih prolaza mehanizacijom po parceli dolazi do opadanja plodnosti i degradacije tla. Velikim brojem prohoda mehanizacijom tlo se gazi po unutarnjem dijelu parcele a posebice na uvratinama, što nepovoljno utječe na njegovu strukturu i plodnost, a time i na urod pšenice.

U provođenje agrotehničkih mjera traktorski i mobilni sustavi gibaju se po unutarnjem dijelu parcele a okreću na uvratinama, pri čemu dolazi do zbijanja tla, ali različitog intenziteta (Ronai, 1989 i Schwngard, 1991). Pri okretanju traktorski sustavi i kombajni na uvratinama dovode do većeg zbijanja tla u usporedbi sa unutarnjim dijelom parcele zbog manjih brzina kretanja i većeg broja prohoda. Manje brzine kretanja na uvratinama dovode da tlo bude dulje vrijeme izloženo djelovanju normalnog tlaka-napona što ga čini zbijenijem. Na povećano zbijanje tla uz nižu brzinu kretanja utječe broj prolaza po uvratini, kao i povećani specifični tlak. Broj prolaza po parceli utječe ne samo na dubinu traga kotača već i na pogaženu površinu. Duljina puta koju pređe traktorski sustav na uvratinama je veća nego u unutarnjem dijelu parcele sveden na širinu uvratina. Na zbijanje tla na uvratinama također utječe način povezivanja poljoprivrednih strojeva. Nošene i polunošene mašine namijenjene za pripremu tla, sjetvu, zaštitu i njegu kultura, pri okretanju na uvratinama podižu se u transportni položaj što dovodi do preraspodele njihovih masa. Masa sa prednjih kotača preraspodjeljuje se na zadnje kotače traktora (Savin i sur., 2007; Savin i sur., 2008), zbog čega je tlo zbijenije na uvratini u u uporedbu sa unutarnjim dijelom parcele.

Tijekom oranja i predsjetvene pripreme tla, traktori sa priključnim strojevima prelazom preko parcela dovode do intenzivnog zbijanja tla, formiranja "plužnog đona" i stvaranja loših uvjeta za nicanje, rast i razvoj korjenovog sistema. Korijen koji raste prema sloju koji je sabijen slabo prodire kroz njega i smanjuje količinu vode i hranjivih tvari dostupnih biljkama. Osim toga, tijekom njege usjeva, prolazak kotača traktora preko korijenskog sustava dovodi do deformacije tla i korijena, što smanjuje njegovu čvrstoću i normalan razvoj.

U proizvodnji poljoprivrednih kultura, poljoprivredna mehanizacija je ključni element jer njezina primjena donosi brojne prednosti. Ispravna primjena mehanizacije je važna, jer prekomjerno korištenje zbija tlo i stvara niz problema, što se očituje negativnim utjecajem na rast i prinos uzgajane biljke (Ramazan, 2012). Gibanje traktora i mobilnih sistema po parceli Ronay (1997) tijekom oranja, pripreme tla, sjetve, zaštite, berbe i prijevoza, što rezultira zbijanjem tla. Posebice je utjecaj povezan s transportnim sredstvima, s obzirom na velika opterećenja na osovinama prikolice i visoki tlak u pneumatiku, gdje nakon žetve usjeva ostaje vrlo zbijeno tlo.

Ungureanu i sur. (2015) obavili su eksperimente u kontroliranim laboratorijskim uvjetima kako bi simulirali tlak traktora U 650, koji rade s silom od 7380 N, i uočio neravnomjernu raspodjelu tlaka preko dubine. Najveće zbijanje tla je na samoj površini 11,39 N cm^{-2}. Porastom dubine od 5 cm tlak zbijanja opada na 7,12 N cm^{-2}, a na 25 cm na 2,68 N cm^{-2}, da bi se na dubini od 35 cm povećao na 4 Ncm^{-2}, a zatim ponovo opao na 1,37 N cm^{-2}. Prema Jug i sur. (2015.) zbijeni sloj tla debljine preko 5 cm predstavlja izrazito veliki rizik koji može uzrokovati pad prinosa i preko 40%.

Zbijanja tla na dubini od 7-21 cm u fazi nicanja na uvratinama je 14,45 daN cm^{-2}, a u unutarnjem dijelu parcele 10,48 daN cm^{-2}. Na istoj dubini, zbijanje tla prije žetve na uvratinama je 14,21 daN cm^{-2} a u unutarnjem dijelu parcele 9,73 daN cm^{-2}. Prosječno povećanje zbijenosti tla na uvratinama od 30,56% u fazi nicanja i 37,65% u vreme žetve, utjecalo je na smanjenje uroda pšenice za oko 26% u odnosu na unutarnji dio parcele (Savin i sur., 2007; Savin i sur., 2008; Savin i sur., 2008a).

Nakon nicanja pšenice prosječna zbijanja tla u unutarnjem dijelu parcele iznosila su 1,75 MPa, dok je na uvratini povećana za 36,57% (2,39 MPa). U fazi žetve pšenice na unutarnjem dijelu parcele zbijanje tla varira u rasponu od 2,14-2,81 MPa, a na uvratinama od 3,38-4,28 MPa, što je više za 54,29%. Prinos suhog zrna pšenice u unutarnjem dijelu parcele kretao se od 3,24-3,90 tha^{-1}, a na uvratini od 2,53-3,14 tha^{-1}. (Barać i sur., 2012). Isti autor (Barać i sur., 2014), navodi da je zbijanje tla na početku mjerenja u pšenici na unutarnjem dijelu parcele bilo u prosjeku 1,64 MPa, a na uvratini 2,55 MPa, što predstavlja povećanje za 58,37%. U vrijeme žetve pšenice na unutarnjem dijelu parcele zbijenost tla iznosila je 2,59 MPa, a na uvratinama 3,98 MPa, što je u prosjeku veća zbijenost za 53,56%. Prinos suhog zrna pšenice u unutarnjem dijelu parcele bio je u prosjeku 5,20 tha^{-1}, a na uvratini 3,52 tha^{-1}, pa je urod manji za 47,81%.

Veliki broj prolaza, naročito na uvratinama uzrokuje intenzivnije zbijanje tla što negativno utječe na promjene u samom tlu kao i na urod koji je bio manji kod pšenice za 44,86%, kukuruza 54,48%, suncokreta 19,09%, soje 11,41% i šećerne repe 52,72% (Nikolić i sur., 2006).

Veći sadržaj organske tvari, bolja prozračnost i veća količina topline uzrokuju veću mikrobiološku aktivnost u oraničnom sloju tla (10-25 cm), što potvrđuju i rezultati istraživanja Jaraк i sur. (2005) i Savin i sur. (2008).

Zbijenost tla koje nastaje uslijed primjene teške mehanizacije izaziva smanjenje brojnosti svih sistematskih i fizioloških grupa aerobnih mikroorganizama, a povećava brojnost anaerobnih bakterija (Govedarica i sur., 1996). Uzorci tla s uvratina imaju viši sadržaj humusa u usporedbi s onima iz unutarnjeg dijela parcele što se objašnjava većim zbijanjem tla na uvratinama i smanjenjem mikrobiološke aktivnosti i intenziteta mineralizacije humusa. Iako je sadržaj humusa veći na uvratinama, zbog zbijenosti tla postižu se manji prinosi pšenice. Ukupan broj mikroorganizama i broj azotobaktera bio je veći u unutarnjem dijelu parcele što se može objasniti poremećenom strukturom i lošim prozračivanjem tla na uvratinama kao posljedicom intenzivnog gaženja i veće zbijenosti tla. Kako dubina raste, broj mikroorganizama u pokusnom tlu se smanjuje (Govedarica i sur., 1996, Nikolić i sur., 2004, Jarak i sur., 2005, Savin i sur., 2007, Savin i sur., 2008, Savin i sur., 2008a).

Prema Nikoliću i sur. (2002) oštećenja zbog prekomjernog zbijanja tla očituju se u porastu troškova proizvodnje od 20% do 40%, prosječnom smanjenju uroda za 10-25%, prosječnom porastu potrošnje goriva za 20-25%, te povećanju investicija za strojeve, objekte i osoblje za 10-25%. Realizirani gubici kao posljedica pretjeranog zbijanja tla iznose 224,5 USD ha^{-1} godišnje.

Cilj ovog rada je odrediti razliku u prinosu na unutarnjem dijelu-sredini parcele u odnosu na urod na krajevima parcele-uvratinama.

MATERIJAL I METODE

Tijekom proizvodne godine 2016/17. u agroekološkim uvjetima središnje Srbije na širem području Kruševca na tri lokaliteta postavljen je proizvodni pokus sa ozimom sortom pšenice Pobeda. Tehnologija uzgoja pšenice na sva tri mjesta bila je ista. Radi razmatranja gaženja tla na uvratinama, odabrane su parcele na kojima se okretanje traktorskih agregata i kombajna obavlja samo na parceli, ne izvan nje, stvarajući na taj način pravu uvratinu. Tijekom žetve metodom slučajnog uzorka, s površine od 1 m^2 u četiri ponavljanja ručno je požnjeven usjev pšenice na unutarnjem dijelu-sredini i krajevima-uvratinama parcele. Uzorci su označeni i stavljeni u papirnate vrećice i odneseni u laboratorij. Prije vršidbe iz uzorka je izdvojeno po 20 biljaka da bi se izmjerila visina biljka (VB) i duljina klasa (DK) u tri ponavljanja. U laboratoriji za Mehanizaciju na Agronomskom fakultetu u Čačku obavljena je vršidba uzoraka pšenice s vršalicom Hege 15. Zrno je posle vršidbe očišćeno od stranih primjesa na selektoru Dakota. Pored visine biljaka i duljine klase utvrđen je prinos zrna (P), masa 1000 zrna (AM) i hektolitarska masa zrna (HM). Za određivanje hektolitarske mase korištena je Šoperova vaga tip ATŽ, a za brojanje zrna automatski uređaj Elmor C3.

Analiza podataka istraživanja temelji se na izračunatim srednjim vrijednostima i njihovim standardnim odstupanjima. Za statističku analizu dobivenih rezultata korišten je statistički model Analyst program SAS/STAT (SAS Institute, 2000). Sve ustanovljene značajnosti utvrđene su na temelju modela ANOVA testa sa razinom značajnosti od 1% i 5%.

REZULTATI I RASPRAVA

Veliki broj prohoda kotača traktora i kombajna preko površine parcele dovodi do zbijanja tla na uvratinama i slabije mikrobiološke aktivnosti koje su stvorile nepovoljne uvjete za razvoj korijenskog sustava i same biljke. Intenzivno gaženje i neravnomjerno zbijanje tla na uvratinama u usporedbi s unutarnjim dijelom parcela utjecalo je na pojavu velike razlike u prinosu. Urod zrna na uvratinama je bio manji u usporedbi s unutarnjim dijelom parcele za 1.496 kg na lokaciji 1, za 2.624 kg na lokaciju 2 i za 1.948 kg na lokaciji 3 (Tablice 1; 2 i 3). Stoga je prinos zrna pšenice na unutarnjem dijelu pokusne parcele bio veći za 44,01% - 69,06% u usporedbi s uvratinom.

Najveća masa 1000 zrna 41,07 g kod ispitivane sorte pšenice Pobeda ustanovljena je na sredini parcele na lokaciji 2. Najmanja masa 1000 zrna 30,96 g na unutarnjem dijelu i 34,01 g na uvratini parcele ustanovljena je na lokaciji 1. Također, na istoj lokaciji utvrđena je najmanja vrijednost hektolitarske mase 66,75 kg hl^{-1} na sredini i 67,60 kg hl^{-1} na uvratini parcela, u usporedbi s vrijednošću hektolitarske mase na ostalim dvjema lokacijama.

Tablica 1 Prosječne vrijednosti ispitivanih osobina ozime pšenice na lokaciji 1
Table 1 Average values of examined properties to wheat winter at location 1

Sorta Variety	Sredina parcele Middle of the plot					Uvratina Headlands				
	x	Min	Max	Sd	Sx	x	Min	Max	Sd	Sx
P, t ha^{-1}	4,895	3,683	6,062	0,972	0,486	3,399	2,445	4,214	0,853	0,427
AM, g	30,96	30,53	31,80	0,572	0,286	34,01	29,15	38,91	5,560	2,780
HM, kg hl^{-1}	66,75	65,54	68,90	1,509	0,755	67,60	66,85	68,40	0,861	0,431
VB, cm	64,30	60,46	71,46	5,036	2,518	60,94	54,20	65,76	4,911	2,455
DK, cm	58,82	54,83	67,03	5,566	2,783	55,43	40,56	69,36	11,78	5,888

Prinos zrna (P), masa 1000 zrna (AM), hektolitarska masa zrna (HM), visine biljke (VB) i duljina klasa (DK)
Grain yield (P), 1000 grain weight (AM), volume (hectolitre) grain weight (HM), plant height (VB), spike length (DK)

Najveća masa 1000 zrna 41,07 g kod ispitivane sorte pšenice Pobeda ustanovljena je na sredini parcele na lokaciji 2. Najmanja masa 1000 zrna 30,96 g na unutarnjem dijelu i 34,01 g na uvratini parcele ustanovljena je na lokaciji 1. Također, na istoj lokaciji utvrđena je najmanja vrijednost hektolitarske mase 66,75 kghl^{-1} na sredini i 67,60 kghl^{-1} na uvratini parcela, u usporedbi s vrijednošću hektolitarske mase na ostalim dvjema lokacijama.

Tablica 2 Prosječne vrijednosti ispitivanih osobina ozime pšenice na lokaciji 2
Table 2 Average values of examined properties to wheat winter at location 2

Sorta Variety	Sredina parcele Middle of the plot					Uvratina Headlands				
	x	Min	Max	Sd	Sx	x	Min	Max	Sd	Sx
P, t ha^{-1}	6,425	5,825	7,463	0,733	0,366	3,801	3,035	4,606	0,654	0,327
AM, g	41,07	40,07	41,80	0,749	0,374	36,40	34,90	37,52	1.095	0,548
HM, kg hl^{-1}	73,29	72,04	75,71	1,731	0,866	69,26	67,77	70,02	1.012	0,506
VB, cm	65,84	63,63	68,10	1,825	0,913	62,85	59,90	68,70	3.967	1,983
DK, cm	59,73	59,36	60,03	0,278	0,139	56,29	53,40	59,83	2.969	1,484

Prinos zrna (P), masa 1000 zrna (AM), hektolitarska masa zrna (HM), visine biljke (VB) i duljina klasa (DK)
Grain yield (P), 1000 grain weight (AM), volume (hectolitre) grain weight (HM), plant height (VB), spike length (DK)

Zbijenost tla i slabija mikrobiološka aktivnost utjecali su na osiguravanje manje količine lako dostupne vode i hranljivih tvari što je rezultiralo manje razvijenim korijenskim sustavom i nižom visinom biljaka na uvratinama u usporedbi s unutarnjim dijelom parcele. Najveća razlika između visine biljaka pšenice na uvratini i unutarnjem dijelu parcele od 8,82 cm ili 13,75% zabilježena je na lokaciji 2. Također, na lokacijama 1 i 2 u središnjem dijelu parcele visina biljaka je veća za 3,36 cm ili 5,51% i za 2,2 cm ili 4,76% u usporedbi s uvratinom (prema redoslijedu).

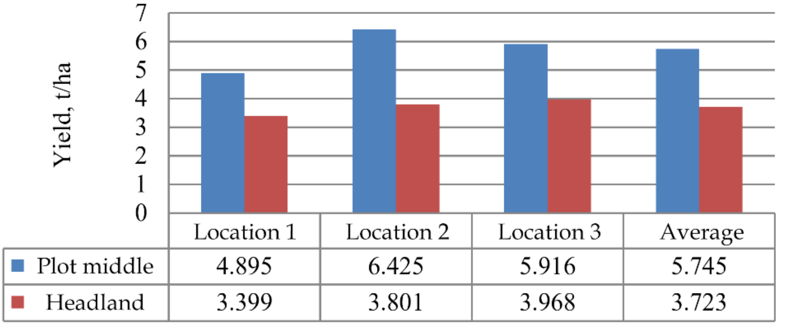
Na unutarnjem dijelu parcele i uvratini najveća visina biljaka i najkraći klas ustanovljen je na lokaciji 3, dok je najmanja visina biljaka i najduži klas zabilježena na lokalitetu 2.

Tablica 3 Prosječne vrijednosti ispitivanih osobina ozime pšenice na lokaciji 3
Table 3 Average values of examined properties to wheat winter at location 3

Sorta Variety	Sredina parcele Middle of the plot					Uvratina Headlands				
	x	Min	Max	Sd	Sx	x	Min	Max	Sd	Sx
P, t ha^{-1}	5,916	3,775	6,940	1,450	0,725	3,968	3,031	5,174	0,900	0,450
AM, g	35,67	28,65	39,36	4,836	2,418	36,42	35,62	37,58	0,828	0,414
HM, kg hl^{-1}	73,11	61,36	77,60	7,850	3,925	75,20	73,46	76,13	1,205	0,602
VB, cm	72,94	67,96	75,76	3,505	1,753	64,12	56,73	71,48	6,145	3,072
DK, cm	46,64	41,00	53,43	5,126	2,563	40,23	36,76	45,09	3,922	1,961

Prinos zrna (P), masa 1000 zrna (AM), hektolitarska masa zrna (HM), visine biljke (VB) i duljina klasa (DK)
Grain yield (P), 1000 grain weight (AM), volume (hectolitre) grain weight (HM), plant height (VB), spike length (DK)

Veliki broj prohoda traktora i kombajna rezultirali su gaženjem i većim zbijanjem tla na uvratinama u usporedbi s unutarnjim dijelom parcele što je utjecalo na smanjenje prinosa u prosjeku za 54,31 % na sve tri lokacije kod ispitivane sorte pšenice (Graf. 1).



Slika 1 Prosječne vrijednosti uroda zrna pšenice u tha^{-1}
Figure 1 Average values grain yield of wheat in tha^{-1}

Rezultati istraživanja u ovom radu o utjecaju zbijanja tla na razliku u prinosu između unutarnjeg dijela parcele i uvratine su u suglasju s rezultatima drugih autora (Nikolić i sur., 2006; Savin i sur., 2007; Savin i sur. 2008; Savin i sur. 2008a; Barać i sur. 2012; Barać i sur. 2014).

Analiza varijance prinosa zrna i produktivnih osobina na središnjem dijelu parcele i uvratinama ispitivane sorte ozime pšenice uzgajane na tri lokacije date su u tablici 4.

Tablica 4 Analiza varijance ispitivanih osobina ozime pšenice
Tablica 4 Analysis of the variance of the examined properties of winter wheat

Utjecaj lokacije na ispitivane osobine Influence of plot location on tested properties				
Osobina/Property	Mean Effect	Mean Error	F (2, 21)	p-level
P, t ha^{-1}	2,1257	2,0233	1,0506	0,3674
AM, g	78,5344	11,1703	7,0306**	0,0046
HM, kg hl^{-1}	98,5480	12,0500	8,1783**	0,0024
VB, cm	73,8906	26,2925	2,8103*	0,0829
DK, cm	533,9849	37,5904	14,2053**	0,0001
Utjecaj mjesta uzorkovanja na ispitivane osobine Influence of sampling location on tested properties				
Osobina/Property	Mean Effect	Mean Error	F (1, 22)	p-level
P, t ha^{-1}	24,5471	1,0088	24,3320**	0,0001
AM, g	0,5046	17,7791	0,0284	0,8677
HM, kg hl^{-1}	0,7921	20,4252	0,0388	0,8457
VB, cm	153,6722	24,8296	6,1891*	0,0209
DK, cm	116,8651	79,1138	1,4772	0,2371
Utjecaj interakcije lokacije x mjesto uzorkovanja na ispitivane osobine Influence of interaction between plot location and sampling location				
Osobina/Property	Mean Effect	Mean Error	F (2, 18)	p-level
P, t ha^{-1}	0,6460	0,9250	0,6984	0,5104
AM, g	31,4101	9,5140	3,3015	0,0601
HM, kg hl^{-1}	20,9599	11,6854	1,7937	0,1948
VB, cm	21,3501	19,7650	1,0802	0,3605
DK, cm	5,9511	36,7017	0,1621	0,8515

Prinos zrna (P), masa 1000 zrna (AM), hektolitarska masa zrna (HM), visine biljke (VB) i duljina klasa (DK)
Grain yield (P), 1000 grain weight (AM), volume (hectolitre) grain weight (HM), plant height (VB), spike length (DK)

Mjesto uzorkovanja je značajno utjecalo na visinu prinosa (F_{exp}=24,3320**), na visinu biljaka (F_{exp}=6,1891*), dok na druga ispitivana svojstva nije utjecalo (Tab. 4). Pored mjesta uzorkovanja, i faktor lokacija je visoko značajno utjecao na masu 1000 zrna (F_{exp}=7,0306**), hektolitarsku masu (F_{exp}=8,1783**) i duljinu klasa (F_{exp}=14,2053**), dok je utvrđen značajan utjecaj na visinu biljke (F_{exp}=2,8103*). Podaci dobiveni u tablici 4. mogu se tumačiti time da su ispitivane osobine masa 1000 zrna, hektolitarska masa, duljina klasa i visina biljaka svojstva sorata i da uz istu tehnologiju uzgoja na njihove vrijednosti pored sorte, tj. Genotipa utječu agroekološki uvjeti, tj. klimatski uvjeti i vrsta tla.

ZAKLJUČAK

U Srbiji, smanjenje plodnosti i pojava degradacije tla, posljedica je primjene konvencionalne obrade tla i velikog broja prolaza traktorskih sustava po parceli. Na temelju dobivenih rezultata može se zaključiti da je intenzivnije zbijanje tla na uvratini u usporedbi s unutarnjim dijelom parcele uzrokovalo stvaranje nepovoljnih uvjeta za rast i razvoj usjeva ozime pšenice i smanjenje uroda.

U konvencionalnoj tehnologiji proizvodnje pšenice, veliki broj prolaza traktorskih kotača i kombajna preko površine parcele dovodi do zbijanja tla na uvratinama i stvaranja nepovoljnih uvjeta za razvoj korijenskog sustava i same biljke. Povećana zbijanja tla na uvratinama smanjila su prinos pšenice od 44% do 69,06%, a u prosjeku za 54,31 % u usporedbi s unutarnjim dijelom parcele. Zbijenost tla i slabija mikrobiološka aktivnost utjecali su na osiguranje manje količine lako dostupne vode i hranljivih tvari što je utjecalo da visina biljaka na uvratinama u prosjeku bude manja za 8 %, a dužina klasa od 6,11% do 15,93 % manja u usporedbi s unutarnjim dijelom parcele. Nije bilo značajnih razlika u vrijednostima hektolitarske mase i mase 1000 zrna pšenice utvrđene na uvratini i unutarnjem dijelu parcele.

ZAHVALA

Rad je dio istraživanja na projektima TR31051 - Unapređenje biotehnoloških postupaka u funkciji racionalnog korištenja energije, povećanja produktivnosti i kvaliteta poljoprivrednih proizvoda; TR 31054 - Razvoj novih tehnologija gajenja strnih žita na kiselim zemljištima primenom savremene biotehnologije; TR 31057 - Poboljšanje genetičkog potencijala i tehnologije proizvodnje krmnog bilja u funkciji održivog razvoja stočarstva, financiran od strane Ministarstva prosvete, nauke i tehnološkog razvoja Republike Srbije.

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THE DECREASE OF WHEAT YIELD ON THE PLOT EDGES – HEADLANDS DUE TO SOIL COMPACTION

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SUMMARY

By executing appropriate agro-technical measures in the process of production of field crops (wheat), due to the numerous passages by machines, the soil gets compacted. In the family farms in Serbia, technological processes of production of field crops comprise specific agro-technical measures, starting with distribution of fertilizers, a multi-phase soil treatment system, followed by sowing, protecting, fertilization, harvesting, transporting of grain and plant residues. Thus, in the implementation of technological operations in the production of plant crops, the land area of the plot is exposed to 10 to 15 passages by tractor and self-propelled systems. A large number of passages by machines result in the soil compaction in the centre of the plot, and especially on the edges - headlands, which negatively affects the yield of cultivated crops and leads to physical and mechanical disturbance of the structure of the soil.

The aim of the research was to determine the difference in yield, plant height, spike length, 1000 grain weight and volume grain wheat in the central part of the plot in relation to the headlands of the plot.

For the purpose of this paper, a trial was set up with varieties of wheat Pobeda at three sites, and the wheat yield was measured on the inner part –plot centre and the edges -headlands of the plot, with more pronounced soil compaction. During the research, in addition to the yield, the following were determined: the difference in plant height, spike length, 1000 grain weight and volume (hectolitre) grain weight in the middle plot and headlands. The yield of wheat on the inner part of the plot at all locations was above 44% to 69.06% to yield realized on the headlands. The average plant height was higher by 4.76% to 13.75%, and the spike length from 6.11% to 15.93% in the middle of the plot relative to the edges - headlands. On the inner part of the plot the weight of 1000 grains and volume weight were lower compared to the values of these properties on the edges.

Keywords: *wheat, headlands, yield, plant height, spike length, 1000 grain weight and volume grain weight.*

47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

THE WEQUAL PROJECT: A WEB PLATFORM FOR MULTIDIMENSIONAL EVALUATIONS OF GREEN INFRASTRUCTURES

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SUMMARY

The aim of WEQUAL project "Web service centre for QUALIty multidimensional design and tele-operated monitoring of Green Infrastructures") is the development of a system able to support a quick environmental monitoring of riparian areas subjected to the realization of new green infrastructures (GI). The Wequal's idea is to organize a service center managing both the Web Platform and the whole data collection and analysis process. Each user (designer, technician, researcher), through a personal account, can access at the service and require the evaluation of alternatives GI projects.

On the Web Platform a set of algorithms runs in order to calculate, through automatic procedures, all the ecological criteria required to evaluate a quality environmental index which describes the ecological state of the monitored riparian areas. For this aim the WEQUI index was developed. In this paper the approach followed to collect the environmental data and the procedures to perform the automatic assessment of the ecological criteria are described. For the computation, the implemented algorithms use data regarding the NDVI index, Digital Terrain Model (DTM), Digital Surface Model (DSM) and a 3D point cloud classification. All the raw data are collected by an UAV (Unmanned Aircraft Vehicle) equipped with a 3D Lidar, multispectral camera and RGB camera.

The computed ecological index is then used to assess the riparian environmental quality at ex-ante and ex-post river stabilization works. This index, integrated with additional not-technical or not-ecological indicators such as investment required, maintenance costs or social acceptance, can be used in multicriteria analyses in order to evaluate the intervention from a wider point of view. The platform is expected to get the interests of GI designers and policy makers, providing a shared environment able to integrate the way some complex indexes can be detected and evaluated and an environment for multidimensional evaluations supported by an expert guide.

Keywords: *Remote sensing, Environmental monitoring, Web Platform, Ecological Index*

INTRODUCTION

In the recent years, the European environmental policies aimed to safeguard the biodiversity of the ecosystems, through the promotion and use of Green Infrastructures (GI) for river stabilization works. For instance, the Water Framework Directive (WFD-2000/60/EC) aims to classify the water bodies and to identify the anthropogenic impacts on that, in order to carry out a qualitative and quantitative evaluation of the improvement of river systems. Meanwhile, the Floods Directive (2007/60/EC) focuses on the design and planning phases of hydraulic works with the aim of reducing the risk of natural disasters due to floods, landslides or erosion and of safeguarding aquatic ecosystems (Rinaldi et al., 2016). The European project EFRE-FESR Südtirol-Alto Adige WEQUAL "Web service centre for QUALIty multidimensional design and tele-operated monitoring of Green Infrastructures" aims at the development of a series of methodologies, integrated in a web platform, able to quickly and automatically assess the environmental impact of longitudinal and transversal hydraulic infrastructures. Therefore, the goal of the research, is to develop a tool, as much objective as possible, to support decision making to various stakeholders in the design and evaluation of river works, such as technicians, administrators or researchers.

The web platform, the heart of the entire evaluation system, has been organized in such a way to guarantee two distinct evaluations:

- The current status of the river, which assesses the environmental quality of a section of river, where a river management system is already installed.
- Forecast state, where the environmental impact of hydraulic infrastructure that could be hypothetically built with the scope of river regulation is evaluated; this evaluation system allows users to compare, through multi-criteria analysis, multiple design alternatives, evaluating the best proposal not only from an environmental impact point of view.

The proposed system, through the use of specific environmental indicators and through a multi-dimensional analysis will be able to assess the level of environmental quality of the evaluated area. The best indicator chosen for this purpose is the River Functionality Index (IFF) (APAT, 2007), which has been re-adapted for project purposes and has taken the name WEQUI Index (Wequal Environmental QUality Index). The development of the new index was necessary in order to obtain a new tool able to perform the assessment in a semi-automatic procedure. In conclusion, the WEQUAL project aims to create automated procedures capable to process raw data from different sensors installed on Unmanned Aircrafts Vehicles (UAV) and to calculate, through the implementation of specific algorithms, the scores to be assigned to the individual criteria provided by the WEQUI index for the evaluation of the status of the rivers environment both *ex-ante* and *ex-post* the Green Infrastructures (GI) installation.

MATERIAL AND METHODS

The WEQUI index, developed for this purpose, is made of 15 criteria. Those criteria define the WEQUAL evaluation matrix. Following a feasibility analysis, 9 of these can be automatically evaluated using specific algorithms, while the rest require a direct manual survey in the field (Table 1).

Table 1 Indicators to be evaluated for the ecological assessment of fluvial areas. In the present table the indicators are divided in automatically assessable or not.

Automatic survey	Manual survey
1) Land use	3) Vertical continuity
2) Lateral continuity	7) Hydrologic regime
4) Longitudinal continuity	8) Chemical quality
5) Morphological heterogeneity	9) Macrobenthos community
6) Retention capability	10) Fish suitability
11) Riparian strip vegetation	15) Carbon footprint
12) Riparian strip width	
13) Riparian strip continuity	
14) Carbon sequestration	

To assign a score for each indicator it is necessary to choose the most representative answer in a list of 4 or 5 possibilities, depending on the situation to be evaluated. According to the indicator, the answer can require the evaluation of the whole riverbeds or the river bank only. Each answer is associated with an exponential score on basis two, from a minimum of 1 to a maximum equal to the base raised to the number of the reference question minus one. Through this approach it is possible to assess the conditions of low or high naturalness. Adding up the result obtained for each criterion the total index of environmental quality for right and left orographic river banks or for the riverbed is calculated.

As previously mentioned, most of the monitoring activities take place using a drone. During a field survey, several missions are planned according to the requests done by the user in the Web Platform. Generally, when a survey is defined, one flight with a LiDAR YellowScan Surveyor sensor, one with multispectral camera Micasense RedEdge and one with RGB digital camera are planned. Thanks to these combinations, it is possible to monitor the portion of the river and riverbanks to be evaluated even in case of difficult access. The collected data are then processed by specific algorithms capable of extrapolating the information needed to compile the individual criteria. For this scope, some of the automatic procedures have been implemented taking inspiration from methodologies already present in the literature (Cavalli et al., 2008; Michez et al., 2013; Tompalski et al., 2017) and adapted to our case, while others have been developed specifically for this study.

Currently the implementation and development phases of the algorithms are being studied. In fact, so far only two algorithms have been developed. Thanks to these algorithms it is possible to classify the use of land (criteria 1 of Table 1), identify the banks and classify the riparian vegetation (criteria 11 of the Table 1). In this preliminary phase, the algorithms have been implemented entirely in MATLAB, then they will be translated into open-source coding language implementable in an easy way on the Web Platform.

Both algorithms use as a starting point the images collected by the multispectral camera and the point cloud obtained from the LiDAR survey. The data obtained from the multispectral images are used for the calculation of different indices for the identification of vegetation, water and ground (e.g. NDVI, NDRE, GNDVI, BNDVI, CCCI, SAVI and OSAVI). While the data obtained from the other sensor are used to obtain 3D models of the terrain (Digital Terrain Model, DTM), of the surface (Digital Surface Model, DSM) and therefore of the vertical profile (Canopy Height Model, CHM) on the monitored area. The RGB camera is used just to take pictures and videos of the monitored area in order to collect a repository of information in case of necessity.

RESULTS AND DISCUSSION

The survey requirement starts with the boundary contouring of the Region Of Interest (ROI) on the Web Platform done by the user. Then all the external operations of field survey for raw data collection can be started. At that point the collected data are updated on the server where all the algorithms can process them to achieve the WEQUI index.

The algorithm used to classify the land use is shown in Figure 1. The evaluation procedure starts considering the region of interest previously drawn by the user. The polygon is used to clip (cropping procedure) both the images obtained from the multispectral, and the cloud of points collected by the LiDAR. Once the analysis area has been extracted, the algorithm proceeds with the following steps:

1. Request to draw a sample area on vegetation and water surface;
2. Calculation of vegetative indices for the determination of threshold values for the discrimination of the vegetative layer from the water layer previously drawn;
3. Classification in the entire ROI, based on the previously calculated threshold values, of the surface where vegetation is present from that where water is present;
4. Calculation of the surface area covered by ground, considering it as the difference between the total analyzed area and the areas calculated in point 3;
5. Characterization of the raw point cloud (using GlobalMapper) for the extraction of the DTM and DSM;
6. CHM calculation by raster subtraction operation between DTM and DSM;
7. Cross-reference of the information obtained in points 3, 4 and 6 to obtain the classification of vegetation and the presence of civil infrastructures;
8. Calculation of the land use percentage for each analyzed type.

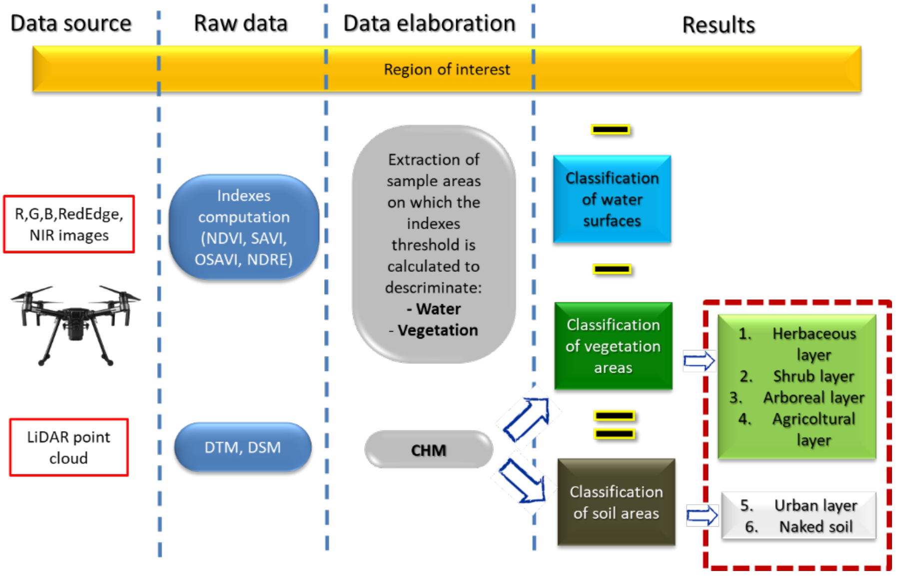

Figure 1 Schematic representation of the algorithm for the automatic classification of land use in the river portion covered by the monitoring

The following image (Figure 2b) shows the result obtained by the automated classification of land use. Here only the macro-items of vegetation, water and ground necessary for the validation of the procedure are considered. In addition to the map, the algorithm can calculate the area of the surface covered by the different types of use.

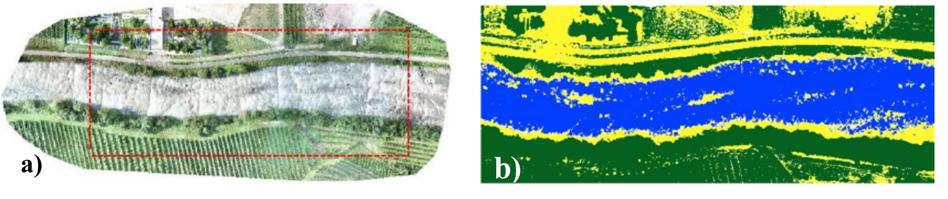

Figure 2 a) The orthophoto acquired by the multispectral camera is shown. on this picture the polygon for the clipping operation can be drawn.
2 b) The result of the automatic computation procedures for the classification of the land use is reported (in green the vegetation, in blue the water and in yellow the ground)

Figure 3 shows the scheme of the computational procedures of the algorithm implemented for the extraction of the banks and the characterization of the vegetation present on them.

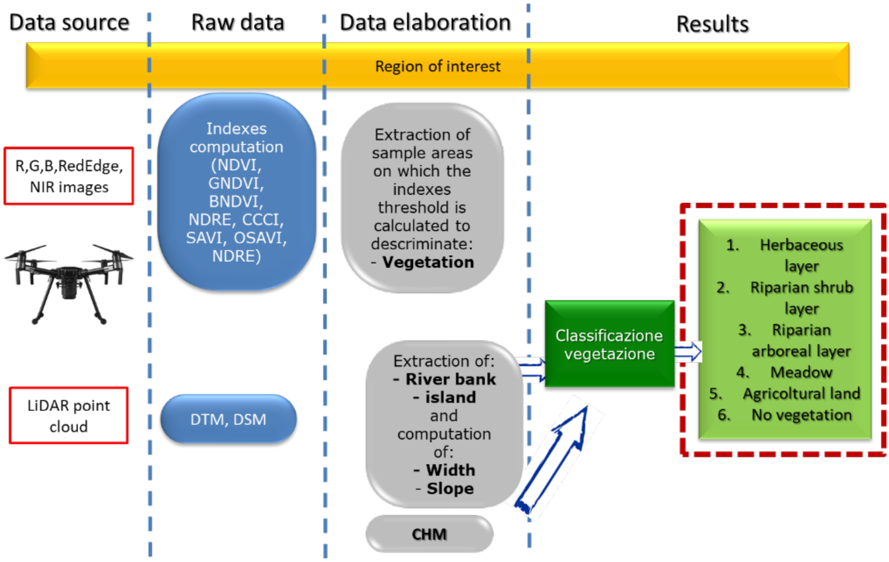

Figure 3 Schematic representation of the algorithm for automatic identification of the banks and classification of riparian and floodplain vegetation in the portion of river affected by the monitoring

Like the previous, this algorithm is based on a first clip operation to extract, from the raw data, those related to the area interested by monitoring. Once this first analysis has been carried out, the algorithm proceeds with:

1. Request to trace a sample representative area for vegetation and water;
2. Calculation of the vegetative indexes for the determination of the threshold values necessary to identify the vegetative layer and the watercourse;
3. Identification of the vegetation layer and river over the entire area of interest;
4. Characterization of the raw point cloud (by GlobalMapper) for the extraction of the DTM and DSM;
5. Identification of banks and islands through the analysis of the frequency distribution of the inclination of the land near or inside the river, considering the cross-section of the river (Figure 4).
6. CHM calculation by raster subtraction operation between DTM and DSM;
7. Cross-reference of the information obtained under 3, 5 and 6 to obtain the classification of vegetation on the banks or islands within the river;
8. Calculation of the percentage of coverage for each analyzed type.

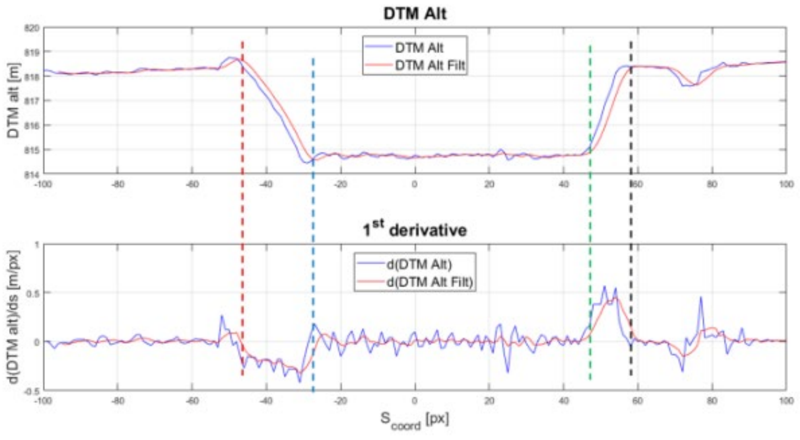

Figure 4 Riverbank extraction from DTM. The algorithm identifies the foot and the riverbank head by means of first derivative analysis of the transverse profile. The slope values of the banks are used for the physical characterization of the banks.

As in the previous analysis, also for this one, the result is a map on which the classification of the riparian and floodplain vegetation are reported (Figure 5). Besides this, the calculation of the areas occupied by the two vegetation types is performed.

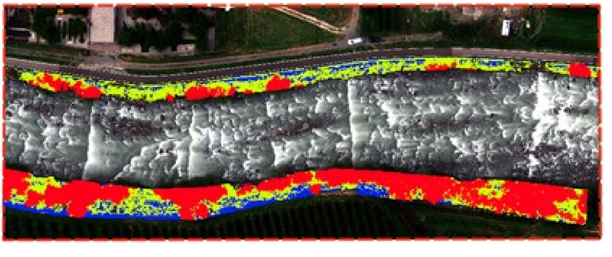

Figure 5 Graphical result of algorithm procedures for riverbanks, riparian and alluvial riparian vegetation (the green, blue and red colors refer to the herbaceous layer, riparian shrubs and riparian arboreal, respectively)

At this point of the research, unfortunately, the validation of the results could only be conducted for the algorithm of the land use classification. Using a GIS software, it was possible to perform a visual classification of the region of interest of the survey. The surface inside the red polygon displayed in Figure 2a, has been firstly identified as vegetation, water and ground, secondly for each classification the total surface has been calculated. The obtained results have then compared with the same results obtained by the automatic method. Table 2 shows the results.

Table 2 Validation of the automatic analysis procedure

	Manual survey	Automatic survey	Differences
Vegetations	53.2%	50.3%	-2.9%
Water	27.2%	21.0%	-6.2%
Ground	19.6%	28.7%	9.1%

The results in Table 2 highlight that the implemented algorithm for the automatic land use classification is capable to well recognize the areas where vegetation is present, while it has uncertainties in the identification of water and ground surfaces. This may be due to possible problems with the recognition of transition zones. In fact, according to the hour and the season in which the flights were carried out, a portion of the image is affected by a shaded band due to the presence of the foliage of the riparian plants. This shading causes a slight variation in the reflectance of these transitional bands which affects the data-processing causing an overestimation of the ground content. A further cause of soil overestimation may be due to the similar reflection between thin water layers within the river and the gravel of the riverbed causing mistakes is the assessment: part of water is identified as ground.

CONCLUSION

The final objective of the WEQUAL project is the realization of a Web platform able to provide decision support for the assessment of the environmental quality of fluvial environment through a semi-automated analysis of a matrix composed by 15 indicators. In this manuscript the preliminary results of the implementation of two algorithms capable of performing, through an automated procedure, the evaluation of i) land use and ii) riparian strip vegetation assessment have been reported. The algorithm for the land use assessment has shown to be enough accurate for identifying vegetation, less accurate in the distinction between ground and water, while the evaluation phase of the results obtained by the second algorithm still needs to be validated. The implementation of the remaining algorithms requires the identification of the river axle. Indeed, with the identification of the river axle it will be possible to distinguish between the right and left riverside and to track the cross sections along the monitored river portion. Thanks to the last information, the physical evaluations of the monitored watercourse can be carried out. Finally, as they cannot be automatically evaluated, the chemical-biological parameters are expected to be collected manually as well as the attribution of the respective scores and their inclusion in the web platform.

ACKNOWLEDGEMENTS

Research funded by the program EFRE-FESR 2014-2020 for South Tyrol – WEQUAL Project – CUP I52F16000840005.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

WATER ALLOCATION FOR AGRICULTURAL USERS BASED ON MULTI CRITERIA ANALYSIS AND USE OF DECISION-MAKING TOOLS

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ABSTRACT

Recent research has signaled promising options to create a unique framework to integrate multi-criteria optimization tools with river basin simulation-optimization models. From the multi-criteria decision-making area Analytic hierarchy process (AHP) is selected to evaluate selected parts of output generated by the river basin simulation-optimization model (ACQUANET) which is applied to allocate water to agricultural users within a given river basin. Multiple runs of a river basin model can produce information about water allocation under different prioritization of users, namely a set of allocation scenarios as possible decision alternatives. The analytic hierarchy process can then be used to efficiently perform the evaluation of scenarios in both individual and group contexts, the latter being especially important because stakeholders' involvement and participation in making decisions is 'a must' in modern decisions. A pilot test of the proposed approach was performed for one hydro-system in Serbia. Another pilot test is under preparation in Portugal and will serve as a verification of the methodology briefly described in this paper.

Keywords: *preference water allocation, network modeling, AHP, ACQUANET*

INTRODUCTION

Current developments in water resources management and agriculture are characterized by use of a wide spectrum of multi-criteria decision-making methods and supporting tools, advanced information technologies, and participation of the involved stakeholders from different sectors. In spite of significant IT sector developments in last two decades, it is clear that the use of expert systems, simulation and optimization models and supporting tools for decision makers does not yet reach an adequate level. Additionally, communication of related issues to the scientific community and society at large still lacks the desired transparency. To properly evaluate alternative solutions in search for the most desired one, it is important to know how the models for decision making are imbedded in computerized systems as closed applications for planning and management of water resources. At the moment, the lack of such information is obvious.

The main challenge behind the research presented in this paper is to explore options for using decision-making supporting tools to interpret outputs from network-based river basin simulation-optimization models in unique scenario-evaluation framework. Its ultimate goal is to enable the synergies of two distinct methodologies (decision-making and simulation-optimization) for evaluating alternative scenarios for water allocation priority to agricultural users, namely small, medium and large-scale farmers' properties within a given river basin (watershed).

The primary goal as stated is to find a way to combine multi-sector information and quantify the effects of planning and usage of natural (and other) resources in the context of sustainable agriculture. The paper is aimed at determining ways to conduct a process of strategic and operational decision-making, preserving long-term, sustainable, and optimal (in a multi-criteria sense) water distribution to target locations, primarily to farms and irrigation facilities. It will explore how advanced technologies integrating IT, GIS and DSS can be used to produce plans for developing water resources. Of interest is to evaluate scenarios for water distribution to agricultural users while assuring integrity and consistency of data relevant for deriving trustful decisions. Enabling the creation of valuable solutions can be an extremely important input to stakeholders (managers, owners, politicians and others) who will be involved in the executive decisions.

The basic problems for water allocation in any watershed (river basin) can be stated as follows:

- Water flow is seasonally uneven, leading to quantity problems throughout the watershed
- In some parts of watershed, water quality could not be satisfactory.
- Usually there is a gap between financial demands and actual investment; existing sources of financing available at most water management levels and in certain segments could be several times less than required.
- Management of the water resources system could be inadequate (inefficient)
- Public participation is not encouraged, and sometimes not even possible.

A main strategic goal in the water sector is to enable maintenance and development of a water regime which attempts to achieve the best and the most complete engineering, financial and ecologic solutions, accounting for integral water management, water protection, protection against harmful effects of water, and water use. To accomplish this goal, contemporary road-maps suggest an integral, complex and unique water resources development system should be created. Creating this system requires development, deployment, operation and continuous upgrading of advanced modeling tools, software, and decision support systems (DSSs).

A DSS is an integrated interactive computer system combining analytical tools and information management capabilities. In general, it is designed to aid decision makers in solving relatively large, commonly unstructured problems. Well known DSSs with application in the water sector include WEAP (SEI, 2018), Mike Basin (DHI, 2018) and MODSIM (Labadie, 2015), but much more are reportedly in use (Srdjevic and Srdjevic, 2017). Earlier this century, an overview of internationally recognized DSSs for water management can be found in (McKenney, 2004). In general, the architecture for DSSs in water resources include artifacts such as data repositories (databases, spreadsheets), data processing (statistics), data visualization (spatial visualization modules, GIS), and also domain technologies such as simulation, optimization, multi-objective decision making, expert and knowledge-based systems, all supported by an user-friendly interface. An illustration of such a DSS architecture is presented in Fig. 1.

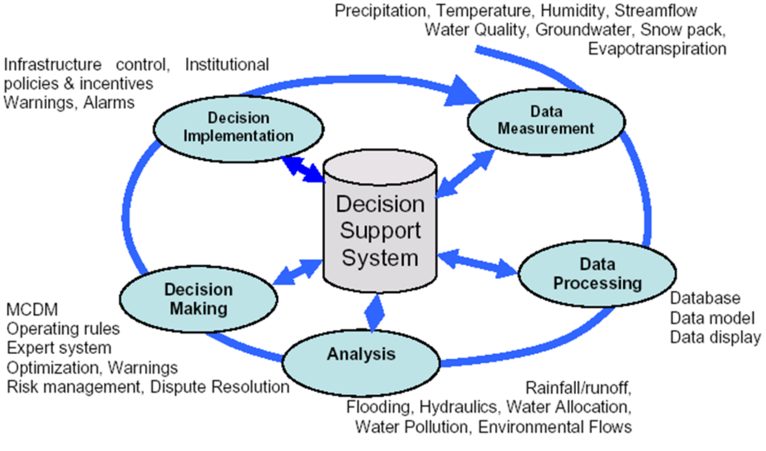

Figure 1 General framework for a water resources decision support system (McKenney, 2004).

As can be seen in Fig. 1, 'Data Processing', 'Analysis' and 'Decision making' are important architectural components, supported by adequate subsystems. The next two subchapters will briefly describe how processing of data can be performed (ACQUANET model), and which decision-making tool can be used (AHP tool) to evaluate scenarios, created after detailed analysis of processed data.

MATERIALS AND METHODS

Network simulation-optimization model ACQUANET

The network river basin computer model ACQUANET is a simpler version of MODSIM, a well-known model/software for solving water allocation problems for multi-year periods. For given hydrological conditions, ACQUANET simulates the operation of reservoirs located at most upstream locations of a watershed and allocates water to downstream users according to initial storages in reservoirs, specified operating rule curves at reservoirs and given priority scheme in overall water distribution. A physical model, usually tree-structured, is automatically modified into a close capacitated network model with a set of no-storage nodes and numerous physical and (added) artificial links as illustrated for a simplified system in Fig. 2. As such, a new model is a closed network, which must be in balance during the given time step (which is defined as one calendar month). After input data is submitted to the model, the multi-year allocation problem is solved as a chain of consecutive monthly optimizations, transferring the necessary information from month-to-month to preserve continuous time flow. This way ACQUANET behaves as a network simulation-optimization model.

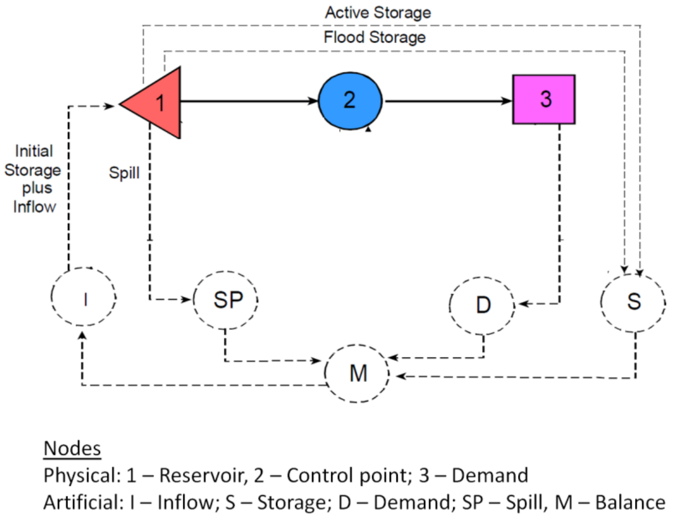

Figure 2 Network modeling concept implemented in ACQUANET
(One reservoir, one control point and one demand point)

The model is strictly deterministic, with the base assumption that hydrological conditions are known for one month ahead. At the beginning of any month within multiyear period, the model 'knows' what inflows will happen during this month, the required storage levels to be met in reservoirs at the end of that month, the demands at all demand points, capacities at all links within a system (rivers, canals, pipelines, transfer waterways, etc.) and what are the priorities of all stated targets (reservoirs' storage levels and downstream demands).

The one-month allocation problem is stated as network linear programming problem:

$$\min F = \sum_{ij} C_{ij} X_{ij}, \text{ for all i and j} \quad (1)$$

Subject to balance requirements at all nodes:

$$\sum_j X_{ji} - \sum_j X_{ij} = 0 \text{ , for all i} \quad (2)$$

and satisfaction of flow conditions at all links:

$$L_{ij} \leq X_{ij} \leq U_{ij}, \text{ for all i and j} \quad (3)$$

where: i, j are used to identify nodes in a network; X_{ij} is the flow in the link [i,j]; C_{ij} is the unit cost of flow through the link [i,j]; and L_{ij},U_{ij} are lower and upper limits on the flow through the link [i,j].

The allocation problem (1)-(3) is solved for each month using given network parameters (inflows, demands, rule curves at reservoirs, capacities on links, scheme of demands' priorities etc.). The solver in ACQUANET is based on Lagrangian over-relaxation algorithm, the network solver is written in Fortran and its interface is created with Visual Basic.

Multi-criteria decision-making with AHP

Among methods for solving discrete optimization problems with more than one criterion and number of alternatives, the Analytic Hierarchy Process – AHP (Saaty, 1980) is one of the most used in both individual and group environments. This method handles efficiently one of the key issues in decision making: eliciting judgments from the decision maker (DM) about the importance of a given set of decision elements regarding the overall goal, with criteria set introduced to locally prioritize (numerically) exposed judgments. If a problem can be structured hierarchically, then a ratio scale can serve as an effective tool to enable this hierarchy by performing pair-wise comparisons.

The core of the AHP lies in presenting the problem as a hierarchy (illustrated at Fig. 3) and pair-wise comparing the hierarchical elements using Saaty's 9-point scale (Saaty, 1980). In this way, the importance of one element over another is expressed with regards to the element in the higher level. The AHP creates so-called local comparison matrices at all levels of a hierarchy and performs logical syntheses of their (local) priority vectors. The major feature of the AHP is that it can thus include in the same framework a variety of tangible and intangible goals, attributes, and other decision elements. In addition, it reduces complex decisions to a series of pair-wise comparisons; implementing a structured, repeatable, and justifiable decision-making approach.

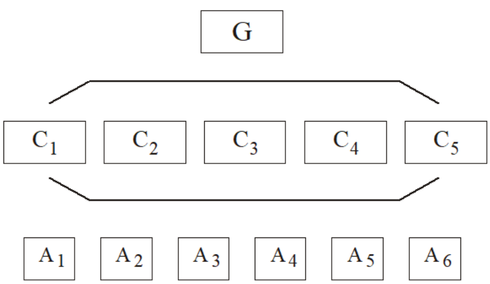

Figure 3 A hierarchy with a goal (G), five criteria (C_1–C_5) and six alternatives (A_1–A_6)

In the standard AHP, an eigenvector (EV) method is used to derive the weights from local matrices; the EV is called the prioritization method, and the computational procedure is consequently called prioritization. After the local weights are calculated at all levels of the hierarchy, the synthesis consists of multiplying the criterion-specific weight of the alternative by the corresponding criterion weight and summing up the results to obtain composite weights for the alternative with respect to the goal. This procedure is unique for all alternatives and all criteria.

The AHP is designed to support decision-making processes in both individual and group contexts. In a group setting various aggregation schemes are applicable, e.g., aggregation of individual judgments (AIJ) and aggregation of individual priorities (AIP) (Forman and Peniwati, 1998), as well as various easy to implement consensus-reaching procedures. Nevertheless, other group decision procedures namely with explicit visual support (e.g. Bezerra et al., 2014) can also be considered for application.

RESULTS AND DISCUSSION

ACQUANET implementation for the Nadela watershed

The Nadela watershed is located in the south-east area of Vojvodina Province in Serbia, (see Fig. 4). There are different water uses of this hydro-system. The main concerns in the watershed are that along the first 30 km of the Nadela canal, water is of the desired quality ('blue and clean') and mostly used for irrigation; however during the summer season and along the downstream final 15 km (before canal's confluence to Danube), it is not always possible to support the ecological minimum flow of 0.5 m^3s^{-1}. In consequence there is high, uncontrolled, pollution of this canal.

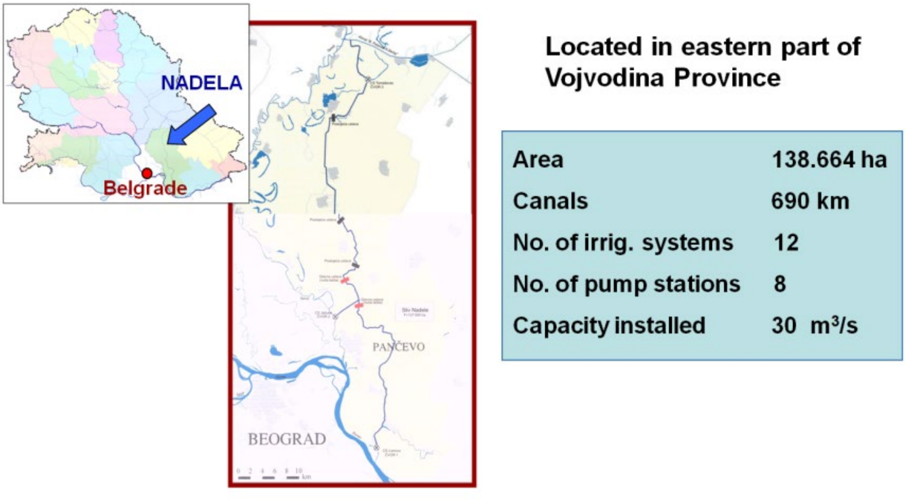

Figure 4 ACQUANET model of the regional hydro-system Nadela

The problem to be solved is thus stated as to identify strategy that will ensure well balanced system use and long-term satisfaction of prescribed system purposes and users' expectations. This strategy has to respect system capacity and its technical characteristics, but also interests of a society including sharing of benefits, environmental protection and balanced economic development of municipalities.

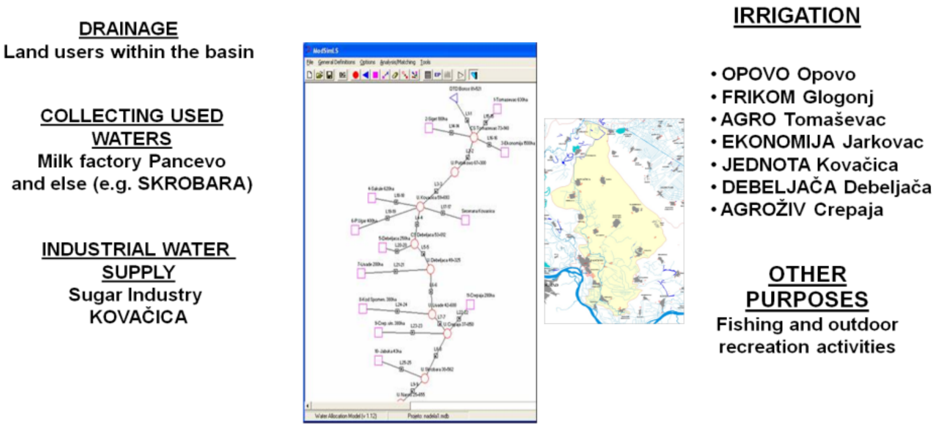

Figure 5 Water users in the Nadela watershed

Part of the strategy is to identify *key stakeholders* and motivate them to participate in decision-making processes (supported by the AHP method). One of the main problems, usually not systematically analyzed in participative decision making, is the selection of stakeholders.

Reed et al. (2009) provides examples of the comprehensive research on typology of stakeholder analysis in natural resources management, resources required, level of stakeholder participation, and strengths and weaknesses of each of the methods identified in the typology. Among models for stakeholders' analysis, the following were considered interesting: interest-influence matrices; focus groups; Q methodology; actor-linkage matrices; social network analysis; knowledge mapping; and radical trans-activeness. Following his recommendations, in any-watershed management eight major stakeholders' groups and their sub-groups should be considered:

1. users (irrigation, industry, fishing ponds, tourism),
2. government (ministries and provincial secretariats),
3. water sector (public water management company and regional water management companies),
4. scientific community (university and research institutes),
5. local authorities,
6. non-governmental organizations,
7. citizen's associations,
8. the general public.

In each situation their stakes should be defined relative to their real involvement, knowledge, interest and responsibility. This will be one of the challenges that will need addressing when ACQUANET multi-year simulations are completed for different scenarios of priority allocation of Nadela waters, particularly to agricultural users along the 83 kilometers long main canal.

The research proposal presented in this paper was created under the bilateral project ‘Multi-criteria decision making/Analytic hierarchy process applications in solving problems of priority water allocation for agricultural users’ (2018-2019). This project is realized by the University of Novi Sad (Serbia) and the University of Coimbra (Portugal).

As a recommendation, in line with the EU Water framework directive, the research team suggests that exploitation of water resources in watersheds in Serbia and Portugal should be planed having in mind existence of different interest parties, their possible conflicts, and also local economic and political environments. Planning should be supported by participative decision-making tools within a graphically enabled information system, to realistically determine how much water is available, to whom and when, and to declare management strategies acceptable to most of stakeholders in watersheds in to countries.

CONCLUSIONS

This paper presents an amended ACQUANET network model application for the water allocation problem in the Nadela watershed in Vojvodina Province in Serbia. Simulation using this model included several multiyear management strategies for water allocation to agricultural users along the 83 km long main canal. Simulations pointed out necessity for the refinement of strategies and for using additional alternative priority schemes to achieve long-term targets in water allocation, especially to agricultural users (small, medium and large size properties). The creation of possible scenarios for water delivery and their evaluation in multi-criteria environments is foreseen as a future challenge for the research groups in Novi Sad and Coimbra. Scenarios will be created by considering local, regional and state-wide conditions, with focus on preferences of local stakeholders (primarily farmers for the Serbia watershed, tourism and energy production for the Portuguese watershed) in the analyzed watersheds in both countries.

The need for including the different stakeholders in the participatory GIS environment is also recognized in this research. Involvement of stakeholders is possible through AHP+GIS methodology and its application for defining suitability for irrigation of land in selected small catchments in two countries, primarily irrigated areas near Bragança in northeast Portugal (Sabor watershed) and the Nadela river catchment in Serbia. Data collection for both case-study areas is underway, and ACQUANET simulations will be repeatedly performed and followed by multi-criteria assessment of different water allocation schemes. Search for best solutions will be combined with assessment of sustainability criteria and related indicators, following ideas presented in previous research (Sandoval-Solis et al, 2011; Srdjevic and Srdjevic, 2017).

ACKNOWLEDGMENT

The authors would like to acknowledge the financial support from the Serbian ministry of education, science and technological development under Grant No. 451-03-1924/2016-09/38. The authors would also like to thank FCT/Portugal support via bilateral project grant 441.00 SERBIA.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

MULTIAGENT CONFLICTS AND RESOLUTIONS IN WATER RESOURCES MANAGEMENT

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ABSTRACT

This paper describes a two-stage group consensus model for reaching the decision as a result of achieved consensus among agents participating in the decision making process for resolving the conflicts in water resources management. All agents evaluate the same hierarchy and produce individual priority vectors for alternatives versus goal. Representing different interest parties, agents can be grouped into sub groups to articulate parties. The consensus convergence model enables identifying most desired strategy that will, expectedly, be more readily accepted and implemented accordingly in real-life situation. A case study example is presented as a problem of how to select most acceptable water management strategy for a regional hydro system in Serbia.

Keywords: *multiagent decision making, AHP, consensus, water resources*

INTRODUCTION

Integrated water resources management requires that both waters and benefits should be shared. As far sharing the 'benefits from the river' is concerned, depending on the basin in case, it includes some or all of the following: a) direct payment for agricultural & municipal water uses; b) payment for fisheries, watershed management, flood control or compensation for costs for damaged land areas and pollution; c) trade agreements on hydro power, cargo transport, and agricultural products; d) agreements over financing and ownership of water projects, infrastructural works and operation and maintenance of existing facilities; e) sharing provision of unrelated goods and services and less tangible benefits such as rural development, tourism, outdoor activities etc.

To ensure application of integrated water management principles, involvement of stakeholders in decision making processes is inevitable. Furthermore, in modern times, with complexities, uncertainties, equity and sustainability issues involved in environmental decision making, new forms of stakeholders' participation are needed. One of the methods that is widely used for participatory decision making is analytic hierarchy process (AHP) (Saaty, 1980). Its recent applications in group decision making in water management can be found in literature (Ortega and Berbel 2010, Blagojevic et al., 2016, Amineh et al., 2017, Woltersdorf et al., 2018, Pluchinotta et al., 2018, Karlsson-Vinkhuyzen et al., 2018, Srdjevic B et al., 2018).

This paper presents experience of Serbian water-related science and engineering in implementing the AHP participative decision-making procedure, aimed to consider the conflict resolution issues in a way that conflict interests can be better recognized, modeled and resolved if interested parties (key players) are motivated to get involved. The main problems stated how to build consensus on idea that given hydro system in watershed is a common good, and how to conciliate different interests and resolve conflicts (at least at basic level), preserving that solution should be sustainable.

A typical regional hydro system in Serbia is selected as a case study example to demonstrate application of two-stage consensus convergence model on resolving major conflicts between upstream and downstream users of the system. The model is based on: (a) hierarchical structuring of decision making problem; (b) applying the AHP by performing individual judgments by acting agents (decision makers); (c) grouping agents into interest sub groups; (d) and two-stage aggregation of computed priorities by the consensus convergence model (Lehrer and Wagner, 1981), first within each interest sub group, and then between interest sub groups. The final consensus-based solution is declared as the final group decision and compared with the solution obtained as a geometric mean, the most widely used method of aggregating individual decisions made by agents.

MATERIALS AND METHODS

The AHP-group method

The AHP is a multicriteria decision making method which requires a well structured problem, represented as a hierarchy. Usually, at the top of the hierarchy is the goal; the next level contains the criteria and sub criteria, while alternatives lie at the bottom of the hierarchy. AHP determines the preferences among the set of alternatives by employing pair-wise comparisons of the hierarchy elements at all levels, following the rule that, at given hierarchy levels, elements are compared with respect to the elements in the higher level by using the certain importance scale. The results are placed in comparison matrices. After all judgments are made, the local priorities of the criteria, sub criteria and alternatives are calculated and synthesized to obtain the final alternatives utilities with respect to the goal. These utilities are commonly called relative weights or priorities).

In the AHP group decision making aggregation of individual priorities (AIP) can be obtained by weighted geometric mean method.

The collective priority vector $\boldsymbol{z}^G = (z_1^G, z_2^G, \ldots z_n^G)$ is obtained by using equation:

$$z_i^G = \prod_{k=1}^{K} \left[z_i(k) \right]^{\alpha_k} \quad \text{i} = 1, 2, \ldots, \text{n} \tag{1}$$

where n is the number of alternatives, K stands for the number of agents, $z_i(k)$ for the priority of ith alternative for kth agent, α_k for the 'weight' of kth agent, and z_i^G for the aggregated group priority value. The weights α_k should be additively normalized prior to their use in (1) and that the final additive normalization of priorities z_i^G is required.

Consensus in group decision making

In a group decision making process, both consensus and consistency need to be pursued and sought after. A solution with a high level of consensus is desirable. Many researchers focus on how to define acceptable level of consensus and, in turn, how to achieve it (Moreno-Jimenez et al., 2008, Alonso et al., 2010, Blagojevic et al., 2016, Dong et al., 2017, Brandt et al., 2017, Oliva et al., 2018). Beside methods proposed in given literature, there are also other formal mathematical methods for reaching the consensus, such as consensus convergence modeling or central tendency methods (middle 'value' is measured using the mean, median or mode). One of the best known formal models is the consensus convergence model (Lehrer and Wagner, 1981), where, by repeatable mathematical procedure and through mutual respect, the decision makers do not only achieve consensus on the issue under consideration, but also agree on the overall relative weight of each member of the group.

This model is considered as suitable conflict resolution method in water management problems because its mathematical structure captures typical situation of disagreement. Refusing to change one's opinion is equivalent, in mathematical terms, to assigning a null weight to other members and full weight to oneself (Hartmann et al., 2009). This situation is pure dogmatism that is unacceptable in modern decision making.

The consensus convergence model

Central idea of the consensus convergence model is assigning the agents' beliefs about expertise of other epistemic agents on the issue at hand (Hartmann et al., 2009).

The weight of respect, w_{ij}, describes the respect agent i has for the opinion or expertise of agent j, and $\sum_{j=1}^{n} \omega_{ij} = 1$ for the group of n agents.

Here we use an adapted version of the consensus convergence model presented in Regan et al., (2006). The procedure is based on original model introduced by Lehrer and Wagner (1981) which uses the weights of respect assigned by each agent, and modified model defined by Regan et al. (2006). The later model proposes using the weights of respect based on the strength of differences in criteria weights assigned by individuals in the group. In this model we can assume that initial criteria weights of n agents are p_1^0, p_2^0, ..., p_n^0 and a metric that calculates weights of respect is:

$$\omega_{ij} = \frac{1 - \left|p_i^0 - p_j^0\right|}{\sum_{j=1}^{n} 1 - \left|p_i^0 - p_j^0\right|} \tag{2}$$

where i refers to the individual who is assigning the weights, j refers to the individual being assigned a weight, and n is the number of group members.

The weights of respect are used to create nxn size matrix W:

$$W = \begin{bmatrix} w_{11} & w_{12} & \dots & w_{1n} \\ w_{21} & w_{22} & \dots & w_{1n} \\ \dots & \dots & \dots & \dots \\ w_{n1} & w_{n2} & \dots & w_{nn} \end{bmatrix}. \quad (3)$$

If P is a vector of initial criteria weights, consensual vector of criteria weights is obtained by iterative equation:

$$P_c = WP_{c-1}. \quad (4)$$

The procedure is repeated until the values of criteria weights in vectors P_c and P_{c-1} are equal within tolerant error limit. Convergence is guaranteed if weights of respect are constant throughout the iteration process for each decision maker.

The problem hierarchy

A typical regional hydro system in Serbia is selected to demonstrate the approach. Main purposes of the system are drainage, industrial water supply, collecting used waters, irrigation, and other purposes (Srdjevic and Srdjevic, 2008). Participants in the decision making process (agents) are identified by responsible public water management authority (PWMA). Invited 23 participants (agents) are briefed on main problems related to long term planning and management of the system, and particularly on a methodology applicable to resolving existing conflicts between interest parties. The final intent of a meeting was to gather parties around the same table and try to solve common problem.

The participants are explained how to act in the decision-making session aimed to reaching a consensus about strategy that will ensure well balanced system use and satisfaction of prescribed system purposes and users' expectations, but also that will respect defined system capacity and wider interests of a society. A discussion helped to elaborate most important decision making issues and to define a global goal as to identify the most desired long-term management strategy. Three criteria and five defined purposes of the system are adopted as evaluation filters that will apply to each of four defined management strategies.

A criteria set on the second level of hierarchy includes three main aspects of the water management within the region, recognized by involved participants from PWMA Vode Vojvodine and the Provincial Secretariat for Agriculture, Forestry and Water Management of the Autonomous Province Vojvodina. The criteria are identified as Economic, Social and Ecological. Different water uses are set on the next lower (third) level of the hierarchy: IR (irrigation), DR (drainage), UW (used waters), IS (industrial supply), and OP (other purposes).

At the lowest (fourth) level, four alternatives are posted representing possible management strategies for the 10-year period 2011-2020. Strategies are adopted after justification provided by the PWMA Vode Vojvodine and participants' notion of global importance of different water uses. From the Table 1, one can easily see that in each strategy one of the purposes of the system is assumed to have dominant priority, and that some purposes have tied priority.

Table 1 Water management strategies (2011-2020) as decision alternatives

	Strategy 1	Strategy 2	Strategy 3	Strategy 4
IRR	top	medium	medium	low
DR	medium	top	low	medium
UW	low	Low	top	low
IS	medium	medium	medium	top
OP	neglectible	Low	low	neglectible

RESULTS AND DISCUSSION

Phase #1

A session started with a 15 minutes brainstorming during which participants from PWMA Vode Vojvodine and the Provincial Secretariat for Agriculture, Forestry and Water Management of the AP Vojvodina found the compromise about relative mutual importance of the three selected criteria. Resulting weights of criteria are derived by AHP's eigenvector prioritization as follows: Economic criterion 0.674, Social criterion 0.226, and Ecological criterion 0.101.

Phase #2

All agents expressed their semantic preferences while performing pair-wise comparisons of elements at the third and fourth level of a hierarchy by judging elements in one level regarding elements in higher level. That means that each agent filled-in 8 comparison matrices: three 5x5 matrices for comparisons of water uses against three criteria, and five 4x4 matrices for comparisons of four offered strategies against five water uses. The resulting local weights of water uses are computed in turn and the AHP calculated the final weights of strategies for each agent.

Phase #3

Agents were grouped into five interest sub groups according to their affiliation, responsibility and present professional (or political) function related to water resources and/or regional system. Sub groups are formed as follows: Sub group 1: Irrigation (5 agents); Sub group 2: Used waters (3); Sub group 3: State/public interest (7); Sub group 4: Industry (4); and Sub group 5: Local authorities (4). For illustration purposes, individually derived weights of the strategies within the Sub group 1 by AHP are presented in Table 2.

Table 2 Weights of the strategies within the sub group 1

Sub group 1	Strategy 1	Strategy 2	Strategy 3	Strategy 4
Agent 1	0.393	0.239	0.175	0.193
Agent 2	0.414	0.236	0.174	0.176
Agent 3	0.411	0.249	0.204	0.136
Agent 4	0.338	0.235	0.229	0.198
Agent 5	0.334	0.219	0.226	0.220
Consensus convergence weights	0.366	0.233	0.212	0.190

To obtain consensus weights of strategies within each sub group, weights of respect of each agent within the same sub group are calculated for each strategy and placed in 'weights of respect matrix' W. For example, for Strategy 1 within Sub group 1, W^{S1}, is provided by using the vector of initial Strategy 1 weights and applying Eq. (2):

$$W^{S1} = \begin{bmatrix} 0.206 & 0.202 & 0.203 & 0.195 & 0.194 \\ 0.203 & 0.207 & 0.207 & 0.192 & 0.191 \\ 0.203 & 0.206 & 0.207 & 0.192 & 0.191 \\ 0.197 & 0.193 & 0.193 & 0.209 & 0.208 \\ 0.197 & 0.192 & 0.193 & 0.208 & 0.209 \end{bmatrix}. \tag{5}$$

By applying Eq. (4), consensual convergence weight 0.366 for Strategy 1 is obtained and this value can easily be compared with individual values in Table 3. The last row of this table contains consensus convergence weights for all strategies within the sub group 1.

By applying the same method, consensus weights for all other sub groups are computed and presented in Table 3.

Table 3 Sub group's consensus weights of strategies

	Strategy 1	Strategy 2	Strategy 3	Strategy 4
Sub group 1	0.366	0.233	0.212	0.190
Sub group 2	0.132	0.222	0.421	0.225
Sub group 3	0.187	0.304	0.310	0.199
Sub group 4	0.128	0.163	0.304	0.405
Sub group 5	0.156	0.161	0.386	0.297

Phase #4

Finally, sub group decisions from Table 4 are aggregated into the group decision by reaching the consensus between the sub groups. Steps in applying consensus convergence model are: (1) Calculate weights of respect between the sub groups for each strategy; (2) Place weights in appropriate matrix; and (3) compute consensus convergence weight of each strategy.

Note that in Phase #3, weights of respect were calculated between the participants within one sub group at a time, while in this phase weghts represent respect of given sub group towards the other sub groups.

The final result (consensus weights) is presented in Table 4 along with the weights obtained by the weighted geometric mean aggregation (Cf. Eq, 1). In geometric mean aggregations it was assumed that individuals in sub groups have equal weights, while at global group level sub groups are different and correspond to their real financial input to present system operation and regular annual investments. That is, sub groups 1, 3 and 4 have been assigned to the equal weight $\alpha = 0.25$, while sub groups 2 and 5 have had the weights of 0.125 each.

Table 4 The final weights of alternative strategies

Weights obtained by	Strategy 1	Strategy 2	Strategy 3	Strategy 4
Consensus convergence method	0.167 (4)	0.204 (3)	0.341 (1)	0.285 (2)
Weighted geometric mean aggregation	0.211 (3)	0.115 (4)	0.365 (1)	0.306 (2)

Both aggregation methods identified Strategy 3 as the best management alternative and Strategy 4 as the second best. Strategies 1 and 2 changed ranks in two aggregation schemes.

CONCLUSIONS

In this paper, consensus of 23 decision makers (agents), divided into 5 interest sub groups, is reached by formal mathematical model that uses philosophical foundations in the structure of negotiation and in consensus building to aggregate group members' values in a way that guarantees convergence towards a single consensual value that summarizes the group position.

The consensus convergence model is proposed as a two-stage procedure that should be applied firstly to reach the consensus within the participants in each sub group, and then re-applied to reach consensus among sub groups. On real-life example we demonstrated application of proposed participatory decision making model of action and we have shown that most acceptable water management strategy for given real-life problem can efficiently be identified. When the results obtained have been presented to participants, they have agreed by acclamation that the best strategy is really the one identified by the model, and that it is likely to have it implemented.

Proposed two-stage consensus model have potential in real-life applications as it has sound theoretical background, and because it avoids some of common pitfalls of ad hoc methods used for decision making. Besides, it is mathematically simple, easy to implement and transparent to participating individuals, subgroups and groups which is of particular importance in practice.

ACKNOWLEDGMENT

This work was supported in part by the Ministry of Education, Science and Technological Development of Serbia under the grant 174003 (2011–2018) - Theory and application of Analytic hierarchy process (AHP) in multi-criteria decision making under conditions of risk and uncertainty (individual and group context).

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znansvteni rad
Original scientific paper

ACCUMULATION OF HEAVY METALS IN VEGETABLES GROWN ON CONTAMINATED SOILS

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ABSTRACT

Vegetables are rich sources of vitamins, minerals, fibers and also have antioxidative effects. Heavy metal concentrations in edible parts of plants are directly associated with their concentrations in soils, but their levels differ significantly with plant species, and sometimes with the genotypes within the same plant species. Heavy metal uptake and translocation are key aspects of plants' ability to accumulate and cope with high concentrations of heavy metals.

The objective of the present study was to investigate heavy metal accumulation in four vegetable species. Two leafy vegetables (parsley, spinach) and two root vegetables (radish, carrot) were cultivated in greenhouses on soil contaminated with heavy metals mixture (Cu, Pb, Zn) with four concentrations (c_1= 1.5 %; c_2= 3.0 %; c_3= 4.5 %, c_4= 6.0 %). The vegetables were grown in a greenhouse until the end of the vegetation period, afterwards being harvested and the concentration of each heavy metal for each plant was determined. Clear differences were found in the concentrations of heavy metals in edible parts of the different vegetables. The concentrations of heavy metals decreased in the sequence as leafy vegetables > root vegetables. Data suggest that growing of vegetables on contaminated soils may pose considerable health risks due to the possible heavy metal ingestion.

Keywords: *accumulation, contaminated soils, heavy metals, vegetables*

INTRODUCTION

Environmental pollution is a big concern nowadays. Anthropogenic activities like mining, industry and agriculture have altered the environment significantly throughout the world, which causes an increase in the lead (Pb), cadmium (Cd), arsenic (As) concentration in soil and water, thus contaminating them (Singh, 2016).

Heavy metals such as Pb and Cd are one of the most toxic elements in the environment and are included in the US Environment Protection Agency (EPA). It is important to know the total metal concentrations for the purpose of evaluating the level of soil contamination, but many studies have shown that the toxicity and mobility of these pollutants strongly depends on their specific forms or binding state (Lei et al., 2010), which determine their bioavailability and thus toxicity in the environment.

Heavy metals, such as lead (Pb), cadmium (Cd), arsenic (As), etc., have toxic effects on human health. Toxic metals can accumulate persistently in the body over a lifetime. High Pb concentrations can adversely influence the intelligence development of children, or induce hypertension, nephropathy and cardiovascular disease (Zhou et al., 2016). Other metals such as copper (Cu) and zinc (Zn) are important nutrients for humans and animals, but excessive ingestion can also have adverse effects on their health (Zhou et al., 2016). For example, a Cu surplus can cause acute stomach and intestine aches, and liver damage, and Zn can reduce immune function and levels of high-density lipoproteins.

Along with the inhalation of contaminated soil particles, drinking of contaminated water, or a dermal contact, consumption of contaminated food has been identified as the major pathway for human exposure to toxic metals (Zhou et al., 2016). Vegetables are important edible crops and are an essential part of the human diet. They are rich in nutrients required for human health, and are an important source of carbohydrates, vitamins, minerals, and fibers (Zhou et al., 2016). Heavy metals can be taken up by vegetable roots, and accumulated at high concentrations in the edible parts, sometimes even if heavy metal is found in soil at low concentrations (Zhou et al., 2016). Several Authors, presented below in detail, have shown that according to metal concentrations found in vegetable tissues grown on contaminated soil, their consumption may pose a health risk.

Lei et al. (2010) conducted a study to investigate the pollution load index, fraction distributions, and mobility of Pb, Cd, Cu, and Zn in garden and paddy soils collected from a Pb/Zn mine in Chenzhou City, China. The samples were analyzed using Leleyter and Probst's sequential extraction procedures. Total metal concentrations including Pb, Cd, Cu, and Zn exceeded the maximum permissible limits for soils set by the Ministry of Environmental Protection of China, and the order of the pollution index was Cd >Zn > Pb > Cu, indicating that the soils from both sites were contaminated with heavy metals, especially Cd.

Jollly et al. (2013) studied concentration of different elements (P, K, Cr, Fe, Co, Zn, Cu, Pb, Cd etc.) and transfer factor from soil to vegetables, including spinach, amaranthus, brinjal, tomato, radish, bean, cauliflower, carrot. In their study, iron was present in small quantities in all types of samples compared to other macronutrient. Among the micronutrients, Cu and Zn were abundant in all varieties, and concentration of zinc was higher comparing to copper. Mn was present in bean only with moderate concentration (26 mg kg^{-1}). Vanadium was present in spinach, amaranthus, carrot and radish, while Cr was present in radish, amaranthus tomato and cauliflower in lower concentrations. Co and Ni were found only in leafy vegetables in low concentrations. Toxic element like As (0.08-0.04 mg kg^{-1}), Se (0.20-0.03 mg kg^{-1}) and Pb (0.980.13 mg kg^{-1}) were present in almost all varieties of samples, but the concentration of As and Se was very low, thus did not have a toxic effect. On the other hand, Pb showed comparatively higher value than the others which may be attributed to plants grown on the agricultural lands located near highways.

Mokgolele et al. (2016) measured concentrations of Cu, Ni and Zn in *Spinacia oleracea* cultivated at a site near the copper and nickel mine in Selebi Phikwe in Botswana. Mean concentrations of Cu, Zn and Ni in a whole plant system (leaf, stem, root) at the experimental site were 7.30 ± 2.51, 6.02 ± 2.16 and 0.03 ± 0.02 mg kg^{-1}, respectively.

Harmanescu et al (2011) measured the concentrations of heavy metals (Fe, Mn, Zn, Cu, Ni, Cd and Pb) found in common vegetables (parsley, carrot, onion, lettuce, cucumber and green beans) grown in contaminated mining areas and compared them with those grown in a reference area. The results showed that the concentrations of all analyzed metals were high, usually over average concentration for Mn, Zn, Cu, Cd and Pb. Particularly, in soil, higher values than intervention threshold values were found for Cu and Pb, and higher than maximum allowable limits for Zn, Cu, Cd and Pb for parsley roots and leaves, carrot roots, cabbage, lettuce and cucumber. Their results suggest that the consumption of some vegetables (especially parsley, carrot and cabbage and less for lettuce, cucumber and green beans) in these areas poses a health risk.

Alexander et al. (2006) studied the accumulation of metals by different vegetables grown on contaminated soil. Five cultivars each of six common vegetables (spinach, carrot, french bean, pea, onion, lettuce) were grown in a control and in a soil spiked with Cd, Cu, Pb and Zn. Highly significant differences in metal concentrations were evident between cultivars of differences were also identified when comparing one vegetable to another, legumes (*Leguminosae*) were low accumulators (Cd, Cu, Pb, Zn), root vegetables (*Umbelliferae* and *Liliaceae*) moderate and leafy vegetables (*Compositae* and *Chenopodiaceae*) high accumulators.

The present study was conducted with the aim to (1) concentration of Cu, Pb and Zn in *Daucus carota* L. (carrot), *Raphanus sativus* L. (radish), *Spinacia oleracea* L. (spinach) and *Petroselium hortense* (parsley) grown in soil contaminated with Cu, Pb and Zn, (2) to evaluate the translocation factors (TF) between the soils and vegetable plant, in order to assess potential health risks which may occur because of the consumption of vegetables grown on contaminated soil.

Carrot (*Daucus carota* L.) is a biennial or annual herbaceous plant, which has a pivotal root in the soil. (Ardelean et al., 2008). The plant has large requirements for moisture, light and soils with light texture, chunky, rich in humus, with slightly acid or neutral reaction. As active principles it contains: antide, carbohydrates, carotenes, Na, K, Ca, P, Fe, vitamins A, B, C, K. The cultivated carrots were of the variety with round roots, the vegetation period 73-78 days. Radish (*Raphanus sativus* L.*)* is a grown herbaceous plant, annual and biannual, which presents a pivoting root in the soil (Popescu, 2010). Is grown in all the country, is pretentious to moisture, prefers middle texture soils that are loose and rich in humus. As active principles it contains proteins, fats, cellulose, mineral salts, carbon hydrates, sodium, potassium, calcium, phosphorus, vitamins A, B1, B2, C. The cultivated radishes were with intense red roots, recommended for crops in the greenhouse, vegetation period 55 days.

Spinach (*Spinacia oleracea* L.) is an annual herbaceous grown plant, having a pivoting root in the soil, up to 180 cm deep, with lateral ramifications. The leaves a long or short petiolate, big, dark-green, smooth with a prominent median nervure. There are 8-12 leaves in the rosette. (Popescu, 2010). Is grown throughout the entire country, it prefers middle texture soils that are fertile permeable, loose, rich in humus and with high moisture. As active principles it contains: protids, carbon hydrates, lipids, chlorophylls, Na, K, Ca, Mg, Cu, I, vitamins A, B1, B2, C. Spinach was cultivated in an early variety, issuing late flower stems, leaves smooth, oval, dark green, vigorous growth.

Parsley (*Petroselium hortense*) is a biennial herbaceous plant that has a pivotal, conical or elongated root in the soil, white-gray, has sweet taste, and a pleasant, aromatic smell. The basal and rosette leaves are long-petiolate, having characteristic smell. The plant needs moderate temperature and humidity. As active principles, it contains: apiol, myristicin, terpineol, cymenes, vitamins A, B2, C (Ardelean et al., 2008). Parsley was cultivated in an early variety with dark green leaves, vigorous, powerful smooth and shoots.

MATERIALS AND METHODS

The experiments took place in the period May - August 2018. The plants were harvested when each of them reached the vegetation period.

The plant species chosen for this study are root vegetables (carrots and radishes) and leafy vegetables (spinach and parsley) because they are the most consumed vegetables for their nutrient-rich leafy and roots. The vegetable crops under study are shown in figure 1.

a) Carrot (*Daucus carota* L.) b) Radish *(Raphanus sativus* L.*)*

c) Spinach *(Spinacia oleracea* L.*)* d) Parsley (*Petroselium hortense*)

Figure 1 Vegetable crops under study

The four plants under study were planted in a controlled medium, using pots to which contaminated soil was added with four concentrations of Cu, Pb, Zn mixtures. In contrast to the soil contaminated with the four solutions of different concentrations, in parallel as reference samples, seedlings were planted in pots with uncontaminated fertile soil.

The physical-chemical properties of the fertile soil were: pH 5.0-6.0; total nitrogen 1.68 %, total phosphorus 0.52%, total potassium 0.85 %, electrical conductibility 1.1, particle elements of over 20 mm maximum 5%, moisture 67.2 %.

The solutions with concentrations of 1.5, 3.0, 4.5 and 6.0 % were prepared individually using copper sulphate, lead acetate and zinc sulphate as reagent, the solvent used in the preparation of the solutions being distilled water.

To obtain mixtures of solutions of Cu, Pb, Zn for each of the concentrations of 1.5, 3.0, 4.5 and 6.0% individually prepared, equal parts were taken from each solution, element respectively concentration, and were mixed until homogenising resulting in the mixture.

The pots in which the seedlings were planted from the four plants were loaded with fertile soil that was mixed and homogenized in turn with each of the four solutions of different concentrations. For each pot the added soil was 250 ml of Cu, Pb, Zn mixture solution per 1 kg of soil.

In the table 1 is presented initial concentration of heavy metals in soil, depending on the four concentrations (c_1, c_2, c_3, c_4). The uncontaminated soil (c_0) was considered the referential sample, and this soil was used to conduct experiments at the four concentrations

Table 1 Initial contet of heavy metal in soil

Heavy metal	Heavy metal concentration				
	$c_0 = 0$ %	$c_1 = 1.5$%	$c_2 = 3.0$%	$c_3 = 4.5$%	$c_4 = 6.0$ %
	Initial contet of heavy metal in soil, mg kg^{-1}				
Copper (Cu)	17.6	33.2	72.4	265.1	378.2
Lead (Pb)	6.75	11.9	54.1	117.3	152.8
Zinc (Zn)	39.8	129.9	253.5	378.4	454.3

In experiments, heavy metal loading was performed by initially loading the soil with each of the four mixture concentrations of Cu, Pb, Zn, without supplementing until harvest. For each plant and concentration, three samples were taken.

The heavy metals (Cu, Pb, Zn) from soil samples (uncontaminated/referential 0%, contaminated with solutions of 1.5 %, 3.0 %, 4.5 % and 6.0 % concentration) was measured using an x-ray fluorescence (XRF) spectrometer QualiX-S2.

The plant samples were dried (70° C, 72 h), grinded and then were digested with nitric acid (65 %) in a microwave digestion system as follow:

- weigh 300 mg of the sample into the digestion vessel and add 7.5 ml of nitric acid.
- heat in the microwave oven with the following program.
- First step: T 150° C, power (%) – 50, time - 5 min.
- Second step: T 190° C, power (%) – 70, time 5 min.

The metal content was measured using a flame atomic absorption spectrometry (FAAS, GBC 932AA or GFAAS, GBC Savant AAZ).

Due to the fact that plants have the capacity to accumulate metals from the soil, the ratio between metal concentration in the plant and in the soil was measured. Using equation (1) (Nedelescu et al., 2017; Mokgolele et al., 2016), the translocation factor (TF) was determined.

$$TF = \frac{heavy \quad metal \quad concentration \quad in\, plant}{heavy \quad metal \quad concentration\, in\, soil} \tag{1}$$

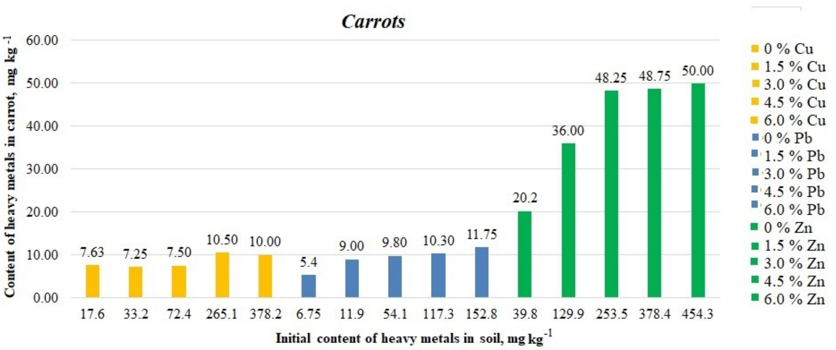
The transfer coefficient studied reflects the ability of the plant to take up the heavy metal from the soil depending on its concentration in the soil.

The results obtained were statistically processed using the Excel 2010 software.

On graphs, where there are points for values of initial heavy metal content in the soil lower than 58.9 mg kg^{-1}, those points represent the heavy metal content of the control plant (grown in deliberately uncontaminated soil, with the natural heavy metal content of the fertile soil).

RESULTS AND DISCUSSION

The concentrations of the heavy metals in the edible parts of the 4 species vegetables are presented in figure 2. Considering all cases of vegetables studied with various mixtures of heavy metal concentrations in the soil, it can be seen that all of them have a tendency to increase the amount of heavy metal accumulated in the plant, with the increase in the initial heavy metal content in the soil. By comparing the values with uncontaminated soil, we notice a high absorption of the three metals in the roots and leaf of the vegetables.



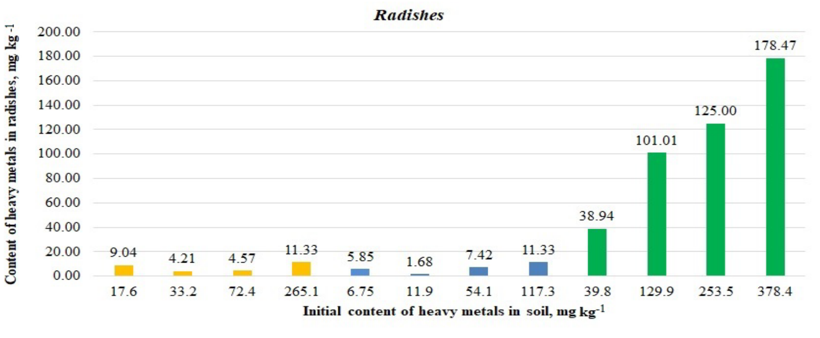


Figure 2 Comparison between the heavy metals initial content (Cu, Zn, Pb) in the soil and in the vegetables

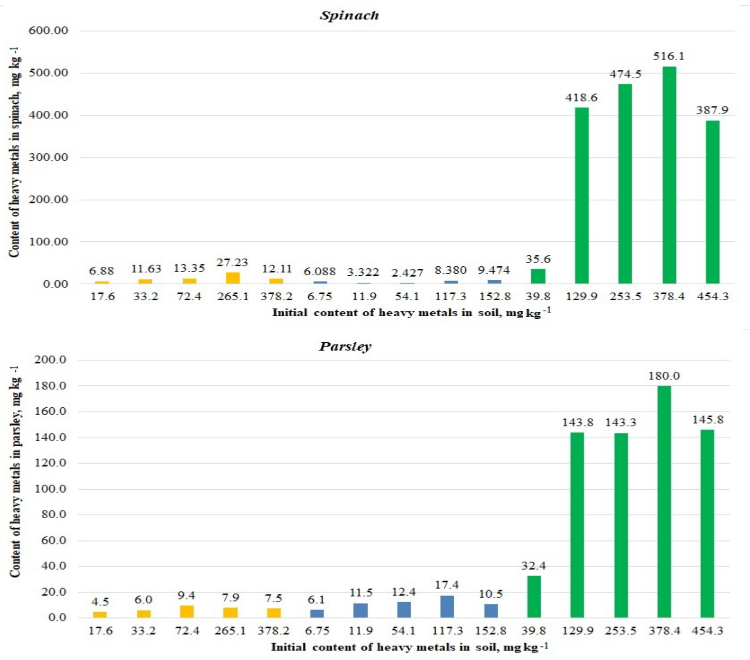


Figure 2 (cont.) Comparison between the heavy metals initial content (Cu, Zn, Pb) in the soil and in the vegetables

For carrot and radish, the values for roots for the three metals progressively increase compared to the blank sample with uncontaminated soil, with the exception of soil sample with a maximum concentration of 6.0% where the roots did not form.

For spinach and parsley, the value for leaf for the three metals progressively increase for the concentrations 1.5 %, 3.0 %, 4.5 % compared to the blank sample (uncontaminated soil). At the high soil concentration of 6.0% (454.3 mg kg^{-1}) it is observed that the values decrease, so the leaves assimilate the metals (Cu, Pb, Zn) to the soil concentration of 4.5% (378.4 mg kg^{-1}).

The analyzed vegetables proved to have different capacity of bioaccumulation, depending on plant species, type of metal, type of soil, etc. (Nedelescu et al., 2017; Augustsson et al., 2015).

In figure 3 is presented the translocation factor depending on soil contamination with different heavy metals for different vegetable species.

The graphs in figure 3 show the following aspects regarding translocation factor distribution to plants:

- translocation factor (TF) higher than 1 were recorded for *spinach* in the case of zinc for mixture concentrations of 1.5, 3.0, 4.5% and for *parsley* in the case of zinc for mixture concentration of 1.5%;
- translocation factor (TF) lower than 0.1 were recorded as follows: for *carrot* in the case of lead with mixture concentration of 6.0% (0.077) and 4.5% (0.088); for *radishes*

in the case of lead with mixture concentration of 6.0% (0.097) and in the case of copper for mixture concentration of 6.0% (0.043) and for mixture concentration of 4.5% (0.063); for *spinach* in the case of lead with the following mixture concentrations: 6.0% (0.062), 4.5% (0.071), 3.0% (0.045) and in the case of copper with mixture concentration of 6.0% (0.032); for *parsley* only in the case of copper with mixture concentration of 6.0% (0.02) and 4.5% (0.03).

The mobility of metals from soil to plants is a function of the physical and chemical properties of the soil and of vegetable species and is altered by various environmental and human factors (Tasrina et al., 2015). The highest TF value was found at carrots 0.8 for Pb, radishes 0.978 for Cu, spinach 3.223 for Cu and parsley 1.107 for Cu. These might be due to higher mobility of these heavy metals with a natural occurrence in soil and the low retention of them in the soil than other toxic cations (Tasrina et al., 2015). According to the soil to plant transfer factor (TF) calculated for tested metals and leafy vegetables consumed by local residents, it can be concluded that Pb and Cu was high accumulator among the investigated metals.

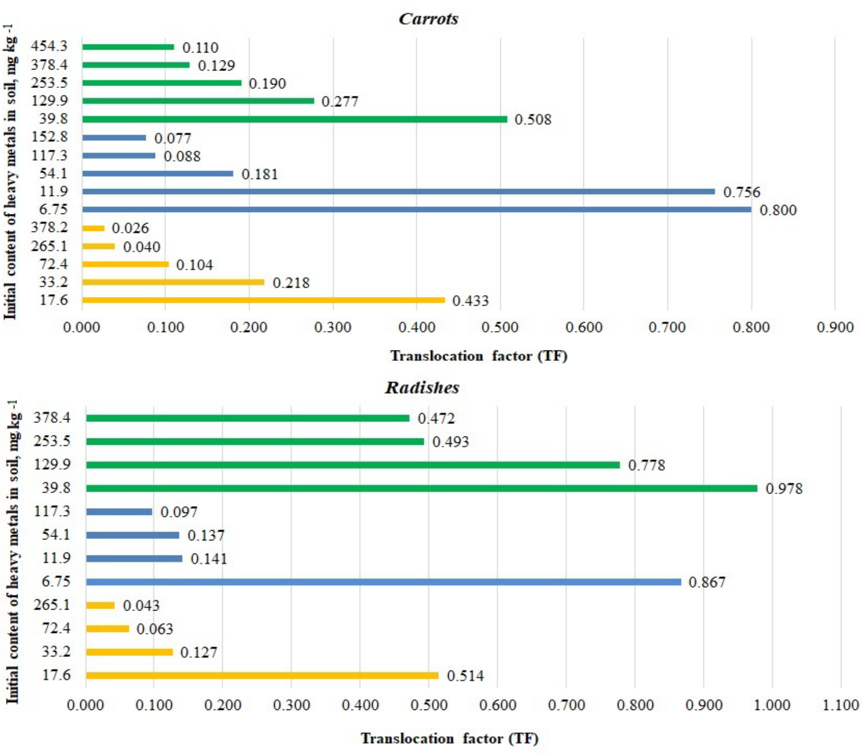


Figure 3 Translocation factor depending on soil contamination with various heavy metals for vegetables

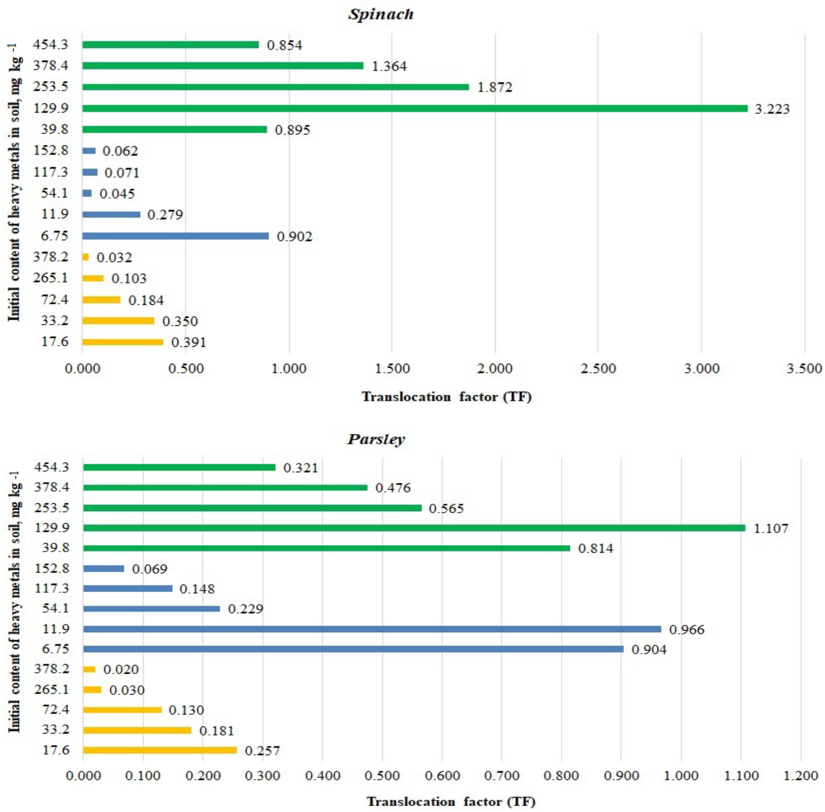


Figure 3 (cont.) Translocation factor depending on soil contamination with various heavy metals for vegetables

With respect to the soil / plant translocation factor, is observed that copper accumulates very well in the four plants, then lead, which is the most toxic metal, and finally zinc.

Following the experiments and the statistical processing of their results, as general phenomenology it is remarked:

- until the end of the vegetation stage (harvest) the plants considered in the experiments continuously accumulate (monotonously increasing) heavy metals from the contaminated soil;
- the transfer coefficient decreases with the increase of the heavy metal concentration in the soil, at least until the end of the vegetation period (harvest).

CONCLUSIONS

As a result of the experimental results obtained after the heavy metal initial soil contamination and their accumulation in roots or leaf of vegetables, the following conclusions were drawn:

- the concentrations of heavy metals in the edible parts of the vegetables decreased in the order of leafy vegetables > root vegetables;
- for roots vegetables, the assimilation of the three metals (Cu, Pb, Zn) was progressive, no matter the metal concentration; for leafy vegetables, the assimilation of the three metals was progressive for concentrations 1.5 %, 3.0 %, 4.5 % and for concentration 6.0 % significantly decreased therefore;
- Zn was the most assimilated in all vegetables, followed by Pb and Cu for carrots, radishes, parsley, and Cu and the least assimilated was Pb for spinach;
- it was found that at concentration 6.0% for each heavy metal (Cu, Pb, Zn), radishes develop only leaf;
- the translocation factor (TF) higher than 1 was recorded in the case of leaf vegetables (spinach, parsley) for Zn.
- the translocation factor (TF) lower than 0.1 was recorded for carrot in the case of Pb, parsley in the case of Cu, radishes for Pb and Cu and spinach for Pb and Cu.
- the translocation factor (TF) of metals from the soil into the roots and leaf of vegetables has indicated metal uptake in the following decreasing order depending on the type of soil: for uncontaminated soil, Pb>Cu>Zn for carrots, spinach, parsley and Cu>Pb>Zn for radish; for soil contaminated with four concentrations Cu>Pb>Zn for all vegetables.

These results show that there are clear differences in the bioaccumulation of heavy metals (Cu, Pb, Zn) in the four studied plants.

The general conclusion for the studied plants would be that the bioaccumulation of heavy metal is lower as the initial heavy metal concentration in the soil is higher. This means that the more intense the soil contamination with heavy metals, the more difficult will be soil phytoremediation with plants of the studied or similar type.

ACKNOWLEDGEMENTS

This paper was financed by support of Executive Agency for Higher Education, Research, Development and Innovation Funding, *Exploratory Research* Programme, PN-III-P4-ID-PCE-2016-0860, contr. 174/ 08.08.2017*, Research on the development of some mathematical models to evaluate the impact of soil contamination on fruits and vegetables –* CONTAMOD”.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

ADVANCED ELECTROCHEMICAL TREATMENT OF THE WASTEWATER FROM CATTLE FARM

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SUMMARY

Worldwide, areas affected by drought and water scarcity are increasing rapidly. Thus, nutrient-rich wastewater has become a valuable resource for farmers. Over 20 million hectares (10% of irrigated land) are irrigated with untreated, partially treated, diluted or treated wastewater. Over 200 million farmers in 44 countries recover daily over 15 million m^3 of treated wastewater for irrigation. High chemical oxygen demand (COD) and biochemical oxygen demand (BOD), heavy metals, nutrients, antibiotics and pathogenic bacteria pose risks for human health and the environment, and high suspended solids can affect the irrigation system. In Romania, large agricultural area is affected by drought and deficient irrigation systems. There is potential for wastewater reuse in agriculture, but different wastewater treatment for agricultural reuse is only tested experimentally. Wastewater samples collected from the lagoon of a cattle farm were tested to determine the microbiological load (total coliforms, faecal coliforms, faecal streptococci) and physico-chemical parameters (pH, turbidity, conductivity, COD, BOD, total N, total P) before and after applying advanced electrochemical treatment. The aim is to reduce wastewater load and to obtain an effluent that can be safely used for irrigation of energy crops in arid, semiarid and sub-humid – dry regions. Removal efficiencies were 59.8% for COD, 82% for BOD, 23.7% for total N and 46.9% for total P.

Keywords: *wastewater, organic load, electrooxidation, electrode, irrigation*

INTRODUCTION

As the domestic demand for clean water increases and drought conditions become more frequent, it is essential to think about non-conventional water resources. It is estimated that over 40% of the world's population will face water scarcity or drought within the next few decades, with significant socio-economic, water and food security impact (Becerra - Castro et al., 2015; Elgallal et al., 2016). Water scarcity is due to several issues: inefficient water distribution networks, lack of emergency plant to face decreasing rainfall and basic infrastructure, poor wastewater treatment, environmental resource degradation, and climate change (Urbano, 2017). In recent years, wastewater recycling in agriculture has gained importance as component of agricultural water supply in several water-scarce countries (Pedrero et al., 2010), were farmers in many arid and semiarid areas were forced to find solutions to irrigate their crops. Worldwide, over 20 million hectares (10% of irrigated land) are irrigated with nutrient-rich wastewater (treated, untreated or diluted). More than 200 million farmers in 44 countries are reusing over 15 million m^3day^{-1} of reclaimed water for irrigation purposes (Elgallal et al., 2016).

Romania is relatively poor in water resources, with only 1870 m^3 of water per inhabitant per year, compared to the average of 4000 m^3 of water per inhabitant per year in Europe. A significant part of Romania's agricultural land already shows the negative effects of climate change and water scarcity. In Southern Romania, known as the Sahara of Oltenia (Dolj County), the desertification affects 100000 hectares and the dunes expand each year by a thousand hectares. Awareness of the imminent implications for agriculture and food security increased the irrigated area to over one million hectares in 2018, compared to less than 300000 ha in 2015, consuming about 1 million m^3 water per year (EU-level instruments on water reuse, 2016). Romania's accession to the E.U. requires compliance with European requirements, and the reuse of wastewater effluents is in line with Objective 6 of the European Union's Sustainable Development Strategy. Although the Romanian legislation does not prohibit the use of irrigated waste water, the relatively low number of users connected to the irrigation system does not stimulate investment in new waste water treatment technologies in order to use them as irrigation water. However, in the long term, the interest in reuse of irrigated water could increase, as Romanian agriculture continues to be dependent on climatic factors. In Romania, reuse of irrigated water is not largely practiced (there is a low demand for the global use of treated wastewater), and different wastewater treatment methods for reuse are only addressed at the experimental level.

High COD, BOD, heavy metals, salts, nutrients (especially nitrogen, phosphorus and potassium), or dissolved organic matter can pose risks in soil fertility and the environment, viruses and pathogenic bacteria threaten human health, and high suspended solids can affect the irrigation system (Petterson et al., 2011; Farhadkhani et al., 2018; Libutti et al., 2018). Regulatory frameworks on the quality of wastewater used in irrigation differ from country to country and compliance with these frameworks requires the analysis of the treated wastewater prior to its reuse. Usually, limits are imposed for physico-chemical (turbidity, pH, salinity or electrical conductivity, suspended solids, heavy metals, BOD, COD, nutrients) and microbiological (*E. coli, Salmonella*, *Shigella*, fecal coliforms, fecal enterococci, nematode eggs) parameters (Becerra - Castro et al., 2015).

Chlorination, ozonation and UVC light are among the conventional disinfection techniques most widely used for wastewater treatment (Valero et al., 2017). The removal of organic and inorganic compounds from wastewater by microalgae, ponds, MBR, membrane technology, advanced electrochemical remediation is widely applied.

Electrochemical remediation technologies have been initially used to remove metals, radionuclides and polar inorganic pollutants from soil and groundwater (Sahu and Chaudhari, 2015). Electrochemical remediation consists in applying an electrical potential difference to electrodes, or to a network of electrodes, inserted in different configurations in the contaminated media (soil or water). Usually, the applied electric potential is in the range of a few V cm^{-1}, while the current density is over the range of 1 mA cm^{-2}. When the current flows through the contaminated media, it causes different physical and chemical phenomena that underline the technologies of continuous current, which include two types of processes, namely, electrokinetic transport (electro-osmosis, electromigration and electrophoresis – phenomena that help the transport, mobilization and concentration of pollutants) and electro-oxidation, which is based on redox reactions that are electrochemically induced (responsible for the mineralization of immobile organic contaminants) (Ribeiro et al., 2016). Advanced oxidation used in wastewater treatment include: electro-oxidation; Fenton, electro-Fenton and photoelectro-Fenton processes; electrocoagulation; electroflotation (Oturan, 2014). Generally, an electrochemical process involves the oxidation reaction at the anode and the reduction reaction at the cathode. Current density is the most crucial for the efficiency of the electrochemical treatment using dimensionally stable anodes (Markou et al., 2017). Despite the high COD removal, in electrochemical methods it should be taken into account the “sacrificial” electrodes and their dilution into the wastewater streams (because of their oxidation) and secondly the generation of significant quantities of sludge during the process (Bensadok et al., 2011).

Wastewater treatment by electrochemical methods seems to be effective both for the reduction of pathogens and for the reduction of organic and inorganic compounds that are resistant to conventional processes.

MATERIALS AND METHODS

Wastewater samples were taken in September 2018, from a large Romanian cattle farm. Within the farm, coarse organic residues consisting of fodder residues, paddock litter and cow manure are collected and stored on the composting platform. Wastewater from the farm is directly collected in a lagoon next to the composting platform, and no other treatment is applied. The wastewater is a mixture of wastewater from paddock washing, liquid manure mixed with solid trapped residues, wastewater from the farm's milk processing plant and meteoric waters. The lagoon is provided with a mechanical system which homogenizes the wastewater prior to its use as a fertilizer on the farmland near the paddocks. During sampling, wastewater collected in the lagoon was continuously homogenized.

Culture medium was prepared to determine the microbiological load of wastewater samples, i.e. the total coliforms, faecal coliforms and faecal streptococci. Culture medium was weighed and prepared in 500 mL Erlenmeyer flasks and sterilized in the autoclave (Panasonic MLS-3781L) at 121 °C for 15 minutes (Figure 2). Petri dishes, pipettes, metal instrumentation and glassware were sterilized in the oven at 180 °C for 60 minutes and then let to cool until use.

Figure 1 Lagoon prior and after wastewater homogenization, and sampling

Wastewater samples, considered to have highly microbial load (considering their origin), were diluted in sterile physiological serum, by performing series of decimal dilutions, in sterile tubes. Prior to being poured into Petri dishes, the culture medium was cooled in water bath at 45 °C. Petri dishes were prepared and analyzed in a biological safety cabinet fume hood (ESCO Micro Class II biological safety cabinet).

Figure 2 Microbiological testing of dairy wastewater samples

For the advanced treatment of dairy wastewater we used the electrochemical remediation, method, classified as continuous current technology, that consists in the application of a constant voltage on a pair of electrodes and involves a combination of processes: electrolytic reactions at the electrode surface; formation of anodic metal and metal hydroxide cations in aqueous phase; adsorption of soluble or colloidal pollutants onto the surface of metal hydroxides; removal of pollutants by electroflotation, sedimentation and adhesion to the bubbles.

The experimental setup consisted in an electrochemical reactor filled with dairy wastewater and two electrodes that were inserted into the reactor. The electrodes were constructed at INMA Bucharest, of stainless steel pipes with both ends welded on the stainless steel plates (Table 1 and Figure 3).

Table 1 Characteristics of electrochemical reactor

Electrodes	
Material	Stainless steel
Shape	Network type
Lenght	200 mm
Diameter	12 mm
Arrangement	Parallel
Number of electrodes	2
Electrochemical reactor	
Material	Plexiglas
Reactor type	Batch mode
Dimensions	500 x 200 x 200 mm
Power supply	
Voltage range	0-150 V
Current range	0-5 A

Three sets of experiments were performed, and different specific voltages were applied to the electrodes: 0.025 V mA cm^{-2} (test E1), 0.05 V mA cm^{-2} (test E2) and 0.1 V mA cm^{-2} (test E3). The maximum exposure time for each test was of 120 minutes and the wastewater volume that was treated was 9 liters.

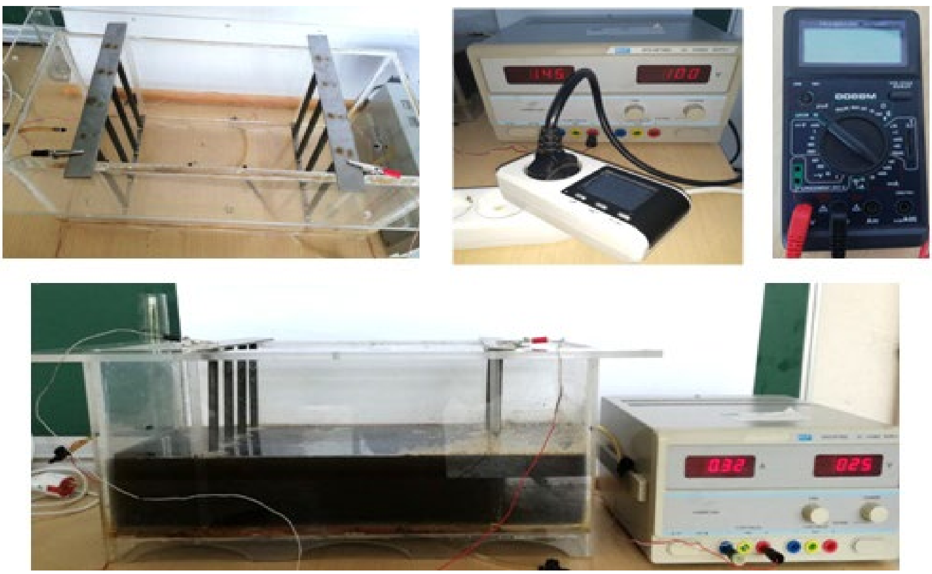

Figure 3 Experimental setup for electrochemical treatment of wastewater

During the tests, the occurrence of foam around the pipes forming the electrode networks was observed (Figure 4), the phenomenon being much more pronounced around the anode (on the right side of the reactor).

Figure 4 Foam formation in the anode area

For each test, wastewater samples were taken at middle distance between the electrodes and then analyzed at exposure times of 15, 30, 60 and 120 minutes. Physico-chemical parameters of wastewater quality and the microbiological load were analyzed according to the methods established by the Romanian STAS 9450-88 "Water for irrigation of agricultural crops".

After the tests, the wastewater in the reactor was left at rest for a week. Thus, it was seen that the solid particles were intensely entrained and separated to the anode area where they were decanted in a thick layer of about 2 cm, unlike the cathode area (left) where the treated wastewater was much clearer, but the solid particle layer was visibly thinner.

RESULTS AND DISCUSSION

The initial parameters for the wastewater are presented in Table 2. The initial pH of wastewater was about 7.8 and had a quite small variation during the tests, reaching the highest value of 8.4. Also, the conductivity ranged between 3.60 up to 3.85 mS cm^{-1}.

Table 2 The initial characteristics of wastewater

Parameter (M.U)	Value	Parameter (M.U)	Value
pH (units)	7.8	Total N (mg L^{-1})	234.2
Conductivity (mS cm^{-1})	3.84	Total P (mg L^{-1})	56.4
Turbidity (NTU)	544	Total coliforms (no. 100 m L^{-1})	700000
TSS (mg L^{-1})	1216	Faecal coliform (no.100 m L^{-1})	92000
COD-Cr (mgO_2 L^{-1})	1512.6	Faecal streptococci (no. 100 m L^{-1})	34500
BOD_5 (mgO_2 L^{-1})	204.6		

The intermediary and final values for the monitored physico-chemical parameters for the dairy wastewater are presented in Table 3. In Table 4, the initial and final values of the microbiological parameters can be observed. Compared to the initial values of all the analyzed parameters, the final ones are considerable smaller for all three tests. In time, the removal efficiency fluctuation is quite evident, but the most important fact is that there is an increase of its values.

Table 3 Variation of physico-chemical parameters during the tests

Sample	pH	Conductivity ($mS\ cm^{-1}$)	COD-Cr ($mgO_2\ L^{-1}$)	BOD_5 ($mgO_2\ L^{-1}$)	Total N ($mg\ L^{-1}$)	Total P ($mg\ L^{-1}$)
E1_15	7.9	3.86	816.6	102	202.7	47.3
E1_30	7.9	3.86	770.2	89.9	201.3	49.3
E1_60	7.9	3.84	779.5	86.7	207.5	47.5
E1_120	8.1	3.81	705.3	74.3	200.4	44.2
E2_15	7.9	3.85	700.6	93.6	204.6	44.2
E2_30	8.0	3.83	668.2	97.5	205.5	44.5
E2_60	8.1	3.76	626.4	55.9	203.5	43.1
E2_120	8.3	3.71	626.4	36.5	178.7	38.3
E3_15	8.0	3.82	730.3	67.6	212.5	43.1
E3_30	8.1	3.77	663.5	57.6	201	45.7
E3_60	8.1	3.74	756.3	67.7	208.9	43.1
E3_120	8.4	3.60	607.8	42.8	193.1	30.0

The pH of the wastewater had a small variation during the tests, its values ranging from 7.8-8.4. According to STAS 9450-88, wastewater samples are poorly alkaline and they can be accepted for use as irrigation water. Conductivity decreases over time and the values show that treated wastewater can be used to irrigate highly saline-tolerant crops.

In Figure 4, the removal efficiency of COD and BOD in time is presented. A specific voltage of 0.05 V cm^{-2} is enough to reach a removal percentage of almost 82.1% for BOD_5. It can be observed that also 0.1 Vcm^{-2} is quite sufficient to remove 79.1% of BOD_5. COD-Cr has an increase of the efficiency in time and the results obtained at the end of test E2 is comparable with the one for the test E3 (59.8%).

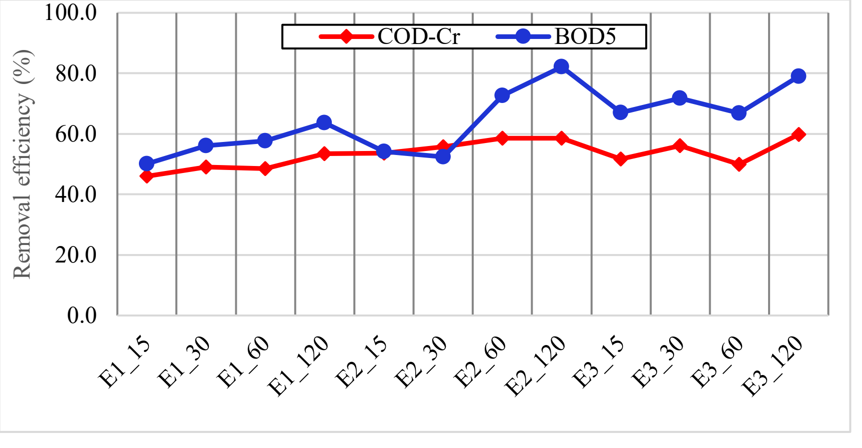

Figure 4 Variation in time of COD-Cr and BOD_5 removal efficiency during three treatment sets

Sengil and Ozacar (2006) treated dairy wastewater by electrochemical treatment using stainless steel electrodes. COD efficiency reached the value of 98% while the optimum current density, pH and treatment time for COD equal to 18300 mg L^{-1} were 0.6 mA cm^{-2}, 7 and 1 min. Melchiors et al. (2016) examined the efficiency of electrochemical method for the treatment of dairy wastewater with initial COD of 8303 mg $L^{-1}$and obtained a significant removal of organic matter (97.4%) using iron electrodes at final pH of 7.4.

Figure 5 presents the removal efficiency in time for the nutrients (N and P) found in wastewater samples. If wastewater rich in nutrients is eliminated in natural receptors, the eutrophication or biostimulation of plants and algae growth appears, leading to high turbidity and water deoxygenation.

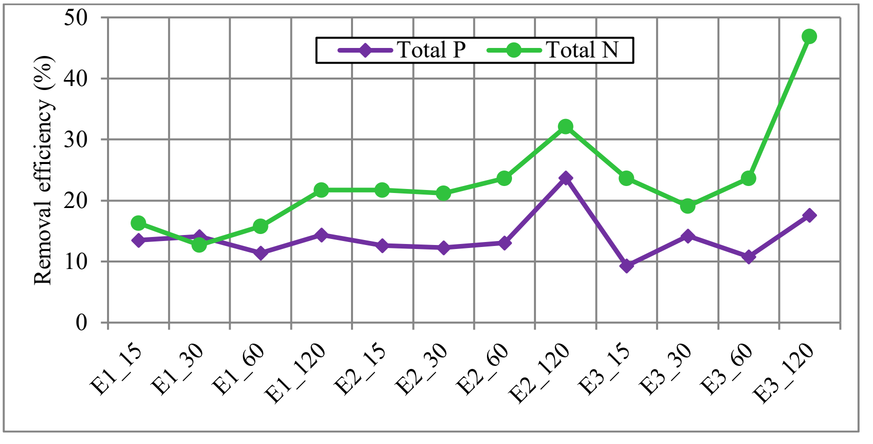

Figure 5 Variation in time of nutrients removal efficiency during three treatment sets

This phenomenon could also occur in treated water storage tanks before entering the irrigation system. Highest removal efficiency in total nitrogen removal was found for test E2_120 (23.7 %), while highest removal efficiency in total phosphorous removal was found for test E3_120 (46.9 %).

Table 4 Variation of microbiological parameters before and after the treatment

Sample	Total coliforms (no. 100 mL^{-1})	Faecal coliforms (no. 100 mL^{-1})	Faecal streptococci (no. 100 mL^{-1})
Initial	700000	92000	34500
E1_120	141000	10900	2780
E2_120	542000	17500	9200
E3_120	175000	17200	3480

Figure 6 presents the efficiency in terms of pathogens removal for the three sets of tests, each after 120 minutes of treatment. Even though the highest removal efficiency for all microbiological parameters is achieved at the end of test E3 (where the highest specific voltage was applied – 0.1 V cm^{-2}) the differences compared to the test E1 are not so significant. Hence, it can be said that higher energy consumption is not justified for gaining only 5 up to 8 % removal.

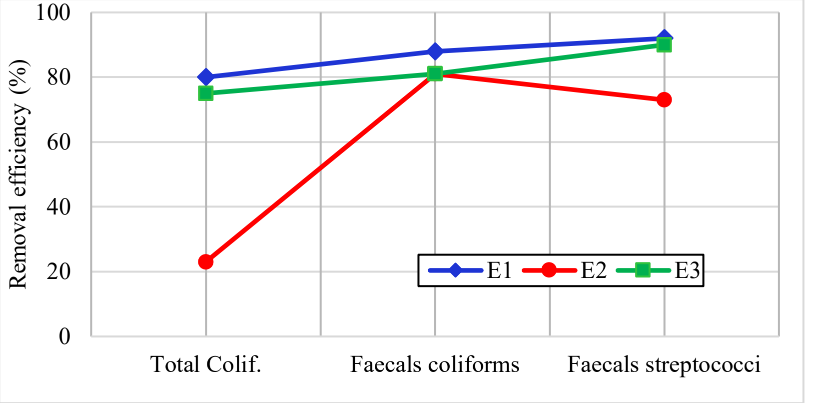

Figure 6 Removal efficiency for the analyzed pathogens during three treatment sets

According to STAS 9450-88, efficiency removal of faecal streptococci after applying the treatment show that the water may be classified as M2 (usable for all soil and plant species except highly permeable soils and plants intended for use as food and feed, fresh or preserved by freezing, but without taking into account the values for total coliforms and faecal coliforms, the water can be classified as type M3 (usable for underground soil with a depth of more than 4 m and for arable crops) whose products are thermally processed, as well as for non-food vegetal products).

Another important parameter that should be monitored is the specific energy consumption:

$$EC = \frac{U \cdot I \cdot t}{V_{tw}} \tag{1}$$

where: EC – energy consumption (kWh L^{-1}), U- the applied voltage (V), I - the average current intensity during each test (A) and t - the treatment period (h), V_{tw} –volume of treated wastewater (L).

For all three tests the specific energy consumption varied from 0.002 kWh L^{-1} for test E1, 0.007 kWh L^{-1} for test E2 and 0.039kWh L^{-1} for test E3. Although energy consumption can be a drawback in the extensive use of electrochemical treatment of wastewater, it should be taken into account that there is potential for the partial or total use of renewable energy sources, such as the photovoltaic panels.

CONCLUSIONS

An electrochemical method was applied using three different specific voltage (0.025 V cm^{-2} – test E1, 0.05 V cm^{-2} – test E2, 0.1 V cm^{-2} – test E3) for the treatment of cattle farm wastewater. Wastewater samples were analyzed in order to observe the treatment efficiency in terms of pathogen removal and physico-chemical parameters reduction.

A specific voltage of 0.05 V cm^{-2} was enough for removal of almost 82% for BOD_5 while 0.1 Vcm^{-2} was sufficient in order to obtain 79% removal for BOD_5. Highest removal efficiency in total nitrogen removal was found for test E2_120 (23.7 %), while highest removal efficiency in total phosphorous removal was found for test E3_120 (46.9 %)

During test E3 the sedimentation of the particles has been more obvious than in the other two tests, even though the pH was between 7.8 and 8.4. In general, the treatment efficiency is better when the pH is closer to acid or basic, compared to a neutral pH.

Efficiency in the removal of pathogens, organic and inorganic pollutants, shows that electro-oxidation can be effective to treat dairy wastewater, for reuse as irrigation water in Romania, and there are advantages that energy consumption can be reduced by using photovoltaic panels, the consumption of Danube or underground water sources could be reduced, while the investments in advanced treatment systems could be encouraged.

ACKNOLEDGEMENT

This work was supported by a grant of the Romanian Ministery of Research and Innovation CCDI - UEFISCDI, Project INNOVATIVE TECHNOLOGIES FOR IRRIGATION OF AGRICULTURAL CROPS IN ARID, SEMIARID AND SUBHUMID-DRY CLIMATE, project number PN-III-P1-1.2-PCCDI-2017-0254, Contract no. 27PCCDI / 2018, within PNCDI III.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

SMART SYSTEM TO MONITOR WASTEWATER TREATMENT BASED ON RASPBERRY PI COMPUTER

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SUMMARY

Sedimentation is a unit operation of high importance in various wastewater treatment systems. In a tank in which the water flow velocity is very low, the particles tend to go to the bottom under the influence of gravity. In this study, a VL53L0X sensor is used to determine the turbidity of the wastewater. The experiments were conducted in the Department of Biotechnical Systems at the Polytechnic University of Bucharest. Experimental data were recorded at different time intervals to analyze the total solids concentration (TSS), representing the interface between the particulate area in the full decanting process and the compacted sludge area. The purpose of this study was to determine the clarification curve of an aqueous slurry of solid particles, using the intelligent Raspberry Pi system. The results obtained for the dishwashing powder used to carry out the experiment, are in line with the other sedimentation rate research, obtaining a power function. The turbidity, measured at 20sec intervals in three different points, had a variation between 260 -11 NTU in the time interval in which the measurements were carried out (about 80 minutes). These results contribute to improving knowledge in the field of wastewater treatment.

Keywords: *settling columns, total suspended solids, turbidity*, *Raspberry Pi*

INTRODUCTION

Sedimentation, also known as settling, is an important process in several of the unit operations in wastewater treatment plants (WWTPs). The most commonly known of these unit processes are primary settling tanks, which are a treatment units before the biological reactor, and secondary settling tanks, which are a clarification step prior to discharge into a receiving water. Moreover, settling also plays an important role in new technologies that are being developed such as granular sludge reactors (Torfs et al., 2016).

Sedimentation is the physical operation that separates solid particles with a density higher than of the surrounding liquid. In a tank in which the water flow velocity is very low, the particles tend to go to the bottom under the influence of gravity. As a result, the supernatant liquid becomes clarified, while the particles at the bottom form a sludge layer and are then subsequently removed with the sludge. Sedimentation is a unit operation of high importance in various wastewater treatment systems. The main objective in most of the applications is to produce a clarified effluent, that is, with a low suspended solids concentration (Marcos von Sperling, 2007).

The cumulative frequency distribution of settling velocities cannot be calculated in a theoretical way because the size, shape and mass density of the particles are unknown and even variable with flocculent settling. The frequency distribution is found experimentally by plotting the percentage of remaining suspended solids against the settling velocity vs that can be calculated from the depth of the sampling port under the water surface (H) divided by the elapsed time t.

In water and wastewater treatment facilities, the mass transport and behaviour of fine-grained cohesive sediments is influenced mainly by flocculation effects and nominal settling velocities of particles. Hence the understanding of batch settling processes of flocs is fundamental for effective thickener/clarifier design and control. The behaviour of flocculating particles and settling trajectories of individual particles is very complex. Flocculation effects and velocities are usually investigated using jar tests to establish dose and settling columns to evaluate the flocculation behaviour. Constant spatial and temporal variations and fluctuating initial conditions in physical sedimentation systems result in difficulty and uncertainty in the predictions of medium- and long-term behaviour of the settling particles (Xu et al., 2008). During the design of sedimentation tanks, data from settling columns are interpreted by a graphical technique. Firstly, samples are collected from different column depths at different times and are analysed for total suspended solids concentration (TSS). The batch settling data is then utilised to compute iso-percentage removal profiles as a function of time and depth. From the graphs, one can predict or calculate the removal efficiency, overflow rate and settling velocities of particles. (Nomcebo et al., 2014).

Usher and Scales (2005), developed an algorithm to account for the solid volume fraction of the thickener underflow and mudline height of fundamental suspension properties. This algorithm could not predict suspension properties in the shear process. Zhou et al., (Zhou et al., 2014), established validated mathematical model as well as three-dimensional computational fluid dynamics (CFD) model to characterizing the flow regions in red mud separation thickener's feedwells. Their results showed that the inlet feed rate and the aspect ratio of feedwells are the most important parameters which affect the RTD of feedwell. They showed that under the optimal operation conditions, the volume fraction of dead zone can be reduced by 10.8% and the volume fraction of mixing flow can be increased by 6.5%.

In this study, a VL53L0X sensor was used to determine the turbidity of the wastewater. Experimental data were recorded at different time intervals to analyze the total solids concentration (TSS), representing the interface between the particulate area in the full decanting process and the compacted sludge area. The VL53L0X is a new generation Time-of-Flight (ToF) laser-ranging module housed in the smallest package on the market today, providing accurate distance measurement whatever the target reflectances unlike conventional technologies. It can measure absolute distances up to 2m, setting a new benchmark in ranging performance levels, opening the door to various new applications. The VL53L0X integrates a leading-edge SPAD array (Single Photon Avalanche Diodes) and embeds ST's second generation FlightSenseTM patented technology. The VL53L0X's 940nm VCSEL emitter (Vertical Cavity Surface-Emitting Laser), is totally invisible to the human eye, coupled with internal physical infrared filters, it enables longer ranging distance, higher immunity to ambient light and better robustness to cover-glass optical cross-talk.

The data recorded with this sensor was used to determine the clarification curve of an aqueous suspension of solid particles using the intelligent Raspberry Pi system. The sedimentation velocity was determined, by means of calculations, with the Pi camera attached to Raspberry Pi device.

MATERIALS AND METHODS

Experimental research was carried out in a stationary field on a laboratory stand, consisting on a plexiglass column, with the dimensions: 220 mm long, 30 mm diameter, 100 ml capacity, VL53L0X turbidity sensor, Raspberry Pi device and Pi camera. Recording of the interface between the clarified water area and the sludge area was viewed in real-time on a PC screen by taking photos at a certain time using a camera connected to the Raspberry Pi device.

To achieve experimental research has been used an aqueous suspension of the dishwashing powder as follows: in 100 mL of tap water was added an amount of 5 g of dishwashing powder.

If in a glass column there is introduced a certain amount of diluted suspension, composed of water and settleable solid particles and let it rest, it can be observed, after a period of time, the appearance of three distinct characteristic areas, namely: a zone of clarified water at the top of the column, a zone with an aqueous suspension of solid particles in the process of sedimentation at the middle of the tube and and a zone with concentrated settled sludge at the bottom of the column, according to the decantation scheme of figure 1 (Safta et al., 2017; Sajeev et al. 2002).

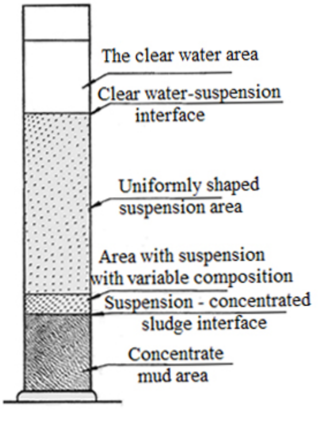


Figure 1 The decantation scheme of a suspension in the stationary column

These three areas are separated by two interfaces, namely: a clarified water – aqueous suspension of solid particles interface and an aqueous suspension of solid particles – concentrated settled sludge interface.

If the interfaces are recorded in time and plotted, the clarification curve of an aqueous suspension of solid particles is obtained, representing the variation of the solution's turbidity over time (Safta et al., 2012).

The purpose of the experiment was to determine the turbidity of the wastewater, the solid particle concentration (TSS) and the sedimentation velocity of the solid particles in the wastewater. In the following are presented the steps to determine these parameters.

Regarding the turbidity of the wastewater, it was measured in three points at different heights on the graduated column, namely at 55mm, 65mm and 75mm respectively. For each set height, the turbidity of the water was measured for about 80 minutes, the measurements being made at intervals of 20 seconds.

The measurements were made using a VL53L0X turbidity sensor, and the values recorded in the NTU were converted to mass concentration using the equation, (Sithebe et al., 2014):

$$\ln(TSS) = 1.5 \ln(NTU) + 0.15 \tag{1}$$

The conversion was based on the method proposed by Packman et al (1999), which consists of the 10-point calibration line of a TSS versus NTU dataset (R2 = 0.97). Based on the experimental data obtained for turbidity, the variation curve of the suspension was determined using a power function of the type:

$$a = k \cdot t^b \tag{2}$$

The measured values used to trace the clarification curve of an aqueous suspension of solid particles.

Regarding the sedimentation velocity of the solid particles, it was determined by calculation using the image processing method of the separation interface between the clarified area and the sludge area with the Pi camera attached to the Raspberry Pi device.

To capture the images, the program created for this type of experiment in the Pyton programming language (version 3.4), running on a Raspberry Pi with Raspbian operating system, was used. In this case, the measurements were also made at 20s.

Several analytical systems have been proposed in the literature to simulate the removal of solid particles. In this study, it was used the mathematical expression proposed by Cho et al. (1993), which introduced the concept of "solid flux" for the calculation of sedimentation. Until the present, two empirical models have been successfully used to design decanters for solid material flows. These include the power law model (Eq. (3)) and the exponential model (Eq. (4)):

$$v = kh^{-n} \tag{3}$$

$$v = k \exp(-nh) \tag{4}$$

where:

k, h and n are the maximum sedimentation rates, the interface level and the model parameter, respectively.

The exponential pattern is reasonable in dilute concentrations but is much more complicated in designing a decanter. The law of power model, on the other hand, becomes infinite in a range of diluted concentrations (Sithebe et al., 2014).

RESULTS AND DISCUSSION

Turbidity data was determined from the three points located at different heights on the sedimentation column for 80 minutes. These were converted to the mass concentration according to equation (1).

In table 1 are presented the turbidity values determined experimentally at three heights: 75mm (T_ex75), 65mm (T_ex65) and 55mm (T_ex55); the turbidity values determined by the regression function: 75mm (T_75), 65mm (T_65) and 55 mm (T_55) and the mass concentration determined after conversion, for five moments of time.

Table 1 Experimental results obtained in the process of sedimentation

Time [min]	T_ex75 [NTU]	T_ex65 [NTU]	T_ex55 [NTU]	T_75 [NTU]	T_65 [NTU]	T_55 [NTU]	Ln TSS_75	Ln TSS_65	Ln TSS_55
10	59.42	25.30	57.70	53.57	34.03	43.83	6.27	5.00	6.23
20	19.93	21.05	26.25	38.52	22.84	29.92	4.63	4.72	5.05
40	19.93	16.94	26.25	27.69	15.33	20.43	4.63	4.39	5.02
60	11.05	9.34	26.25	22.83	12.14	16.34	3.75	3.50	5.05
80	11.05	13.04	26.25	20.07	10.39	14.08	3.75	4.00	5.05

Based on experimental data was plotted the clarification curve corresponding to the three points in which was measured the turbidity (Figure 2).

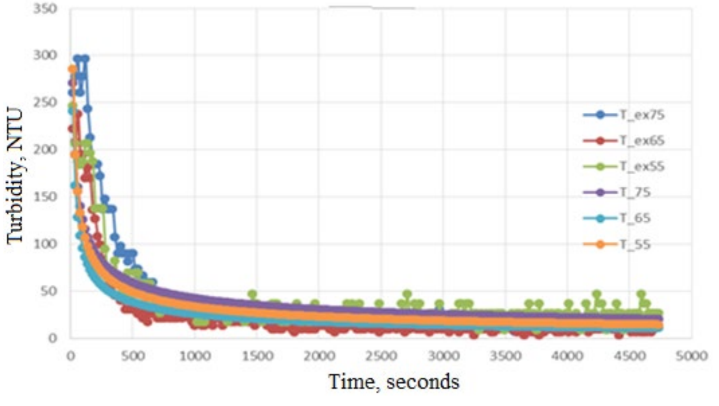


Figure 2 The turbidity variation over time for the three points of measurement (T_ex75, T_ex65, T_ex55 - the experimental values T_75, T_65, T_55 - the values determined by regression)

The experimental results, for all three set heights, were processed using Microsoft Excel using regression analysis for each sedimentation area. According to figure 2, it can be seen that the turbidity value in the 80 minutes in which the measurements were made, for the height of 75 mm decreased from 260 NTU to approx. 11 NTU, for the height of 65 mm the turbidity had values between 222 and 13 NTU, and for the height of 55 mm, the turbidity had variations from 246 to 26 NTU.

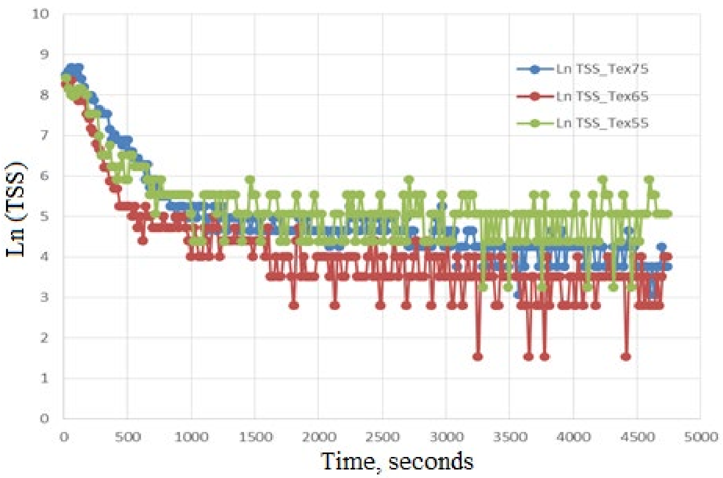


Figure 3 The variation of the natural logarithm of the concentrations to solids

In the graphically represented data sets a reasonable match of experimental data with regression data is observed. According to this variation, it can be observed that as time passes, the degree of turbidity in the solution decreases. The same can be seen in figure 3, where is presented the variation in time of the natural logarithm of the solid particle concentration.

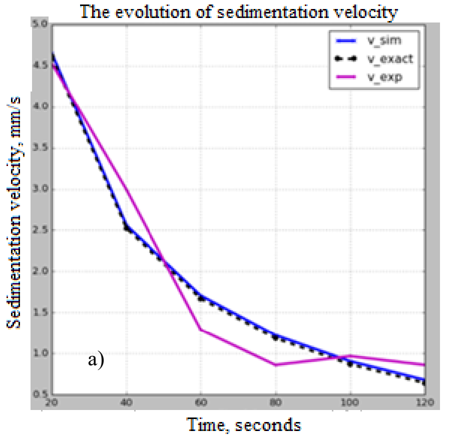
In datasets (Figures 2 and 3), it can observe a correlation of the data with those obtained by Sithebe et al. (2014).

Figure 4a shows the evolution of sedimentation rate over time, determined by calculation using equation 4, following the experimental determination of the level of the separation interface between the clear area and the sludge area (Figure 4b), by processing the images captured by means of the Pi camera. In Figure 4a, the magenta colour curve represents the experimentally determined sedimentation velocity values and with the blue line, the sedimentation velocity values calculated by numerical integration of the differential equation from the model proposed by Je and Chang (2004), in their paper:

$$dv / dt = a / t^k \quad (5)$$

The dotted line in the graphical representation indicates the values of sedimentation velocity calculated analytically by solving the differential equation mentioned above.

It is noticed that at the initial moment, the sedimentation velocity value is 4.5 mm s^{-1}, and in second 120 it decreases to 0.8 mm s^{-1}. This shows that the sedimentation velocity of solid particles in an aqueous solution decreases over time.



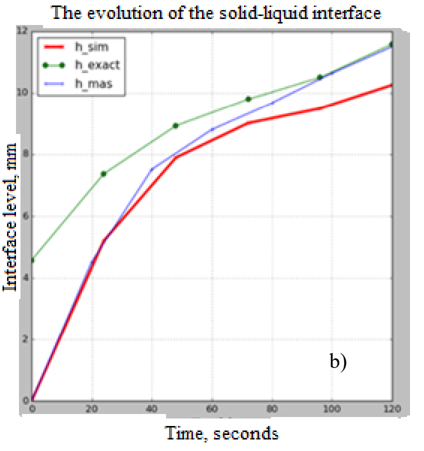


Figure 4 a) the rate of sedimentation variation over time
b) the evolution of the solid-liquid interface

In Figure 4b, the blue curve represents the variation of the height of the interface between the clarified area and the sludge area determined experimentally, and in red is represented the height of the interface calculated by numerical integration of the differential equation:

$$dh / dt = 3a \cdot t^2 + b \cdot t + c \quad (6)$$

The green line indicates the height values of the analytically calculated interface by solving the differential equation mentioned above. Figure 4b shows that the height of the solid particle layer increases over time.

The experimental results obtained are in correlation with those obtained by Sithebe et al. (2014), as well as those obtained by Je and Chang (2004).

CONCLUSIONS

Sedimentation is a unit operation of high importance in various wastewater treatment systems. In a tank in which the water flow velocity is very low, the particles tend to go to the bottom under the influence of gravity. The results obtained for the dishwashing powder used to carry out the experiment, are in line with the other sedimentation rate research, obtaining a power function. The turbidity, measured at 20sec intervals in three different points, had a variation between 260 -11 NTU in the time interval in which the measurements were carried out (about 80 minutes). It was also noted that the velocity decreases with time as fewer and less heavy particles remain in suspension.

Automation of data analysis will enable engineers and scientists to perform more advanced interpolation/optimisation schemes of settling column data to improve design accuracy.

ACKNOWLEDGEMENT

This work was supported by a grant of the Romanian Ministry of Research and Innovation CCDI - UEFISCDI, Project INNOVATIVE TECHNOLOGIES FOR IRRIGATION OF AGRICULTURAL CROPS IN ARID, SEMIARID AND SUBHUMID-DRY CLIMATE, project number PN-III-P1-1.2-PCCDI-2017-0254, Contract no. 27PCCDI / 2018, within PNCDI III.

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ECONOMIC DESIGN OF DRAIN DEPTHS AND SPACING USING DIFFERENT EU AND NON-EU MODELS

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ABSTRACT

Many agricultural systems are being affected by regional climate change. With the increase of the agricultural land prices and the demand for more food, there have been tendencies to increase productivity and use of new areas for crop production in which land drainage may be needed. Therefore, the studies of economic evaluation of agricultural drainage projects are necessary.

Land drainage is a critical water management tool for the sustainability of cropping productivity systems. Land drainage provides environmental benefits when it is sustainable designed securing the conservation and improvement of soil resources quality. A key aspect of this problem is the correct determination of distance between drains based on a series of environmental and human-induced factors.

Currently there are many EU and non-EU models used in land drainage systems design. This paper will approach several of them from EU and South-America and will apply them for a couple of case studies from western Romania.

The main aim is to emphasize the necessity of approaching a wide range of elements (radial head losses, flow regime, complexity of drainage formula) in designing a sustainable land drainage system. The results gained from applying different programs (with different characteristics) demonstrated the importance of implementing this approach.

Keywords: *agricultural systems, land drainage, design, models*

INTRODUCTION

The climate is changing. Significant increases in precipitation, both average and extreme are visible around the world. Maintaining and improving soil fertility in areas affected by excess moisture is a major concern of all many countries in their efforts to ensure basic needs like food and habitable land for a population which is in a continuous growing and which presents a high interest for developing their economic activities. Water excess from agricultural lands can be sustainable managed with an efficient agricultural drainage system which will need to enable the shift from a strategy of rapid removal of all excess water to one that continuously controls water levels within an environmental framework (Ritzema and Stuyt, 2015; Meyer and Keiser, 2016)

The main objective of an agricultural drainage system is to provide for a root zone the environment that facilitates plant growth and optimizes crop production. Thus, drainage of agricultural land is a critical water management tool for the sustainability of cropping productivity systems considering the links between this sustainability and the control of water logging and salinization processes from root zone. Land drainage also provides environmental benefits when it is sustainable designed securing the conservation and improvement of soil resources quality. A key aspect of this problem is the correct determination of distance between drains based on a series of environmental and human-induced factors.

Land drainage design projects must also consider the improvement of the social-economic sector but also the compliance of environmental regulations. A special attention must be granted in planning, design, implementation, exploitation and maintaining a drainage system, in all development phases in order to ensure that the impact on environment, once determined, is minimized at acceptable dimensions from all perspectives.

Land drainage became in time a much diversified instrument. If till some decades ago, land drainage was focused almost exclusively on removing the water excess, modern drainage is part of water integrated management, removing or conserving the necessary water volumes and being also preoccupied by water quality and environmental values. Water resources integrated management represents a process which promotes the coordination of water development and management with soils and other resources which are relating with it in order to maximize the economic and social sectors in an equitable manner and without compromising the sustainability of vital ecosystems. In this way it is necessary for drainage to realize a balance between water excess control and conserving soil humidity (Schultz, 2017).

Modern drainage serves today not only agricultural sector but also a large area of economic objectives and activities. The objectives and results of applying land drainage systems must be quantified from qualitative and quantitative point of views. The systems of assessing the performance of a land drainage system are still in an incipient phase, a stage which assumes continuing the researches in this domain. Because drainage is a vital part of water integrated management, this thesis supposed an inter-disciplinary research (Vlotman, 2017)

For realizing some efficient technical and economical drainage studies, the IT component became in the last years very important, modeling programs being those which can offer the best information on time evolution of environmental components as result of implementing a land drainage system.

MATERIALS AND METHODS

This paper is focused on Folea-Sipet-Cerna land drainage system which is part of a larger arrangement named Nord Lanca-Birda (see figure 1).

We could identify in this area alluvial soils, with small hydraulic conductivities. The impermeable soil layer was located at 3 m depth. The climatological data (monthly precipitation and temperatures) used in this paper were collected from Banloc meteorological station (see figure 2).

For determining the distance between drains were used several programs based on non-steady state equations like Glover-Dumm, Jenab, Guyon. These equations were translated in different excel application or programs like Espadren. The results from these applications were included in more advanced programs like Sisdrena which are able to forecast the drained volumes from this land drainage system.

Espadren is an application developed in Costa Rica for simplifying the computation of distances between drains using steady-state equations (Donnan, Hooghoudt, Dagan, Ernst) but also non steady-state equations (Glover-Dumm and Jenab) for open channels and buried drains. Espadren was realized using Visual Basic environment.

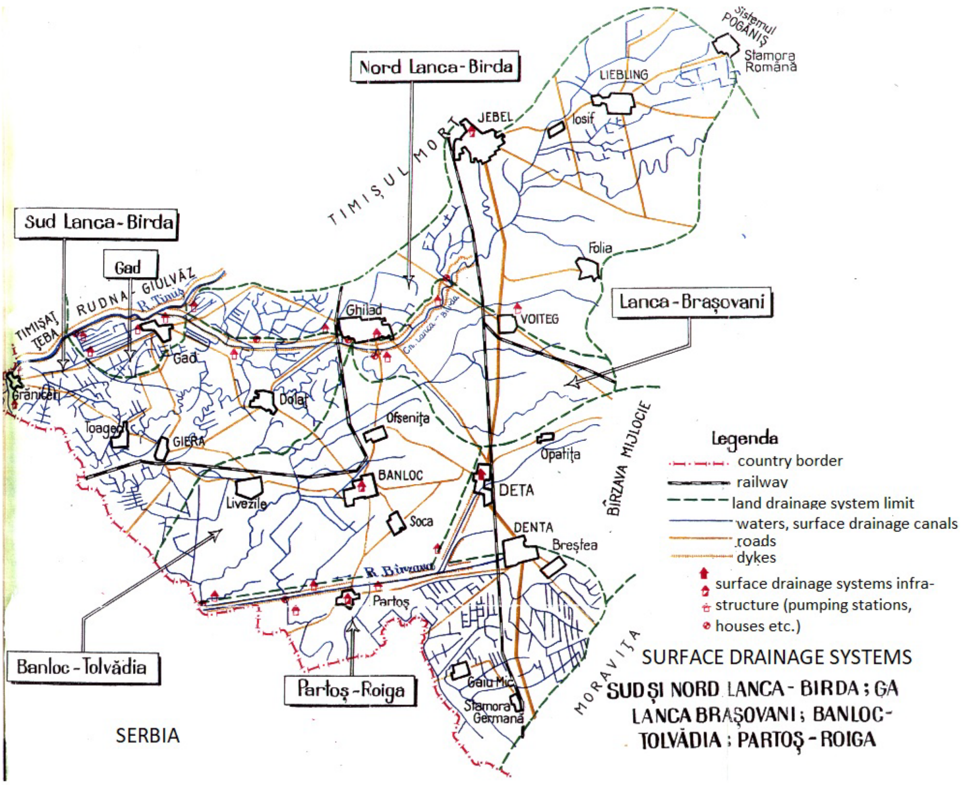

Figure 1 Folea - Sipet - Cerna land drainage system

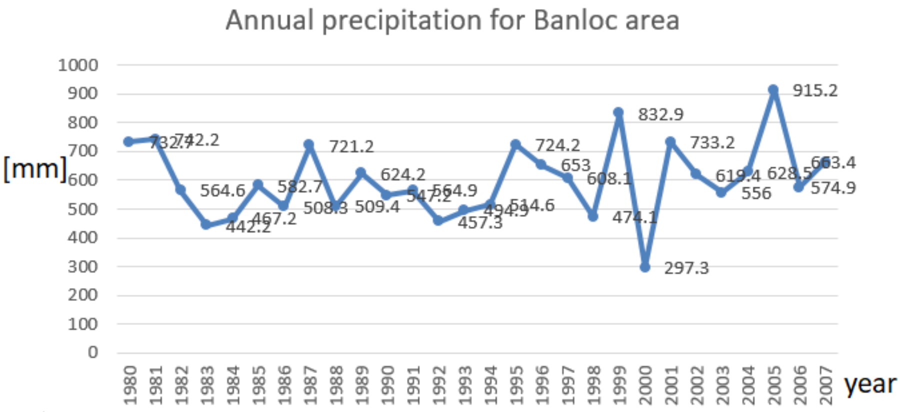

Figure 2 Annual precipitation values for Banloc area

SISDRENA was coded in Visual Basic 6.0 at the Department of Biosystems Engineering (LEB), "Luiz de Queiroz" College of Agriculture (ESALQ/USP), Piracicaba, SP, Brazil. It is a one dimensional model that accounts for the major components that affect the water balance in a section of homogeneous soil with unit surface area, located midway between two parallel drains and extending from the impervious layer to the soil surface. These components are: precipitation, runoff, infiltration, percolation to groundwater, upstream from the groundwater level to the root zone, evapotranspiration, drainage and vertical "seepage".

Folea-Sipet-Cerna land drainage systems was designed using classical methods without IT support. The authors tried to provide solutions for a future rehabilitation of this arrangement, severely affected by lack of investments and agricultural system reorganization.

The design methods proposed by authors are not very known in Romania, especially when we discuss about ESPADREN and SISDRENA programs. Thus, the results presented in this manuscript will combine Romanian land drainage experience with IT improvements from South-America and represented a first step in correlating trans-continental researches on land drainage systems design.

RESULTS AND DISCUSSION

For the Folea-Sipet-Cerna area, the drainage solution should consist of tubular drains in filter trenches plus deep loosening on 60 cm (repeated 2-3 years) plus mole drainage to 70 cm. The distances between drain tubes will be calculated based on soils texture and conductivity

The distance between the drains is most affected by the value of the hydraulic load loss and respectively the hydraulic conductivity of the soil. For very low Ksol values (0.01 - 0.02 m / day), the results are almost similar, demonstrating almost identical behavior of very little permeable soils to land improvement measures (in this case underground drainage).

The results of running these previously mentioned programs are presented in the following tables:

Table 1 The results of calculating the distance between drains in non-permanent regime using the Espadren program, Glover-Dumm formula

Nr. Crt.	H_{imp} m	H_{dren} m	h_0 m	h_t m	t days	K m/day	r m	p %	L m	d
1	3	1,44	0,6	0,8	2	0,06	0,04	2	12,97	0,89
2	3	1,44	0,6	0,8	3	0,06	0,04	2	16,47	0,98
3	3	1,44	0,6	0,8	4	0,06	0,04	2	19,46	1,04

where H_{imp} is the depth of impermeable layer, H_{dren} is the depth of drains line, h_0 is the initial depth of water table level, h_t is the final depth of water table level, r – drain radius, p – soil porosity, L – distance between drains, K – soil hydraulic conductivity.

Table 2 The results of calculating the distance between drains in non-permanent regime using the Espadren program, Jenab formula

Nr. Crt.	H_{imp} m	H_{dren} m	h_0 m	h_t m	t zile	K m/zi	r m	p %	L m	d
1	3	1,44	0,6	0,8	2	0,06	0,04	2	11,73	0,85
2	3	1,44	0,6	0,8	3	0,06	0,04	2	14,93	0,94
3	3	1,44	0,6	0,8	4	0,06	0,04	2	17,66	1,01

H_{imp} is the depth of impermeable layer, H_{dren} is the depth of drains line, h_0 is the initial depth of water table level, h_t is the final depth of water table level, r – drain radius, p – soil porosity, L – distance between drains, K – soil hydraulic conductivity.

Table 3 The results of calculating the distance between drains in non-permanent regime using an excel application based Glover-Dumm formula

t days	h_0 (m)	h_t (m)	H_{dr} (m)	K (m)	p (%)	r (m)	u (m)	D (m)	L_{est} (m)	d (m)	D_h (m)	L_{calc} (m)
2	0,8	0,6	1,4	0,06	2	0,04	0,13	1,6	4	0,45	0,8	9,39
3	0,8	0,6	1,4	0,06	2	0,04	0,13	1,6	4	0,45	0,8	11,5
4	0,8	0,6	1,4	0,06	2	0,04	0,13	1,6	4	0,45	0,8	13,28

H_{dren} is the depth of drains line, h_0 is the initial depth of water table level, h_t is the final depth of water table level, r – drain radius, u – wet perimeter, D – distance from drain line to impermeable layer, L_{est} – estimated distance between drains, K – soil hydraulic conductivity, L_{calc} – calculated distance between drains.

Table 4 The results of calculating the distance between drains in non-permanent regime using an excel application based on Guyon formula

Nr. Crt.	K m/day	p %	h_0 m	h_t m	D m	r m	u m	t days	L_{est} m	L_{calc} m	d_{calc}
1	0,06	2	0,8	0,6	1,6	0,04	0,13	2	4	10,07	0,79
2	0,06	2	0,8	0,6	1,6	0,04	0,13	3	4	12,63	0,88
3	0,06	2	0,8	0,6	1,6	0,04	0,13	4	4	14,87	0,95

H_{dren} is the depth of drains line, h_0 is the initial depth of water table level, h_t is the final depth of water table level, r – drain radius, u – wet perimeter, D – distance from drain line to impermeable layer, L_{est} – estimated distance between drains, K – soil hydraulic conductivity, L_{calc} – calculated distance between drains.

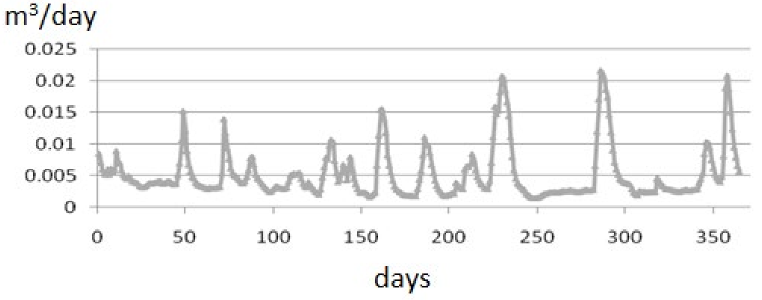

Figure 3 The graph of drains discharched flow for the solution offered by Espadren program, no-filter option (m^3/day for 365 days)

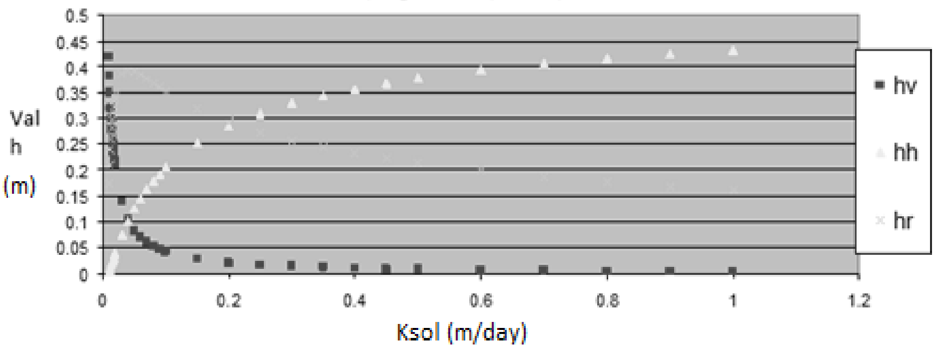

Figure 4 Variation of head losses (hv – vertical head loss; hh – horizontal head loss; hr – radial head loss) depending on hydraulic soil conductivity (Ksol) for a 5 cm diameter drain tube without filter (simulation using Espadren input values)

The radial head loss is directly proportional to the distance between the drains. As the Ksol increases, the effect of the filter attached to the drain is reduced, but the relationship between the radial load loss and the distance between the drains is retained, by example for an increase in radial head loss of x times, we identfied an increase in the distance between the drains of 10%. Water entrance resistance in drain tube (or drain-filter complex) is a resistance of the flow form vecinity and is affected by the physical properties of the altered soil around the drain, the distance between the drains and the materials used. Water entrance resistance can be calculated theoretically from the shape and distribution of drain tube perforations, or by accurately shaping the flow of water to drains.

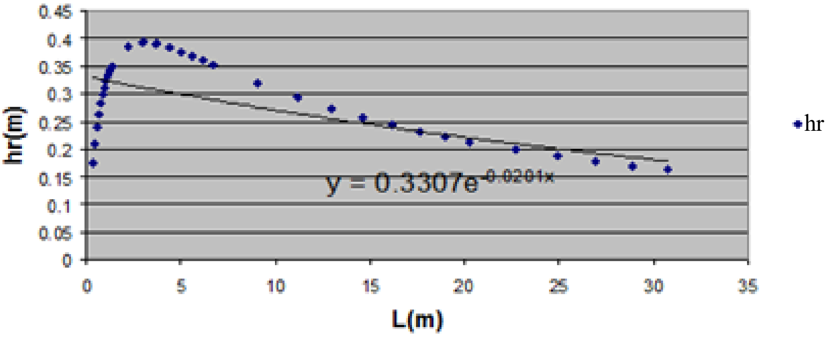

Figure 5 The relationship between hr and L for a 5 cm diameter drain tube without filter material (simulation based on Espadren data)

By comparing the results obtained with the Espadren program (drainless filter - entrance loss is not taken into account) with the DrenVSubIr program (drain having sand filtering material and also considering the head loss of water at the water inlet in the drain filter complex) it can be seen that the effect of this filter (filtering material) is very low. However, ignoring this type of loss of load in determining the distance between drains can lead to considerable errors with economical impact. With regard to the filter material, the most important feature with impact in designing the distance between the drains is the thickness of the filter material (again an economical aspect of land drainage design) and not the initial or postfill permeability coefficient. For the studied cases, the radial head loss has no influence, while the horizontal head loss is only related to the hydraulic conductivity of the soil (is proportional to Ksol) and can be defined by logarithmic equations. The pattern of water flow in the drainage area is very complex due to soil alteration, where the physical characteristics are heterogeneous and change over time, making it difficult to predict. A thorough analysis can be performed to identify dominant variables of head loss in drainage design. The results obtained can thus be used to determine the parameters used as input data in the design of an underground drainage system. (Halbac and Miranda, 2012).

CONCLUSIONS

The international technical literature regarding drainage design foresees many equations for non-steady state regime with various degrees of complexity. Some of these equations become consecrated among researchers and designers involved in drainage issues. Theoretical studies, laboratory and field research have all contributed to a gradual increase of knowledge on drainage materials and their performance. The complexity of the physical properties of the soil is the reason that some problems are not yet adequately solved.

Land drainage systems should be designed to minimize subsurface drainage but also maintaining production benefits. Soils have differing optimum spacing for maximizing production and this should be considered in designing an economic efficient land drainage system. In addition, the economic return for the drainage system will vary with soil type and drain spacing.

Using an economic design approach in determining the distance between drains can have environmental benefits given that in many situations the economic return may be maximized at a wider drain spacing and the wider drain spacing may reduce the volume of subsurface drained water and subsequent export of nutrients. The distance between the drains is sensitive to changes in the radial component and to the hydraulic conductivity of the soil, but is not subject to alterations in the case of changes in the horizontal and vertical components. Thus, future land drainage projects should pay attention to the variation of head losses components and their weights as key indicators for designing sustainable arrangements.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

NATURE-BASED SOLUTIONS FOR FLOOD RISK MANAGEMENT: A ROMANIAN CASE STUDY

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ABSTRACT

Water-related risks are among the most expensive natural disasters. In particular cities are increasingly vulnerable against such events. Nature-based solutions (NBSs) are suggested as sustainable way of addressing water-related risks. In the current research funding landscape, nature-based solutions seem to be regarded as panacea for many environmental issues. In addition, natural water retention measure (NWRM) concept offers new opportunities and brings added-value. These types of measures not only serve to reduce risk and provide more robust flood protection; they also provide additional environmental services including increased biodiversity and recreation opportunities. However, a common characteristic of green infrastructure measures is that they often claim more land than traditional methods. Making this – often privately owned – land available respectively getting land user implementing the measures is thus one of the key challenges of implementing measures to mitigate or adapt to water-related risks.

This paper will explore several aspects of nature-based solutions and natural water retention measures flood risk management based on current relations climate change – water cycle – natural ecosystems.

Keywords: *nature-based solutions, water retention, ecosystems, water cycle*

INTRODUCTION

Changes in the frequency of extreme water hazards (such as floods), may be one of the most significant consequences of climate change. Water-related risks – such as floods, coastal storm surges, flash floods - are among the most expensive natural disasters in Europe. Worldwide, climate change is expected to increase average air temperatures values and to increase the spatio-temporal variability of precipitation events, something that most likely will lead to even more intense and frequent water hazards. Water hazards may have enormous environmental, social and economic consequences, and it is expected that effects from climate change will exacerbate their occurrence and impacts in the future.

The magnitude of threats attributable to water hazards and climate change, and their territorial distribution, is presently not fully known. The Intergovernmental Panel on Climate Change (IPCC) states – with "high confidence" – that damages by water-related risks will substantially increase in Europe (IPCC, 2014) due to changing hydro-meteorological conditions. In addition to known changes in environmental conditions, there are also feedbacks between intensification of land and water use, which contribute to increasing risks. Cities in particular are increasingly vulnerable to such events – as recent flash floods in Central Europe illustrated during summer 2016. Nature-Based Solutions (NBS) to water-related risks cannot entirely substitute traditional measures such as flood pathway and receptor approaches (both structural and behavioural, e.g. flood walls, channels, flood warnings), but its potential value for mitigation and adaptation has been widely recognized.

NATURE-BASED SOLUTIONS FOR FLOOD RISK MANAGEMENT

There is an increasing interest in adopting NBS globally. A wide range of public and private stakeholders are keen to explore the potential multiple benefits NBS can deliver. In addition, such approaches can simultaneously contribute to meeting the objectives of different European Union (EU) policies (e.g. the Water Framework Directive, the Floods Directive, the EU Climate Change Adaptation Strategy). Traditional flood protection measures, mainly based on grey infrastructure (i.e. dikes, dams, etc.) are not sufficient to cope with dynamic flood risk alone. NBS are promising options to complement grey infrastructure measures in mitigating flood risks. NBS are actions which are: (1) inspired by, (2) supported by or (3) copied from nature. NBS for risk mitigation and adaptation in river catchments involve for example Natural Water Retention Measures (NWRM), space for the rivers, or measures for resilient cities.

NBS types of measures not only serve to reduce risk and provide more robust flood protection; they also provide additional environmental services, including increased biodiversity and recreation opportunities, as well as delivering other, unseen environmental services such as improved water quality and aquatic habitats. However, a common characteristic of green infrastructure measures is that they often claim more land than traditional methods do. This land type, already in use for other purposes, is also often privately owned. Mobilizing private land for temporary flood storage it means having to coordinate different actors and institutions in water management. This particularly includes engaging landowners and land-users actively in developing and implementing management plans (Hartmann, 2011), but it also implies for managers to employ a more trans-disciplinary perspective and creating governance mechanisms for transferring benefits from the downstream beneficiary to the upstream provider (Machac et al., 2017). There are few, if any, working models for such transfers of benefits and their development will require collaboration from all communities of end-use implementers – those who must benefit from the implementation on the ground level. This includes municipal and other governmental stakeholders, but also the land owners/users who will benefit from the reduced flood risks, in return for some level of compensating for those benefits. Such a benefit transfer policy will be extremely difficult to impose from the top. What is particularly needed are dialogue tools which, in concert with the latest and most accurate valuable tools, can be used to encourage the effective adoption of such nature-based technologies.

With NBS, two interconnected issues are at stake: (i) almost all NBS measures require more land than traditional grey infrastructure do. A dike against inundations is for example much more land thrifty than a retention area will be. Within retention areas, controlled retention areas are far more effective, but alluvial forests will be much more valuable in terms of its ecological benefits. Although somewhat simplified, the more nature-based a solution is, the higher will be its demand for land; (ii) land needed for NBS is often owned by private landowners rather than public stakeholders. Green roofs – a NBS for resilient cities – can only be effectively implemented on a larger scale if landowners agree on implementing them. Further, such measures can raise conflicts around land-use issues4. Thus, making land available and getting the land owner/user to implement the measures is one of the key challenges for NBS to contribute to mitigating and adapting to water-related risks.

Several instruments for land use management already exist in different countries. Water management usually prefer having full ownership of riverside properties (Hartmann and Spit, 2011). Technical needs and essential requirements for land use in retention areas and polders justify this position; still it frequently causes conflicts with landowners. Land acquisition often protracts the realization of a project and expropriations are rarely used because of administrative hurdles. Prevalent methods in many countries are freehand purchase, other trade-offs and exchanges of land for requested sites, or rural-land readjustment. Most of these methods are expensive, time consuming and administratively complex. Therefore, water authorities experiment with upstream-downstream agreements, such as in Austria, forms of co-financing and negotiated governance schemes in UK or attempts to solve through existing planning laws and voluntary, collaborative processes like in Norway (Collentine and Futter, 2016; Seher and Loschner, 2016; NOU, 2013). Also Payments for Ecosystem Services (PES) are employed. Those redistributive mechanisms have become popular, in particular, in watershed management to optimize resource management and also for poverty alleviation. However, despite considerable efforts in flood risk management over the last few decades, the implementation of measures which increase retention throughout the catchment and promote resilience in urban/peri-urban areas are still in their infancy, both in research and in practice (Knieling and Mueller, 2015).

NBSS FOR FLOOD RISK MANAGEMENT: A ROMANIAN CASE STUDY

This paper approaches western and southern parts of Romanian territory, areas characterized by a high density of land drainage and irrigation system which provide several important regulating ecosystem services like flood retention, groundwater recharge etc. These areas were frequently affected floods and droughts requiring breaking down disciplinary boundaries between engineers, ecologists, agronomists, economists, hydrologists and climate scientist and the appliance of some reliable climate-energy-economic models as well as land-use models.

The importance of NBSs was emphasized in 1910 by Romanian Minister Grigore Antipa in justifying the need for preservation of natural Danube meadows (Figure 1).

He argued that:

- Ponds exert a positive moderating influence on the climate (comparable to that of forests) by acting as sources of moisture and vapor condensation
- The ponds in the Danube meadow act as "valves", which are needed to prevent flood water rises that can cause flooding and breaking of dams in the case of historic highs
- Under their natural regime, the Danube's ponds when used for fish have the highest productivity in Europe
- Using grey infrastructure for flood defense is very costly
- The meadows prevent loss of nutrients carried away by the Danube
- The meadows are suitable for development of willows, poplars, and even oak forest belts (Antipa, 1910; Antipa, 1913; Dan, 2014).

Unfortunately, these measures were put into practice only for a very short period of time (Botzan et al., 1991; Stoiculescu, 2008).

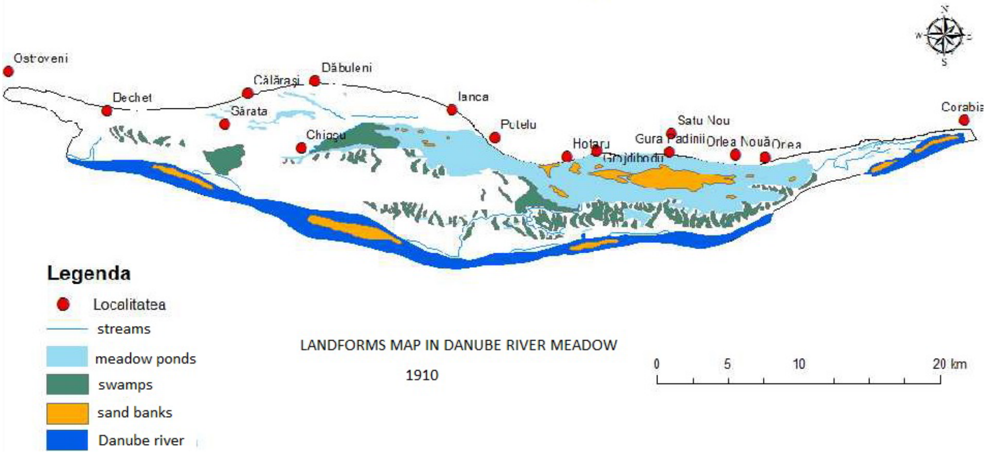

Figure 1 Landforms map in Danube river meadow

Over the last century, the landscape of the Danube River floodplain faced major changes. Most of the large alluvial plains, mixed with marshlands and small lakes, along the Romanian side of Danube, have been affected by river embankments, drainage systems and urban sprawling. A consequence was that an important strip of land (width ranges from 1 to

10 km in our study area), once a wetland prone to floods, has been converted to arable land (Craciunescu et al., 2010).

During 1960 - 2010, a number of around 400 important floods occurred, among them 39 are considered significant historical floods, based on hydrological criteria and criteria that took into account the magnitude of the floods negative consequences. Thus, there were designated 36 significant historical events for the inland rivers and 3 for the Danube, and 375 areas with potential significant flood risk on the inland rivers and 24 on the Danube. During this period, there have been registered 237 victims (6.6 average victims/event). More recent history of floods in Romania shows the great impact of this hazard on people and infrastructure: the 2005 and 2006 floods have affected over 1.5 million people (93 dead), have destroyed an important part of the infrastructure and have caused estimated damages of over 2 billion Euro (IGSU, 2016).

Based on flood hazard and flood risk maps elaborated in the third stage of Floods Directive, National Administration “Apele Române”, under the scientific coordination of National Institute of Hydrology and Water Management, had developed Flood Risk Management Plans (FRMPs) for all 11 River Basin Authorities (RBAs) and Danube river. The main chapter of the FRMP consists in proposed measures by the RBAs that aim to reduce flood risk. The measures are with applicability at national, river basin and areas with significant potential flood risk level and include the following aspects:

- Studies for Danube meadow re-naturation including displacement of several settlements
- Creation of some polders in cascade
- Establishment of several reservoirs
- Maintaining dikes only around major objectives

Unfortunately, a significant part of these measures remained only at intention level.

One of the NBSs implemented in western Romania for the management of excess water appears to have its origins in this historical period. In a historical perspective, removal of excess water, which largely affects land in western Romania, was approached by two main methods: land drainage and examples of measures which bear NBSs characteristics. While land drainage was intensively practiced later (during the Communist period), with very good results in agriculture, measures bearing NBSs characteristics were also implemented based on traditions transmitted by farming families.

Land drainage possess the capabilities to provide important ecosystem services mainly from the first three categories: supporting, provisioning and regulating services. The main potential supporting ecosystem services are including soil erosion control, soil nutrients recycling and soil organic matter accumulation. Land reclamation and improvement works like land drainage are focused mainly on increasing food production and have the potential to provide important ecosystem services. Moreover, these works also generate a series of provisioning, regulating and supporting services including here groundwater recharge, flood and sediment retention, carbon sequestration, erosion control, accumulation of SOM, recycling of soil nutrients, supporting species diversity etc.

The actual methodology in designing land reclamation works in Romania has an economic approach: reducing the effects/ removing the stress factors for maintaining/ increasing agricultural production at low costs. Unfortunately, many key issues as the potential impact on environment, adaptation to climatic variability, soil and water conservation aspects, climate change manipulation techniques using these works, are not considered.

Two of the most important regulating ecosystem services for western Romania are flood retention and groundwater recharge. Unfortunately, the uncontrolled and intensive drainage practiced in western Romania severely affected the capacity of groundwater recharge. Currently, in extreme western part of Romania as well as in some areas from southern part, aridization becomes more and more clearly a feature of local climate.

DISCUSSION

A major obstacle in studying NBSs concept in Romania is that the scientific literature on this subject is relatively poor and the concept of NBSs was insufficiently studied. Currently, in Romania we can notice a lack of documented information on NBSs. The concept of NBSs was and still is described almost solely in official documents such as translations of European Union (EU) documents, different declarations issued by non-government organizations (NGOs), theories expounded in farming magazines. Moreover, the NBSs concept is very difficult to identify as pure 'nature-based solutions' in Romanian scientific literature.

The NBSs concept is not explicitly used in the national RBMP, which consists in a synthesis of the 11 River Basin Management Plans, covering Romanian part of the Danube River basin. Within the proposal for the second RBMP there is no improvement in the general operationalization of ecosystem service concepts. However, in the second RBMP for entire Danube River Basin District, there are mentioned the links with Green Infrastructure Strategy, which is a strategically planned network of natural and semi-natural areas managed to deliver a wide range of ecosystem services, floodplains being good examples of multiple ecosystem services provider (ICPDR, 2015; Grizzetti et al., 2016).

CONCLUSIONS

Unfortunately, at national level, after the NBSs concept emerged, there was little interest in promoting it for flood risk mitigation purposes. The situation worsened due to an emphasis on the quantity, and not the quality, of implemented measures. Other factors that negatively impacted NBSs implementation were the low level of knowledge of people involved in this field, with insufficient skills in ecosystem services and they neglected topics such as water management, risk management, biodiversity, and the uncertainties regarding NBSs financing.

Most existing research initiatives on flood risk management focus on technical or hydrological aspects, forecasting, disaster management, or institutional governance. The lack of collaborative approaches with land owners/users remains a major hurdle for flood risk management, a fact that has been confirmed in earlier research. Generally, water management has first dealt with technical and hydrological issues before addressing land management, and then found implementation to be hampered by the lack of land management approaches. Land owners/users are often regarded as mere recipients of water management, not as key stakeholders. Most existing research initiatives on water-related risks focus on technical or hydrological aspects, forecasting, disaster management, or institutional governance aspects. Approaches for collaborating with private land users to realize mitigation and adaptation measures on private land are lacking both in theory and practice. If land management for NBS is not properly addressed and scaled up to the catchment-scale (or aquifer) NBS for flood risk management will remain ineffective and inefficient.

New programs must be based on instruments of land management i.e. policy interventions that influence the activities of the target groups so that these will be compatible with the political aims. Such instruments can be established from scratch, but experience shows it is often better if building on already existing structures, even ones rediscovered after periods of oblivion, transposed from a rural to an urban setting, combined with other in a complex intervention strategy, and so forth. It demands a more robust understanding of how the impact of the changing relationship between climate change, water cycle and natural ecosystems must be integrated with participative processes aiming at improving implementation.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

EFFECT OF OZONE ON *SALMONELLA ENTERITIDIS* AND *ESCHERICHIA COLI* IN CONTAMINATED WATER

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ABSTRACT

Due to its excellent disinfection and oxidation properties, ozone can be used to reduce the microbial load in water. Contaminated water often contains a large number of microorganisms including bacteria and pathogenic germs, harmful to human and animal health. In this paper, ozone efficiency was tested for the treatment of water containing cell suspension of Salmonella enteritidis and Escherichia coli. Ozone was generated by corona discharge method in an ozone generator OZONFIX 8G. Analyses were performed both for determining cell viability by total plate count technique, and for recording cell growth curves in liquid culture after applied ozone treatment. The concentration of ozone as oxidizing agent in water was determined at different time intervals by the titrimetric method. The study demonstrated that the two bacterial species had a high sensitivity to ozone action under the method conditions. Ozone has shown a strong inhibitory effect on bacteria both in terms of survival and multiplication of surviving cells.

Keywords: *disinfection, microbial inactivation, iodometric method*

INTRODUCTION

Ozone is an attractive disinfectant being widely used to inactivate pathogens in drinking water. It is a strong oxidising agent and an exceptionally good disinfectant, effective in destroying bacteria, viruses, parasites and other microorganisms when compared with other widely used chemical disinfectants (Xu et al., 2002; Lazarova et al., 2013). Moreover, ozone does not leave any trace of the residual product upon its oxidative reaction comparing to chlorination treatment (Goncalves, 2009). Lately, ozonation treatment represents an alternative to chlorination in drinking-water disinfection (Verma et al., 2016). Bacteria, including *Escherichia coli, Staphylococcus aureus, Bacillus cereus, Bacillus megaterium, Salmonella typhimurium, Shigella flexneri*, and *Vibrio cholerae* are sensitive to ozonated water under various conditions (Restaino et al., 1995).

Rojas-Valencia (2011) reported that ozone disinfection is very effective for removal of total coliforms and chlorine resistant microbes including pathogens, which are especially resistant to most other disinfectants.

The presence of pathogens can represent a problem for the human health since they can reach natural water courses in large amounts. One of the most common enteric microorganisms is *Escherichia coli* (Gomes et al., 2018), a coliform bacterium commonly found in the lower intestine of warm-blooded organisms.

Prabakaran et al. (2012) have analyzed ozone treatment by applying to human pathogenic bacteria such as *Escherichia coli*, *Pseudomonas fluorescens*, *Salmonella typhi* and *Klebsiella pneumoniae*. Among the treated bacterial species, *E. coli* revealed high sensitivity to ozone treatment compared to other bacterial strains.

For ozone generation, there are four recognized methods namely: corona discharge, ultraviolet radiation, electrolysis and radiochemical method. The use of electrical power to generate ozone by corona discharge is the most commercially viable method, due to some advantages: high ozone concentration, best for water application, fast organic removal (Goncalves, 2009; Smith, 2018).

The present study investigated the effect of ozone for the treatment of water containing cell suspension of *Salmonella enteritidis* and *Escherichia coli* using an ozone generator OZONFIX 8G.

MATERIALS AND METHODS

Ozone production

Ozone was produced by a mobile ozone generator type OZONFIX 8G, with the following characteristics: ozone production 8 $g \cdot h^{-1}$, power 16 W, air cooling, gas flow (measured) 2.5 $L \cdot min^{-1}$, used for air and water treatment. All the experiments were conducted at temperature of 20 °C.

Methods of analysis

For determination of the formed ozone and oxidizing agents in the liquid medium, the traditional iodometric analysis method was used (Masschelein, 1998). The gas produced by the ozone generator was bubbled through a ceramic frit into 200 mL of 0.2 M KI solution in a cylindrical vessel, thus the height of the liquid was 15 cm. Generated ozone, as well as any other oxidizing agents, reacted with iodide to form iodine. Samples of 10 mL were taken after 30 seconds to 20 minutes.

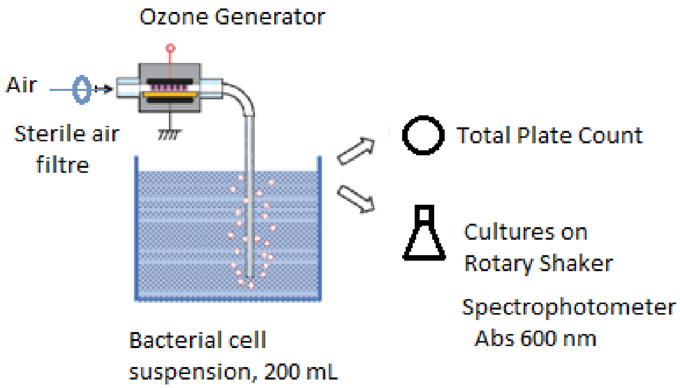

Figure 1 Schematic diagram of ozone treatment

Bacterial strains and culture media

Volumes of 10 mL of both E. coli ATCC 11229 and S. enteritidis ATCC 13076 bacterial cells suspension obtained on Nutrient agar medium in tubes were used to inoculate 100 mL of Nutrient broth in Erlenmeyer flasks. The cultures were incubated in a rotary incubator (Thermoshake, Gerhardt) at 37 °C and 150 rpm for 24 hours. A volume of 1 mL of each bacterial culture was used to prepare the 200 mL of cell suspension for ozone treatment. The ozone produced by the ozone generator OZONFIX 8G was bubbled into the cell suspension and the samples were collected after 15 sec, 30 sec, 1 min, 2 min, 3 min, 5 min, and 10 min, for total plate count analysis. The results were compared to initial cells suspension, untreated. In the same time, for each exposure time, another volume of 1 mL was pipetted into liquid culture medium in Erlenmeyer flasks and allowed to grow in the rotary incubator. The dilution of each sample and the addition of agar medium have been made as quickly as possible, because the interaction of RONS (reactive oxygen and nitrogen species) produced in ozone generator with bacterial cells was very strong. The number of total viable cells was determined in Petri dishes, at 37 °C, after 48 hours. The inactivation efficiency was measured by logarithmic inactivation rate $\lg(N_0/N_t)$, where N_0 and N_t were the number of viable bacterial cells before and after inactivation. The liquid samples in Erlenmeyer cultures were analyzed during 24 hours of incubation, by reading the absorbance values at 600 nm. All samples were performed in triplicate.

RESULTS AND DISCUSSION

The bacterial strains *E. coli* ATCC 11229 and *S. enteritidis* ATCC 13076 were analyzed for total viable cells after ozone treatment by plate count technique and the results are presented in Table 1. The values of ufc mL^{-1} for the two bacterial species after ozonation at different times, compared to untreated control sample, showed great difference. Although after 15 seconds cell viability showed only a slight decrease, after 30 seconds it decreased with an order of magnitude for both the bacterial strains. The microbial inactivation efficiency after 1 minute of ozonation was 1.98 log for *E. coli* and 2.15 log for *S. enteritidis*.

Keeping the bacterial cells in ozone bubbling water for more than 1 minute, caused irreversible damage and cell death.

Table 1 *E. coli* and *S. enteritidis* growth after different time of ozonation

Strain/Ozonation time	*E. coli* ATCC 11229 ($ufc\cdot mL^{-1}$)	*Salmonella enteritidis* ATCC 13076 ($ufc\cdot mL^{-1}$)
Reference (untreated sample)	$1.9x10^5$	$2.4x10^5$
15 sec	$1.2x10^5$	$1.7x10^5$
30 sec	$5x10^4$	$6x10^4$
1 min	$2x10^3$	$1.7x10^3$
2 min	0	0
3 min	0	0
4 min	0	0
5 min	0	0

The growth behavior of the tested bacterial strains has been examined through measurement of absorbance at 600 nm in cultures incubated on rotary shaker, for 24 hours. The obtained results are shown in figure 2.

The characteristic appearance of growth curves for both bacterial strains showed a lag phase of 6-7 hours for the reference and cell cultures treated 15 seconds, 30 seconds and 1 minute with ozone, and a longer lag phase, of about 14 hours, for 2 minutes of ozone treatment cultures. This can be explained both by the lower number of survivors in ozonated samples and also by the cellular lesions that occur and are repaired in a longer time. For an ozonation time of more than 2 minutes, the cell damage was too great and could not be repaired. For all cases, the absorbance values were dependent of the ozonation time, and the lag phase was as long as the duration of treatment was greater. After 24 hours on the rotary incubator, the measurement of absorbance showed that in control culture and in cultures exposed 15 sec, 30 sec at ozone treatment the absorbance values were quite close, and slightly lower for the treated cells for 1 minute. In the case of cells from the samples treated 2 minutes with ozone, the absorbance after 24 hours was much lower, with values of 2.4 (compared to 3 in control culture) for *E. coli* and 1.9 (compared to 2.6 in control culture) for *S. enteritidis*.

Previous studies on ozone inactivation of microorganisms in water have found similar results. Xu et al. (2018) showed a significant antimicrobial effect in cultures of *Escherichia coli* and *Staphylococcus aureus* after current air-liquid discharge plasma. They described damaged bacterial outer structures, decreased concentration of cellular protein and nucleic acid after ROS treatment. The effect of O_3/Cl_2 disinfection on opportunistic pathogens in drinking water distribution systems was studied in 2018 by (Wang et al. (2018). These authors have shown that ozone disinfection inactivated or damaged the bacterial cells due to its strong oxidizing properties. In 2009, Lee et al. (2009) measured the total cell count (TCC) and intact cell count (ICT) by flow cytometry in order to evaluate the inactivation kinetics of bacteria in ozonated water, showing that the bacterial communities may have high and low ozone sensitivity.

Patil et al. (2009) studied the inactivation of *E. coli* in orange juice and showed that the applied gaseous ozone treatment resulted in a population reduction of 5 log cycles.

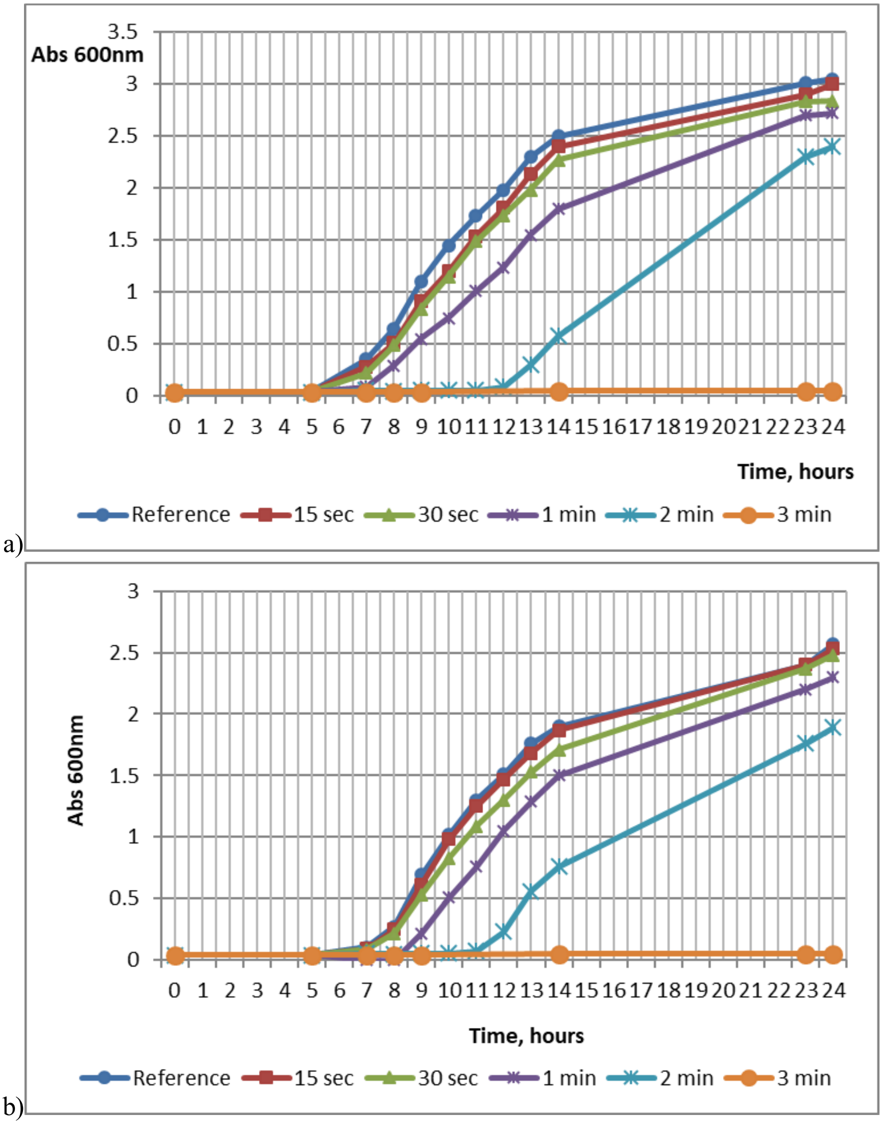

Figure 2 Values of absorbance at 600 nm in a) *E. coli*, b) *Salmonella enteritidis* cultures on rotary shaker after ozone treatment compared to untreated reference

In the experimental conditions, the variation of the ozone concentration in the bacterial cell suspension showed that after the first few seconds, the ozone begins to accumulate in the water. After 30 seconds of ozonation, the concentration of ozone was 43 $mg \cdot L^{-1}$ and after 2 minutes was 160 $mg \cdot L^{-1}$.

In Figure 3 can be observed that the accumulation of ozone and, eventually, of nitrogen oxides (resulted from the oxidation of atmospheric nitrogen entered into device) begins immediately. In theory, plasma generates different reactive species: O_2 can generate reactive oxygen species while air can generate both reactive oxygen species and reactive nitrogen species (Oh et al., 2016). The results of Oh et al. (2016) are in accordance with the previous research carried out in distilled water treated with gas bubbling generated by corona discharge using an ozone generator type OZONFIX 8G (Dinca et al., 2018). The ozonated water contained nitric oxides and O_3, as determined in the UV absorption spectra between 200-300 nm.

All reactive oxygen and nitrogen species that accumulated in water have had a major impact on the structure of bacterial cell of *E. coli* ATCC 11229 and *S. enteritidis* ATCC 13076.

The tested bacterial strains seem to have had a similar sensitivity to ozone treatment in water. The results obtained by plate count technique and the growth curves differ slightly and show that higher concentration of reactive species of ozone and nitrogen oxides can caused major lesions in bacterial cells and their death.

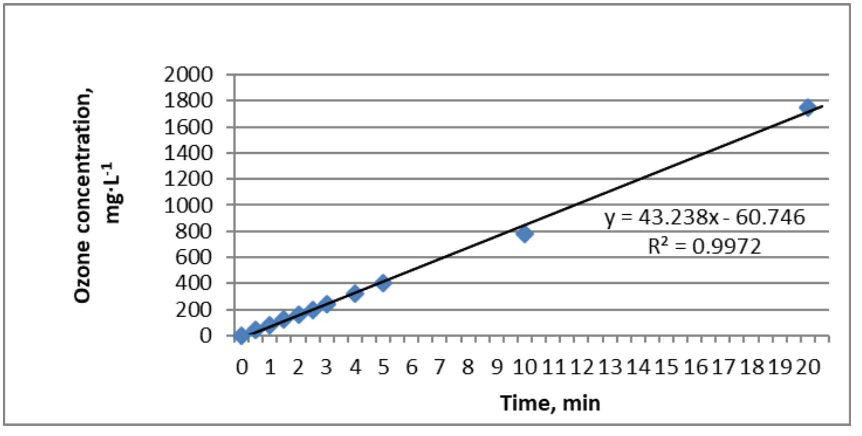

Figure 3 Variation of ozone concentration in time

CONCLUSIONS

The ozonation of contaminated water has considerable antimicrobial effect due to the strong oxidizing properties of oxidative reactive species formed by corona discharge.

The bacterial strains of *E. coli* ATCC 11229 and *S. enteritidis* ATCC 13076 had a great sensitivity to ozone treatment. After 1 minutes of exposure to ozone, the viability of cells decreased with 2 orders of magnitude, and the effect became lethal after 2 minutes, as demonstrated the plate count analysis.

In liquid media, on a rotary incubator at 37 °C, the growth curves showed lower values of absorbance at 600 nm and larger lag phases for the treated bacterial cells, in both cultures of *E. coli* ATCC 11229 and *S. enteritidis* ATCC 13076 when compared to untreated control.

ACKNOWLEDGEMENTS

This work was supported by a grant of the Romanian Ministry of Research and Innovation CCDI - UEFISCDI, Project INNOVATIVE TECHNOLOGIES FOR IRRIGATION OF AGRICULTURAL CROPS IN ARID, SEMIARID AND SUBHUMID-DRY CLIMATE, project number PN-III-P1-1.2-PCCDI-2017-0254, Contract no. 27PCCDI / 2018, within PNCDI III.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

DRIP IRRIGATION IN POTATO CULTIVATION

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ABSTRACT

The aim of this research was verification of drip irrigation effect on potatoes under conditions of higher regions in the Czech Republic. Growing technology using drip irrigation combined with fertigation was verified. After the planting irrigation pipes were put under the soil surface on the ridge top. Two cultivars ~~s~~ differing in vegetation duration were used for planting – early cultivar Monika and medium-early cultivar Jolana. Eight variants of irrigation combined with N fertilization were established. A technique for irrigation management was determined based on soil conditions. Nitrogen fertilization during season was done in two variants: 120 kg N ha^{-1} prior to planting and 60 kg N ha^{-1} at planting + 60 kg N ha^{-1} in four irrigation rates (15 kg N ha^{-1} for each). In the trials an effect of irrigation on all studied factors was detected. Potato yield was significantly increased in variants with irrigation compared to non-irrigated variants. There were no differences found between full and split N rate application.

Keywords: *drought, climatic changes, yield, fertigation, cultivar*

INTRODUCTION

Weather conditions have the highest impact on potato production size (Levy and Coleman, 2014; Haverkort, 2018). In recent years, weather has been characterized by fluctuations above the long-term normal. In the regions of the Czech Republic with higher above sea level, where the most important potato production is grown, temperatures exceed the long-term normal and precipitation is slightly below average and unevenly distributed. In decisive stages of the growing season precipitation is not optimal for potato growth and development. This could be improved by irrigation, which has been necessary as surface spraying for early potatoes in drier regions of the Czech Republic with altitudes below 100 m. However, the decisive potato production is grown in localities with altitudes around 400 m, where water deficit has become a limiting factor under climate change. Potatoes are highly sensitive to water stress, especially in early and medium developmental stages, when water shortage results in yield reduction and potato quality impairing (Wohleb et al., 2014). On contrary, toward the end of the growing season consequences of drought are not so significant (Lynch et al., 1995). Harris (1992) defines a linear relation between potato yield and precipitation during the growing season, when potato yield was 140 kg ha^{-1} increased with every mm of precipitation. Now, it is also important to solve water supply in potato production regions of the Czech Republic in higher above sea level. The basic measure includes a more effective irrigation technique than surface spraying, which has its limitations and shortages (Shock et al., 2013). Drip irrigation has been considered a very effective system and it has been widely used especially in Israel (Tal, 2016). Based on Trifonov et al. (2017) potato is sensitive to excess or deficit irrigation and therefore it requires the efficient water use. The trials with drip irrigation, also done in Israel, indicate the lower the irrigation dose, the higher the water productivity regardless of the dripper discharge or sparing, so if available agricultural lands are not a limiting factor, higher yields can be obtained with a low irrigation dose in a larger area, with no significant reduction in tuber quality. However, it is not the case of Europe, therefore technical irrigation parameters and/or irrigation management based on crop requirements must be evaluated. Bani-Hani et al. (2018) use crop evapotranspiration for drip irrigation control. Based on five levels of modifications in calculations of the dose the results indicated that irrigation to 100 % of evapotranspiration was the optimum regime for maximizing potato production. Mubarak et al. (2018) irrigated in their trials when soil moisture in the active root depth was within the range of 75-80 % of field capacity as determined by the neutron probe technique. Drip irrigation has many advantages, there are no effects of unfavourable weather, such as strong wind or high temperature causing rapid soil drying, and this technique enables common application with fertilizers close to the plants (Zhou et al., 2015).

MATERIALS AND METHODS

The trial was established between the years 2016 and 2018 on the fields of Potato Research Station belonging to Potato Research Institute Havlíčkův Brod located at altitude of 465 m. The soil type was cambisol, pseudogley and medium sandy loam. Two potato cultivars (early Monika and medium-early Jolana) were planted at spacing of 750 x 290 mm. Planting dates in 2016, 2017 and 2018 were 26.4., 10.5. and 25.4., respectively. Eight irrigation variants were established in four replications and for each cultivar combined with N fertilization (Tab.1). Trial plot size was 20.9 m^2 (2.25 m x 9.3 m) with 96 plants based on randomized complete block system. For subsurface drip irrigation STREAMLINE 16060 pipes were used, with distance of 500 mm between drippers and performance of 1.05 l ha^{-1} (i. e. with parameters 2.79 l $ha^{-1}m^{-2}$ =2.79 mm h^{-1}). Pipes were buried in the depth of 30-40 mm under the soil surface on the ridge top. Soil moisture for irrigation rate calculation was separately measured for each irrigation variant using VIRRIB sensor. Specific moisture, with that irrigation was automatically started, is given in Tab. 1. Irrigation rate was uniform – 10 mm. The number of irrigation rates and total water amount is given in Tab. 2. Nitrogen fertigation during the growing season was done using YaraLiva Calcinit (15.5% calcium saltpeter) in four irrigation rates (15 kg ha^{-1} each) from the stage of flower-bud initiation to full flowering (phenological stage 55–80 based on international BBCH scale). Fertigation was done at potato crop elongation (BBCH 80). For fertigation Dosatron D3 was used, mixing the fertilizer solution with irrigation water based on the set concentration. In the non-irrigated variant with fertilization during the growing season N rate was broadcasted in the same fertilizer at once on the soil surface.

Harvest in 2016 was performed on October 21st, in 2017 on October 18th and in 2018 on October 5th.

Table 1 Variants of the field trial

Variant	Irrigation under volumetric soil moisture	N fertilization prior to planting (kg ha^{-1})	N fertigation (kg ha^{-1})
1	No irrigation	120	-
2	15%	120	-
3	20%	120	-
4	25%	120	-
5	No irrigation	60	60
6	15%	60	60
7	20%	60	60
8	25%	60	60

Table 2 Number of irrigation rates and total applied water amount in the years 2016 - 2018

Variant	2016 year		2017 year		2018 year	
	Irrigation rates	Total water amount (mm)	Irrigation rates	Total water amount (mm)	Irrigation rates	Total water amount (mm)
1	0	0	0	0	0	0
2	6	55	10	96	8	74
3	10	99	14	136	14	130
4	17	163	24	243	21	184
5	0	0	0	0	0	0
6	6	55	10	96	8	74
7	10	99	14	136	14	130
8	17	163	24	243	21	184

Climatic conditions are given in Tab. 3. All trial years could be characterized as extremely hot, with significantly higher temperature compared to the long-term mean during the growing season. The year 2018 was the driest one and low precipitation was also recorded in the other years, what resulted to drought stress in non-irrigated crops.

Statistical assessment was done using variance analysis in STATISTICA CZ programme version 10.0 MR1. Distinctive identification of water stress of tested cultivars was monitored in field conditions on small-scale experimental plots by unmanned aircraft (Phantom 4 Pro, Matrice 600 Pro). The Wiris 2nd gen thermal camera together with the RGB camera attached to the UAV was used for image recording. Flights were operated using the DJI GS Pro software, flown with 80m AGL parameters with 80% overlay of x and y shots at a constant speed of 3 m s^{-1} in scanning time between 12-15pm UTC. The images were orthorectified based on the GPS coordinates of the OneButton program. For further processing and evaluation, the ThermoFormat and CorePlayer and ImageJ analytics tools were used. ImageJ was used for image analysis. From the obtained data, specific vegetation index ExG (2*g-r-b) indicating the condition of the plants along with canopy temperature was calculated. A vegetation index is an indicator that describes the greenness and health of each pixel of the image (Bunting and Lucas, 2006).

Table 3 Weather conditions during the growing season (2016 - 2018)

Indicator	April			May			June			July			August			September		
	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
Monthly temperature normal (°C)	7.3			11.6			15.2			16.5			16.4			12.3		
Monthly mean temperature (°C)	7.8	6.9	7.3	13.6	14.0	16.3	17.4	18.4	17.4	18.9	18.7	19.7	17.4	19.3	21.1	16.2	11.2	14.6
Monthly precipitation normal (mm)	42.5			76.3			91.4			80.9			86.6			48.2		
Monthly precipitation amount (mm)	24.2	116.1	21.0	45.8	81.4	58.0	68.8	102.2	11.7	112.2	103.5	30.8	27.8	17.4	29.7	10.9	63.4	84.2

RESULTS AND DISCUSSION

Figures 1-3 show that early cultivar Monika responded with a significant yield increase to higher irrigation rates. In 2016 and 2017 significant differences for variants without fertigation were in principal recorded between non-irrigation variant (1) and variants with higher irrigation rates (3 and 4), although trends of yield increase with higher irrigation rates were clearly visible in this cultivar. In 2016 potato yield (Fig. 1) under conditions of full N rate applied prior to planting (120 kg $ha^{-1)}$ was 18.9 % increased between non-irrigation (var. 1) and the lowest irrigation level (var. 2). In variant 3 a significant difference was 32.3 % and 49.3 % with the highest irrigation level (var. 4). At the same time, it was found that split N rate (60 kg ha^{-1} prior to planting and 60 kg ha^{-1} in fertigation) had no impact on potato yield.

In 2017 (Fig 2) a significant yield increase was 57.3 % for medium (var. 3) and 59.3 % for high irrigation rate (var. 4) compared to the non-irrigated variant.

In 2018 (Fig. 3) really transparent results were obtained for responses of Monika to increasing irrigation water rates confirmed with statistically significant differences between all variants 1-4 (with full N rate prior to planting). Between non-irrigation (var. 1) and the lowest irrigation level (var. 2) a significant yield increase by 42.3 % was found, by 58.7 % compared to variant with medium irrigation level (3) and by 73.3 % compared to variant with the highest water rate (4). No significant differences were found between variants with full N rate prior to planting and split rate with 50 % N supplied in irrigation water during the growing season; determined trends show that fertigation using fertilizer (nitrate N) has even a negative effect on potato yields.

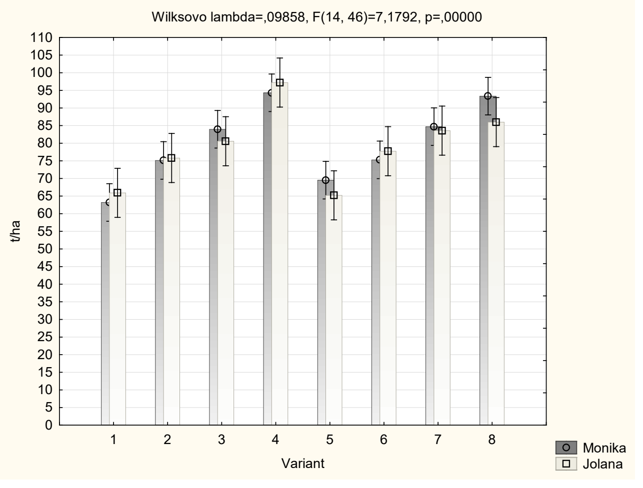

Figure 1 The effect of variants on potato yield in 2016

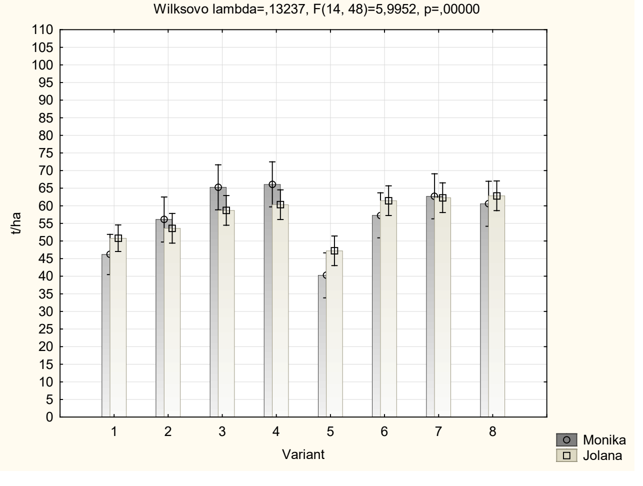

Figure 2 The effect of variants on potato yield in 2017

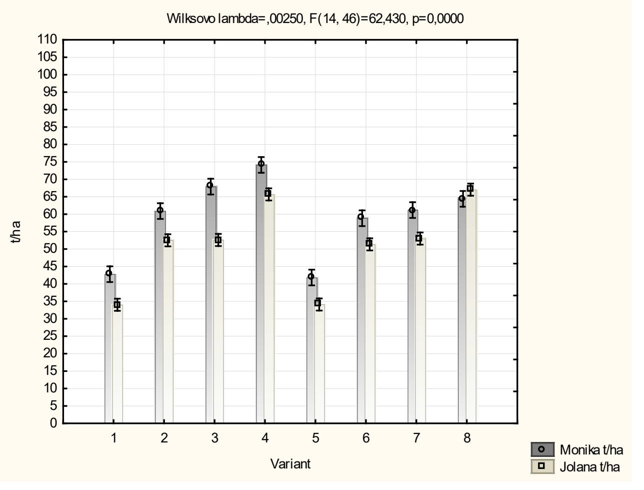

Figure 3 The effect of variants on potato yield in 2018

For the medium-early cultivar Jolana similar trends were recorded as for Monika; however with lower significance of differences. Potato yield in 2016 was increased compared to non-irrigated variant 1 by 15.0 (2), 22.3 (3) and 47.5 % (4) between mentioned variants and a significant difference was only determined in the variant of the highest irrigation level (4). In 2017 Jolana did not respond so intensively as Monika; a yield increase was only 11.9 (2), 22.5 (3) and 25.9 % compared to non-irrigated variant 1. In 2018 significant differences were also not obtained between all variants similarly as for Monika, but only between non-irrigation (1) and lowest irrigation (2), by 54.3 % and by 93.1 % compared to the variant with the highest irrigation (4). Between variants with full N rate applied prior to planting and split rate with 50 % in irrigation water during the growing season the same statement is true as for Monika.

Statistical differences between cultivars were only found in 2018 detrimental to Jolana, although the tendencies from previous years indicated this trend.

The response of cultivars to drip irrigation was studied by several authors, e.g. Mubarak et al. (2018) concluded that results of trials with two spring potato varieties (Spunta and Marfona) and four irrigation methods (drip irrigation with two modes of dripper spacing/dripper flow; 30 cm and 4 l ha^{-1} and 60 cm at 8 l h^{-1}, sprinkle irrigation and furrow irrigation) did not show any differences between both varieties. Moreover, no difference in marketable yield, total dry matter, and harvest index were found between irrigation methods (these authors applied irrigation water amount based on the same principles of soil moisture as we used in our trials). On contrary, Samaee et al. (2017), who studied 11 genotypes, could categorize varieties in 4 groups according to the estimated drought tolerance and sensitivity indices, based on the significant results in the field of the irrigation effect on potato yields.

It can be concluded that irrigations alone were highly positive as regard as potato yields. This finding coincides with the results by Wang et al. (2017), in whose trials compared with the control (natural growth) drip irrigation increased potato yield by 7 644 kg hm^{-2}, the increasing rate and commodity rate were respectively 12.75 and 98.4 %. Rolbiecki et al. (2015) also found that drip irrigation significantly increased the marketable potato yield from

17.4 to 36.3 t ha^{-1} (109 %), the weight of a tuber and the number of tubers per plant. Nitrogen fertilization through drip system increased potato yield by 5.9 t ha^{-1} (25 %).

Variants with split N application did not differ from potato yield level of variants with full N rate application prior to planting. The same results were obtained by many authors. Zhou et al. (2015) followed plant needs, when based on the model of nutrient state in drip irrigation they always supplied 20 kg N ha^{-1}. In total, the authors supplied 100 kg N ha^{-1} compared to usual rate of 120 kg ha^{-1}; however, yield results were not significant. The same authors later concluded the same results again (Zhou et al., 2018). Contrary to that, Jolaini and Karimi (2017) reported from the results of the combined analysis a significant effect of N and interaction of N and irrigation frequency on yield and water use efficiency. Similarly, Ghiyal et al. (2017) found that when fertigation applied on every 3rd day with the application of 120 kg N ha^{-1} was found significantly superior to all other tested combinations (the experiment comprising of four N levels, i.e. 90, 120, 150 a 180 N kg ha^{-1} and three fertigation frequencies, i.e. every 3rd day, every 6th day and every 9th day). Probably it would be more effective to split N rate into all fertigation rates in lower amounts than 4 x 15 kg N ha^{-1}. It is also confirmed by Lu and Liu (2017). An explanation of various effect of fertigation in irrigation water could also be in use of various N forms. Gao et al. (2018) studied 10 combinations of sources, placement and timing, as well as fertigation, on irrigated processing potato (cv. Russet Burbank) grown for a total of five site-years in the Province of Manitoba, Canada. Average marketable tuber yields for fertilizer treatments were significantly greater than those for the unfertilized control. Split application of urea at planting and hilling, and urea at planting with fertigation occasionally increased marketable tuber yields on sites of coarse textured soils. Use of polymer-coated urea or stabilized urea with inhibitors did not affect yield, quality or N use of potato. In our trials we used nitrate N that apparently did not have such a positive effect. In our trials N was only applied in irrigation water; however, recently results have also been published regarding application of phosphorus and potassium. As referred by Eissa et al. (2018) the injection of urea phosphate with irrigation water every day caused a 22% increase in the marketable potato yield compared to the other variants (P forms and application frequency). Zeid et al. (2017) used four sources of potassium with three rates, applied through irrigation water. As regards as sources and rates of potassium fertilizers, results showed significant differences among the sources and rates of potassium fertilizers on total yield, tuber weight, tuber diameter, specific gravity and starch content of tuber. The data revealed that K_2SO_4 was the best among other sources.

It is an example from the whole experiment, how the single plots are evaluated from UAV platform equipped with different sensors (1” RGB sensor of DJI phantom 4 pro, Wiris 2nd gen thermal 640 x 512px, 7.5 – 13.5 μm camera flown with DJI matrices 600 pro attached on Ronin MX) of different spectral range and sensitivity. For example, the plots of two cultivars, irrigated and non-irrigated was used (Fig 4). The ExG colour index was used to evaluate current state of the biomass. Monika had a higher biomass compared to Jolana on non-irrigated plots while Monika had higher biomass than Jolana on irrigated plots (Fig. 5). They maintain the same relationship even during irrigation treatment. Compared to non-irrigated plots, they have a higher proportion of biomass in irrigation. The ExG colour index has often been used to evaluate plant biomass (Box et al., 1989).

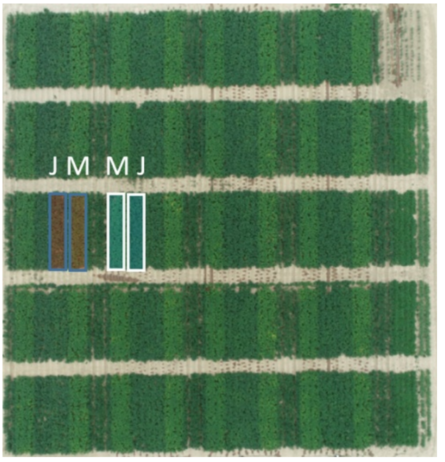

Figure 4 General view on the experimental field showing position of evaluated plots (red – nonirrigated, blue – irrigated; J for cultivar Jolana, M for cultivar Monika); 80m above ground level

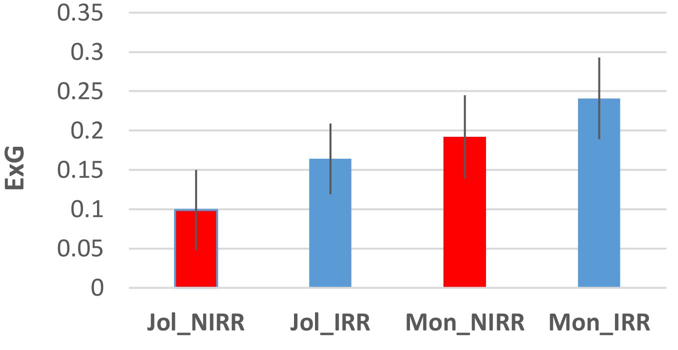

Figure 5 Mean value of ExG colour index (2*g-r-b) of experimental plots showed in Fig 6

There is the same view of the all-experimental field from infrared camera expressed in false colour representing a different canopy temperature (Fig. 6) (Jackson et al., 1981; Rinza et al., 2018). Obviously, non-irrigated plots have higher temperature than irrigated ones. In detail, the distribution of temperature frequencies is almost the same for both cultivars without irrigation (Fig. 7). The temperatures distribution of Jolana was narower in comparison with wider temperature distribution of frequencies of Monika. The difference in the mean temperatures of Jolana and Monika was 1.8 °C and 1.1 °C. The difference in the minimum temperatures of Jolana and Monika was 0.8 °C and 1.2 °C.

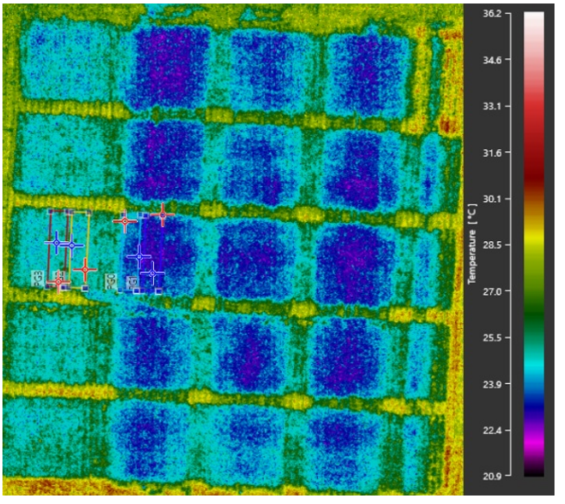

Figure 6 Thermogram of selected experimental plots (see Fig 1) in false colour from 20.9 to 36.2 °C; red cross – maximum temperature, blue cross – minimum temparature of evaluated plots; PG0 – Monika irrigated, PG1 - Jolana irrigated, PG2 - Monika nonirrigated, PG3 - Jolana nonirrigated

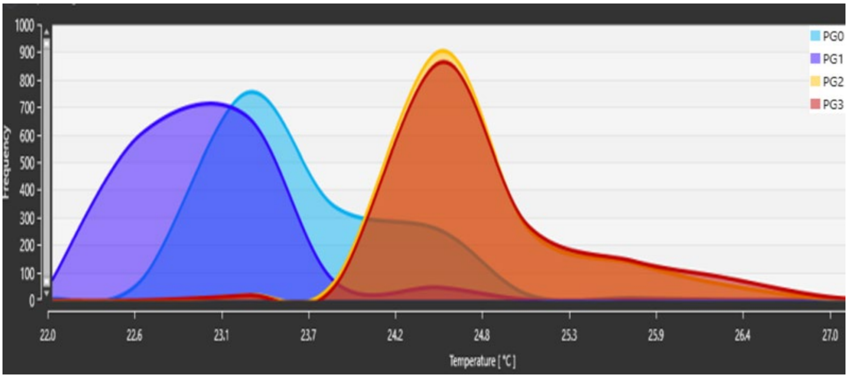

Figure 7 Distribution of temperature frequencies of experimental plots (for details see Fig 4 and 6)

The results showed that data obtained from the colour image as an Excess Green Vegetation Index (ExG index) are important for the machine vision of plant canopies. Infrared images can be used to assess the physiological state of potato plant, and after further studies they can be used as real data for irrigation management.

CONCLUSIONS

- A positive effect of drip irrigation on potato yield of two studied cultivars was evidenced; significantly the highest yields were recorded for the highest irrigation level;
- any effect of split N rate was not found, when 50 % N was applied in four doses combined with drip irrigation;
- the cultivar effect was manifested in significant differences only in 2018;
- the year effect was significant; however only between the year 2016 and the other years;
- infrared images can be used to assess the physiological state of potato plant, and after further studies they can be used as real data for irrigation management.

ACKNOWLEDGEMENT

The contribution was compiled under financial support of the Ministry of Agriculture of the Czech Republic in the project NAZV QJ1610020

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

AUTONOMOUS POWERING OF AN ORCHARD IRRIGATION SYSTEM AND FRUIT STORAGE

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ABSTRACT

This study presents a conceptual scheme of an autonomous solar energy system, which is used to power the irrigation system in orchards, combined with a fruit storage. It is accepted that the orchards/store have no direct access to irrigation water, nor electrical energy, therefore the photovoltaic system should work in an autonomous mode. During the months April to September, the energy of the photovoltaic system is used to power pumps, which use underground water for irrigation and store it in a reservoir. During October to January the generated solar energy is used to maintain the temperature-humidity requirements of the fruit storage. The analysis also includes the irrigation and storing requirements of common Bulgarian fruits (apples and pears), and their compatibility with the climate in Ruse during the storing months.

Keywords: *irrigation system, fruit storage, orchards, PV energy, refrigeration.*

INTRODUCTION

The use of renewable energy sources in the agricultural sector, and especially photovoltaic (PV) ones, is a topic often investigated. Different studies presented the use of solar energy for drying of fruits and vegetables. Stiling et al. (2012) presented the use of mobile concentrating solar panels in a fruit drier. Similarly, Eltawil et al. (2018) used PV energy to enhance the dryer performance with a DC fan.

Other studies have investigated the use of PV energy in pump irrigation systems. Chen et al. (2013) concluded that alternative energy sources are unsuitable for irrigation of cotton crops. Powell et al. (2016a) and Powell et al. (2016b) stated that unless energy generation closely matches the timings of irrigation energy demands, it is unlikely the investment will pay off.

In another study was investigated the use of PV energy for powering a DC motor vapor compression refrigerator with thermal storage (El-Bahloul et al., 2015). The results were satisfactory and showed that such system could be used in hot arid areas for refrigeration of post-harvest crops. In another study, IDCOL (2017) presented a solar hybrid cold storage, developed for the climate of Bangladesh. The test scenarios included different temperatures regimes (2° C to 10° C) and the relative humidity was set for 90% with a 5% hysteresis.

The available studies show that if a PV energy source is to be efficiently used in the agricultural sector, the daily solar energy should closely match the load profile. This would be hard to achieve unless a combination of different loads is chosen, which can match the PV energy profile.

There are no known studies, which investigate the applicability of PV energy in irrigation systems for the region of Ruse, Bulgaria. There are also no known studies, which investigate the combination irrigation system – fruit storage. The goal of this study is to analyse and investigate the possibilities to use PV sources to power a combined irrigation system - fruit storage load for the climate of Ruse, Bulgaria. During the spring and summer months, the solar energy will power the irrigation system of an orchards and during the autumn and winter months, it will be used to provide the temperature-humidity regime in a fruit storage system.

MATERIALS AND METHODS

Irrigation requirements of fruit crops

The irrigation requirements of common Bulgarian fruit crops, as well as their response to insufficient water, have been covered in several articles. Kireva and Petrova-Branicheva (2018) reported an irrigation schedule (number of irrigations) for “Florina” apples as follows: April – 0 or 1; May – 2; June – 3; July – 5; August – 5; September – 2. The irrigation norm for 100% irrigation has been reported as 22 mm. Similar results were provided for “Vilyamova maslovka” pears, with an average of 16 irrigation, 24 mm each. The results also showed that a 20% reduction in the irrigation norm leads to 7% reduction in the apples yield and 25% in the fruits yield. Similarly, a 40% reduction in the irrigation norm leads to 13% and 39% reduction of the apples and fruits yield, respectively.

In an earlier study, Kireva et al. (2017a) reported similar irrigation norms for “Florina” apples. The results showed that a 100% irrigation norm leads to 64% increase in the apples yield, compared to no irrigation. If the irrigation norm is fulfilled at 80% and 60%, the apples yield is increased with 54% and 42%, respectively.

In another study, Kireva et al. (2017b) reported the apples yield increase with 61%, 50% and 34%, for irrigation norms 100%, 80% and 60%, respectively, compared to no irrigation.

The available information about common fruit cultures in Bulgaria, which are of interest to the study, has been summarize in Table 1. As can be seen, the fruits will be harvested in the end of September, therefore their post-harvest processing and storing should begin afterwards.

Table 1 Common drip irrigation norms for different orchard crops.

Orchard crop	Irrigation months	Number of irrigations	Irrigation norm, mm	Total, mm
“Florina apples (Kireva and Petrova-Branicheva, 2018)	April - September	17	22	374
“Vilyamova maslovka” pears (Kireva and Petrova-Branicheva, 2018)	April - September	16	24	384
“Florina” apples (Kireva et al., 2017a)	May - September	17	19	323
“Florina apples” (Kireva et al., 2017b)	May - September	17	19	323

The climate of the region

The climate of the region of Ruse, Bulgaria, is characterized by relatively high temperatures during the summer, getting up to 40 °C and relatively low temperatures during the winter, sometimes getting down to -20 °C. The average day, night and daily temperatures for each month of the year are presented in Figure 1 (HikersBay website). The months of interest to this study are October, November, December and January, when the harvested fruits will be stored. In October, the average day and night temperatures are 18 °C and 6.5 °C, respectively. In November they get down to 10 °C and 1.9 °C, respectively, while in December and January they get slightly above and below 0 °C. This information will be further analysed later in this study.

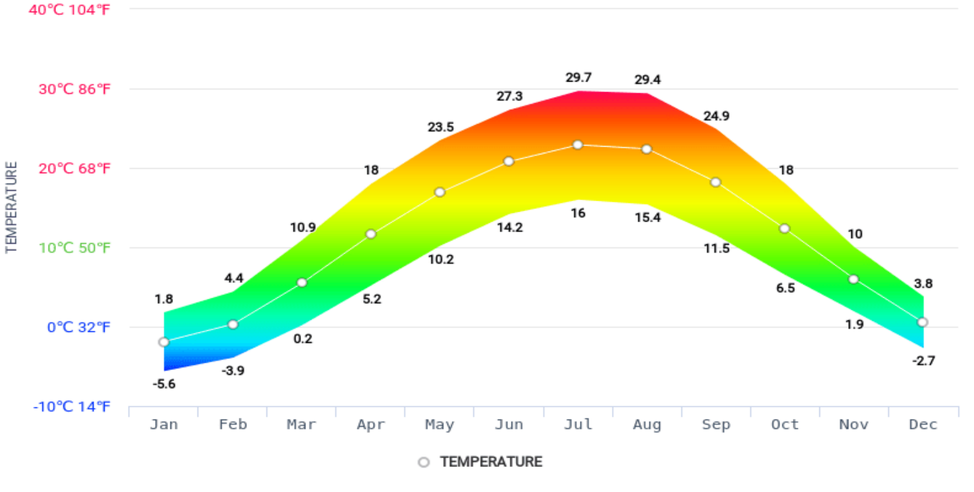

Figure 1 The average day, night and daily temperature in Ruse for each month of the year (HikersBay website).

The solar radiation, available in the region, is assessed using experimental data from the Zita Ruse PV power plant, owned by Zita Ruse Karbochim Ltd., which is freely available on the SunnyPortal website. The Zita power plant has 117 kWp installed power and is storing data since 2008. The average specific PV system yield in kWh kWp^{-1} for each month of the year, estimated with data from 2008 to 2018, is presented in Figure 2. The most solar energy (140-160 kWh kWp^{-1}) is available in May, June, July and August. During April and September, there is also relatively high yield, reaching 120 kWh kWp^{-1} on average. In the months March and October, the yield is around 100 kWh kWp^{-1}, while in the winter months it falls significantly down to (40-60) kWh kWp^{-1}.

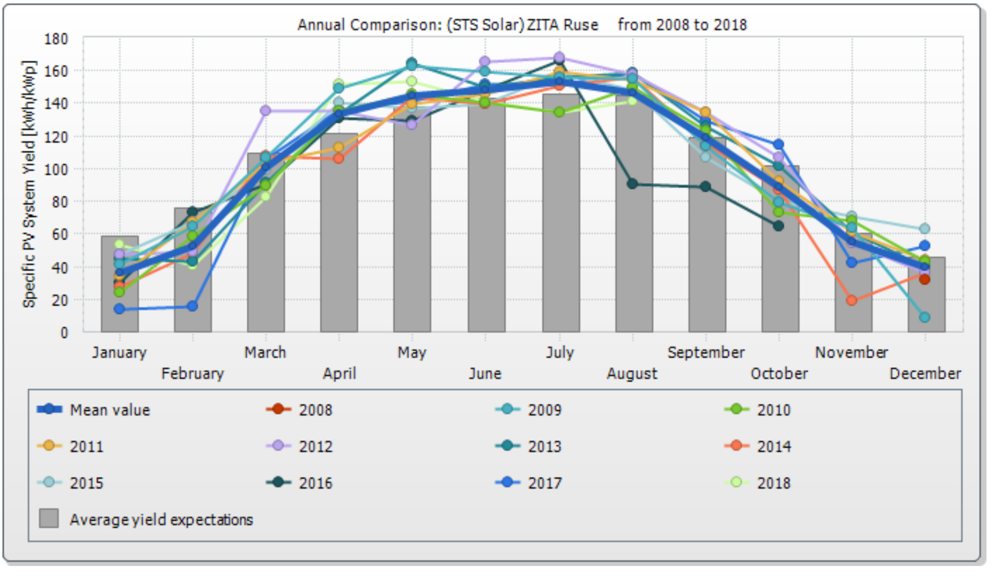

Figure 2 Specific PV system yield of the Zita Ruse power plant (SunnyPortal website).

Storing requirements of fruit crops

There are five primary environmental variables, which influence the storage duration of crops – temperature, relative humidity, and the concentration of O_2, CO_2, and ethylene (Saltveit, 2003). The concentration of the different gasses is managed by providing a certain airflow in the storage, therefore the main two parameters which should be maintained are temperature and relative humidity. The optimal temperature for apples is considered 0-4 °C and for pears - 0 °C, and the relative humidity should be kept in the range (90-95) % (Katic et al., 2010).

The influence of storage temperatures has been thoroughly investigated in numerous studies. Salomao et al. (2009) investigated the influence of two storage temperatures on several types of apples: “McIntosh”, “Gala”, “Fuji” and “Golden Supreme”. At 11 ºC all apples were in good condition after 21 to 93 days of storage and no patulin was detected. On the other hand, when stored at 20.5 ºC, for the same incubation time the concentration of patulin was six times the maximum allowed.

Khorshidi et al. (2010) investigated the influence of storage temperature on fruits pollution, diameter, weight, volume, firmness and other characteristics. The parameters were investigated at 0 ºC, 5 ºC and 12 ºC temperature and 80% relative humidity. The results showed that after one month of storing the parameters were getting worse with the increase of temperature. Similarly, Itai et al. (2015) investigated the response of “Gold Nijisseiki” pears to different storing temperatures: 0 ºC, 4 ºC, 10 ºC, 15 ºC and 22 ºC. The results showed that after 30 days of storing the fruits firmness suffered seriously only at 22 ºC, although other parameters of the pears showed similar results at 15 ºC and 22 ºC.

Other studies investigated the impact and management of relative humidity. Tu et al. (2000) investigated the influence of relative humidity on different parameters of stored apples at 20 ºC. After 30 days of storage, the weight loss at 95% relative humidity was approximately 1%, while at 65% it was 4 %. In another study, Islam et al. (2013) demonstrated an appropriate watering regime could maintain appropriate storing parameters inside storage.

The available information clearly indicates that if appropriate relative humidity is maintained, the common fruits in Bulgaria, apples and pears, have a certain tolerance to the temperature, from 0 to 12 ºC. Under such conditions, the fruits could be stored for a couple of months without a significant loss of quality.

Storage systems

There are a couple of cooling methods used for fruit storing (Mitchell and Crisosto, 1995). The Room cooling method provides cold air over stacks of fruit of containers, therefore removing heat from them. With this method the air flow should be at least (60-120) m min^{-1}. Similar methods are the Forced air cooling and the Forced air tunnel cooling, which provide higher velocity for faster cooling. Similar approaches are the Cold wall forced-air cooling and the Serpentine forced-air cooling methods.

Another approach is the hydrocooling, whose idea is to get the fruits in contact with cold water (Mitchell and Crisosto, 1995). This method provides the fastest cooling and is usually used in packing lines.

The cooling itself can be implemented using different technologies, such as refrigeration, air conditioning, evaporative cooling and thermal cooling. The air conditioning approach is generally not used for long-term storage because of the expensive VAC technologies (Sultan and Miyazaki, 2017). This technology would also be expensive to implement in an autonomous PV system because of the unsuitable load profile. The evaporative cooling approach provides cooling by forcing the air through a wet tunnel, which effectively reduces its temperature and increases its relative humidity. Sultan et al. (2018) and Chinenye et al. (2013) investigated the applicability of this approach for different climates and showed that with high environmental temperatures, this method could provide a reduction of temperature with more than 10 °C. However, the evaporative cooling method is not very efficient with lower air temperatures, such as the ones expected in Bulgaria during the autumn and winter months.

A significantly different approach was presented in Katic et al. (2010), where a refrigerator was powered with PV energy. The energy was used in three ways – to create ice, for ventilation and for controlling the air exchange openings. The system also had a battery, which was responsible for the cooling during the night time, yet the experiment was carried out at high environment temperatures.

RESULTS AND DISCUSSION

There is an obvious correspondence between the load profile of the irrigation pumps, which are required during the warm months (April to September), and the available solar energy. Yet, if the PV energy during the cold months of the year remains unused, this would reduce the payback of the investment. In this study we suggest the PV energy, which is available during October, November, December and eventually January, to be used for providing the temperature-humidity requirements of fruit storage.

Such combination is applicable for the climate of Ruse, Bulgaria for several reasons. As can be seen from Figure 1 and Figure 2, during October, the average day temperature is 18 ºC, therefore even though the PV production gets lower; this shouldn't be a significant problem as less energy would be required for refrigeration. During the nights, the average temperature is 6.5 ºC, therefore relatively good storing conditions could be provided even without additional energy (Natural ventilation). This means that in theory the PV refrigeration system could work without a battery bank, which would lower the investment significantly.

In November, the average day temperature is 10 ºC, therefore the low amounts of available PV energy should be able to provide the necessary refrigeration. The average night temperature (1.9 ºC) is inside the optimal storing range of Apples and very close to that of Pears, thus natural ventilation could again be sufficient. Measures should be taken to ensure the required relative humidity though.

In December and January, the average day temperature is inside the optimal range for apples, yet during the nights a heating might be required. When solar energy is available it could be used to provide the necessary heating, or alternatively a backup diesel generator could be used.

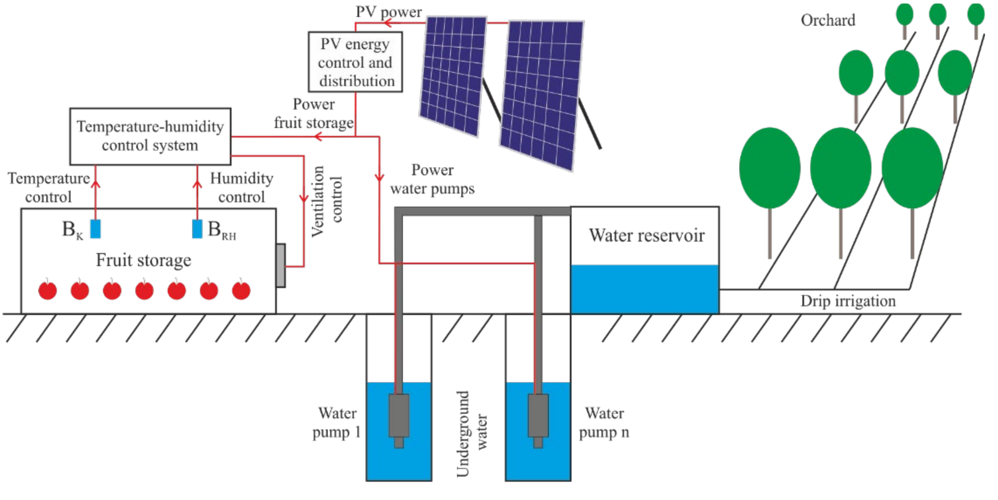

Figure 3 Conceptual scheme of the PV powered combination of orchard irrigation system with fruit storage.

The use of the fruit storage could be changed annually, depending on the weather forecast. In case of warmer years, the apples could be stored in December and January in order to obtain higher prices. On the other hand, in cold years, when the winter temperatures get way below zero, the owner might either use backup diesel generator to provide the required heating or consider selling the fruits earlier.

The conceptual scheme of the suggested system is presented in Figure 3. The PV energy control and distribution system will be responsible for determining the number of pumps that can be powered and switching them on/off or for powering the Temperature-humidity control system (refrigeration system), depending on the month. The refrigeration system will control the temperature and humidity inside the fruit storage and will take measures when PV energy is available (day time).

The exact refrigeration technology, which should be used in the fruit storage, shall not be specified in this study, as it requires further investigation. Nevertheless, the performed analysis suggests that there are several options, considering the climate conditions in Ruse, Bulgaria during the months November-January.

The suggested combination of irrigation system with fruit storage, powered by an autonomous PV system, has a number of advantages:

- No electrical energy is bought;
- The price for irrigation water is lower;
- The orchard and fruit storage could be at a site without access to electricity/water, therefore the land price would be lower;
- No taxes for connecting the site/facility to the electrical/irrigation network are payed;
- The produced fruits could be stored in the storage, which allows the owner to sell part of the yield outside the season at a higher price.

There are also some negative aspects to such approach though:

- A greater initial investment;
- The solar energy generation is a random process, therefore there are situations in which the supplied amount of irrigation water will not be enough. Furthermore, the temperature-humidity requirements of the fruit store might not be always met for the same reason. The missing energy could be compensated with backup diesel generators, but this means additional investment/expense/maintenance costs.

CONCLUSIONS

In this study is performed an analysis of the combination of orchard irrigation system with fruit storage, powered by an autonomous PV generator. The goal is to assess the applicability of this combination for the climate of Ruse, Bulgaria. The PV energy is used to power the irrigation system during the months April to September. For the months October to January, the available PV energy is used to provide the necessary temperature-humidity requirements of the fruit storage.

In this study were also analysed the requirements of the common Bulgarian fruits (apples and pear) in terms of irrigation and storing parameters. The results showed that, considering the environment temperatures during the “storing” season, low amounts of energy will be required to maintain the microclimate in the fruit store. During the days, the solar energy will be used to provide the parameters, while for the night there are two options: use natural ventilation or backup diesel generator. However, it is important to note that the climate conditions in Ruse during the autumn and winter months are very close to the optimal storing requirements of apples and pears.

Based on the performed analysis, a conceptual scheme of an autonomous PV powered system has been presented, which will be responsible for powering the irrigation pumps and for the providing the refrigeration in the fruit storage. More studies are required in order to obtain the optimal type of fruit storing technology, for the climate of Ruse, Bulgaria, during the investigated months.

ACKNOWLEDGMENTS

The study was supported by contract of University of Ruse Angel Kanchev, № BG05M2OP001-2.009-0011-C01, "Support for the development of human resources for research and innovation at the University of Ruse Angel Kanchev". The project is funded with support from the Operational Program "Science and Education for Smart Growth 2014 - 2020" financed by the European Social Fund of the European Union.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

SOLAR ENERGY POTENTIAL TO POWER THE IRRIGATION OF ORCHARDS IN BULGARIA

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ABSTRACT

In the present study the solar energy potential in the region of Ruse, Bulgaria, is investigated, in order to be used for powering an irrigation system in orchards. The climate conditions in Ruse, the water requirements of common Bulgarian fruit crops as well as the different types of irrigation pumps are analyzed. Based on the analysis is proposed a concept for irrigation system, powered by an energy from autonomous photovoltaic sources. Different number of pumps is turned on, depending on the available power, and the underground water is pumped into a reservoir. The load profile of the water pumps is compared with that of solar energy and if their power is significantly lower than the peak power of the photovoltaic generator, there is a very good match. The peak of solar energy is in the summer months, which also corresponds with the requirements for irrigation of the inspected fruit crops. The stored water is used by a drip irrigation system when additional water is required for the orchards.

Keywords: *PV energy, irrigation, orchards, load profile, pumps*

INTRODUCTION

Providing irrigation water for crop growth is crucial for resource-use efficiency. Water is provided by either rainfall or irrigation, but in both cases the amount of water supplied is rarely exactly the same as that required (Cammarano et al., 2012). The climate conditions in Bulgaria are characterized with dry and hot summer, therefore irrigation is a mandatory agro technical procedure, which will ensure better growth and fertility of the fruits in orchards (Isperih municipality, 2014).

A design requirement of irrigation farms is to store the excess water in water storages, in order to ensure successful management of the irrigation deficit (Powell and Scott, 2011). Moreover, in case of using solar energy, it can be better utilized by storing water in advance of the demand period, therefore reducing the reliance on potential small daily extraction limits during the irrigation season. Previous studies have investigated the use of photovoltaic (PV) energy in irrigation systems. Chen et al. (2013) studies the applicability of renewable energy sources for irrigation of cotton crops. The results were unsatisfactory. Later on, Powell et al. (2016a) and Powell et al. (2016b) stated that there should be a very good match between the profiles of power generation and irrigation, to have a successful investment. However, there are no known studies for the climate of Bulgaria, which investigate the applicability of PV energy for powering the irrigation system in orchards.

Orchards are often located in remote areas, without direct access to water and electrical energy. Numerous studies have reported that providing irrigation to fruit crops could increase the yield with up to 64% for apples (Kireva et al. 2017a, Kireva et al. 2017b), while for pears the increase is significantly higher (Kireva and Petrova-Branicheva, 2018).

The goal of this study is to analyze the possibilities to power the irrigation systems of orchards with PV energy in the region of Ruse, Bulgaria.

MATERIALS AND METHODS

Climate and solar energy potential in the region of Ruse

The climate in the region of Ruse, Bulgaria is characterized with hot summers and cold winters, with the highest average temperatures being in July and August (Figure 1). The rainfalls have an average peak in the end of May and the beginning of June, reaching on average up to 70 mm and 85 mm respectively (Figure 1) (HikersBay website).

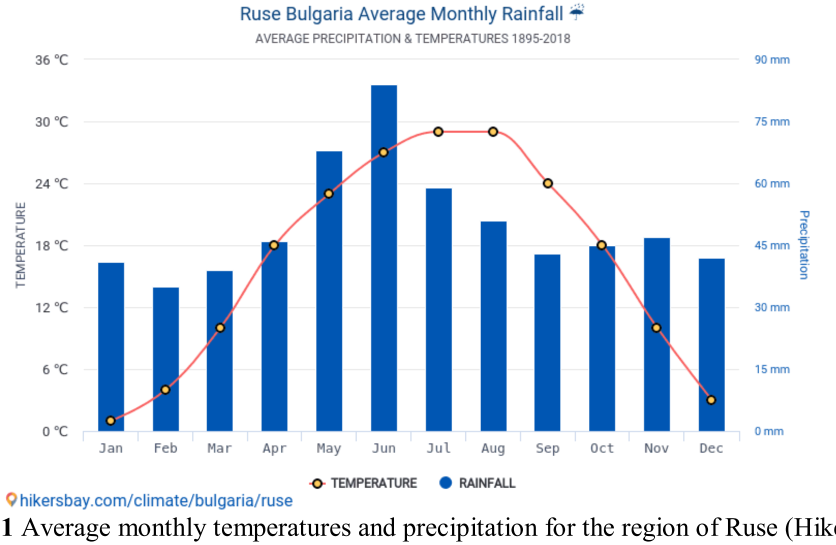

Figure 1 Average monthly temperatures and precipitation for the region of Ruse (HikersBay website).

The region of Ruse is also characterized with the lowest cloudiness during July and August, therefore the PV generated solar energy has a peak in these months. In Figure 2 is shown the cumulative monthly generated photovoltaic energy for each month of the year, provided from the Zita Ruse PV power plant, which is characterized with 117 kWp installed PV power. The used information is freely available from the Sunny portal website.

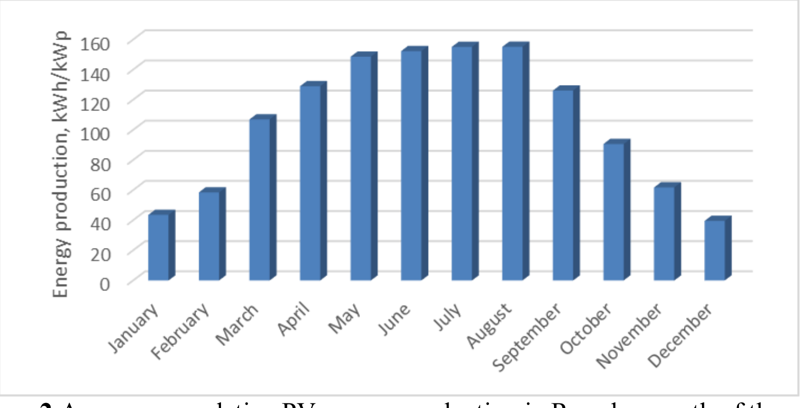

Figure 2 Average cumulative PV energy production in Ruse by month of the year.

From Figure 2 can be seen that the highest amount of energy is available in the months May, June, July and August (more than 140 kWh per 1 kWp installed power), followed by April and September with 120 kWh kWp^{-1}.

Water requirements of fruit crops

Multiple studies have investigated the fruit trees irrigation requirements in Bulgaria. In Water and Rural Institute – Sofia (2012) is stated that irrigation of orchards should be done when the soil humidity is below (70-75)% of a certain level. In the summer months is suggested irrigation each 12-15 days, starting from May until September. For apples and pears is also suggested an irrigation 7-10 years before the harvesting. An average of 6-7 irrigations are suggested for apples, pears and quince for the climate of Bulgaria, 90-100 l/m^2 each (for 4 years trees) (Water and Rural Institute – Sofia, 2012).

Kireva and Petrova-Branicheva (2018) suggested 17 number of irrigations for apples, 22 mm each, for the period from April to September. For pears were used 16 irrigations with 24 mm norm. The study also showed that a 20% (40%) reduction of the irrigation norm reduces the yield with 25% (39%) for pears and 7% (13%) for apples.

Kireva et al. (2017a) used 17 drip irrigations, 22 mm each, for the period from May to September. This study also reported that a reduction of the irrigation norm leads to reduced apple yield. When the irrigation was at 100% the yield was 2087 kg da^{-1}, while for 80% and 60%, the yield was reduced to 1952 kg da^{-1} and 1808 kg da^{-1} respectively. Kireva et al. (2017b) reported similar results.

The above information has been summarized in Table 1. It could also be concluded that some crops, such as apples aren't greatly influenced by reduction of the irrigation norm, while others, such as pears, significantly reduce their yield.

Table 1 Common drip irrigation norms for different orchard crops.

Orchard crop	Irrigation months	Number of irrigations	Irrigation norm, mm	Total, mm
Apples, pears, quince (Water and Rural Institute – Sofia, 2012)	May-September	6-7	90-100	540-700
“Florina apples (Kireva and Petrova-Branicheva, 2018)	April - September	17	22	374
“Vilyamova maslovka” pears (Kireva and Petrova-Branicheva, 2018)	April - September	16	24	384
“Florina” apples (Kireva et al., 2017a)	May - September	17	19	323
“Florina apples” (Kireva et al., 2017b)	May - September	17	19	323

The available information about the irrigation periods clearly shows there is a very good correspondence with the available solar energy in the region.

Irrigation with underground water

Underground waters in the region of Ruse are commonly at depths between 20 and 30 m, therefore the water pumps should be sized for such depths. Furthermore, in this study we are investigating small orchards, therefore the installed PV power will be low. Therefore, in order to optimize the use of the generated PV energy, we are aiming at low-power water pumps.

Considering in this study is investigated an autonomous irrigation system, powered with PV energy, an obvious solution is to use DC water pumps. On the market are available different DC pumps, working at 12 V, 24 V and 48 V (Elektronikabg website). The working voltage should be chosen depending on the required power of one pump, in order to reduce the current, and therefore to reduce the power losses in the wires, as well as the investment losses due to the wire width. For example, in small sized orchards a water pump with the following characteristics could be used: voltage – 48 V, power - 400 W, water flow rate – up to 3 m^3 h^{-1}, water depth – up to 50 m.

A more common solution is to use AC pumps. An example for such pump is the Metabo P 2000 G garden pump: voltage – 230 V, power – 450 W, water flow rate – up to 2 m^3 h^{-1}, water depth – up to 30 m (Metabo website).

It should be noted, that water flow rate is given at 0 m depth, and the increase in the depth of the pump will reduce it. The dependency is individual for each pump and is generally linear. For example, the flow rate dependency on depth for different Metabo water pumps is shown in Figure 3. It can be seen, that at 25 m depth, the flow rate will be reduced from 2 to only 0.5 m^3 h^{-1}.

As can be seen, DC power pumps ensure better ratio between power and flow rate. On the other hand, the price of AC pumps is lower, but they will require an inverter to convert DC to AC voltage. Obviously, the proper way to choose an irrigation pump is a cost-benefit analysis, which is out of the scope of this study.

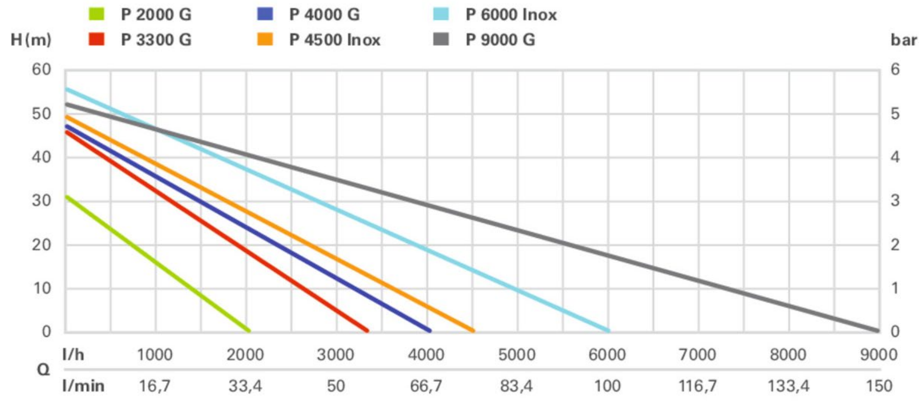

Figure 3 Dependency of the water flow rate from the water depth for different Metabo pumps (Metabo website).

RESULTS AND DISCUSSION

In the present study we suggest the irrigation system, shown in Figure 4. The energy, generated by the PV generators, is used to power multiple irrigation pumps. In case of DC pumps, they are directly powered through the PV controller, which decides which pumps should be powered, and which should remain turned off. All underground water is pumped into a reservoir, which stores the water for later usage. When the orchard requires irrigation, the stored reservoir water is used to provide drip irrigation to the fruit trees.

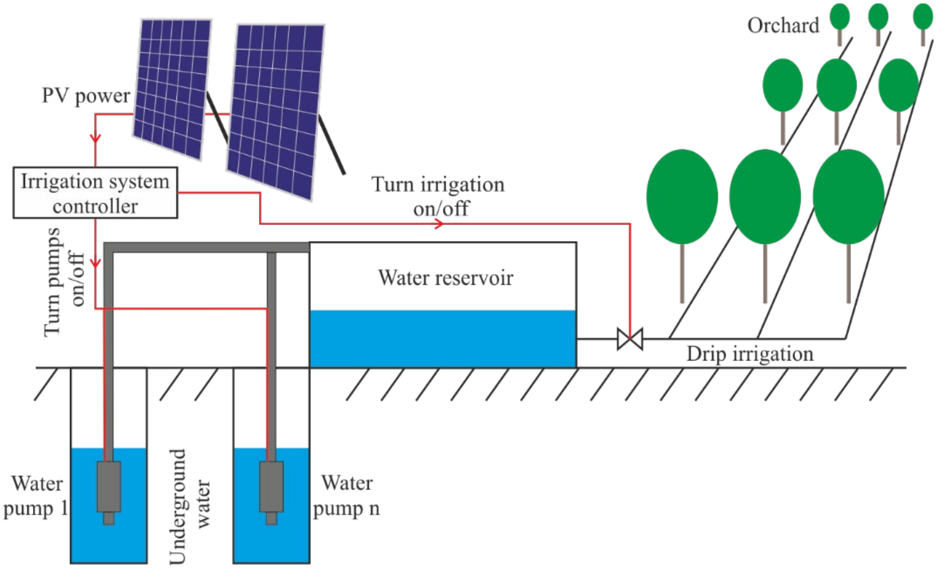

Figure 4 Conceptual scheme of an irrigation system for orchards, powered by an autonomous PV system.

There are two options in terms of powering the pumps with PV energy, depending on the irrigation pumps used. When DC pumps are used, the generated PV energy is directly used to power the water pumps. When higher power pumps are required, the generated DC power is converted to AC one through an inverter (Figure 5).

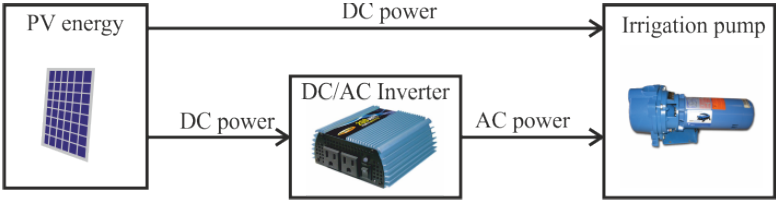

Figure 5 Powering of the irrigation pump

Sample load profiles of the generated PV power and the used power by 200 W water pumps, are shown in Figure 6. The number of used pumps depends entirely on the available PV power and is decided by the Irrigation System Controller. As can be seen from Figure 6, if the generated peak PV power is significantly lower than the power of a single water pump, there could be a very good match between the load profile of the generators and the consumers. Nevertheless, there will always be unused PV energy, as there can be no perfect match.

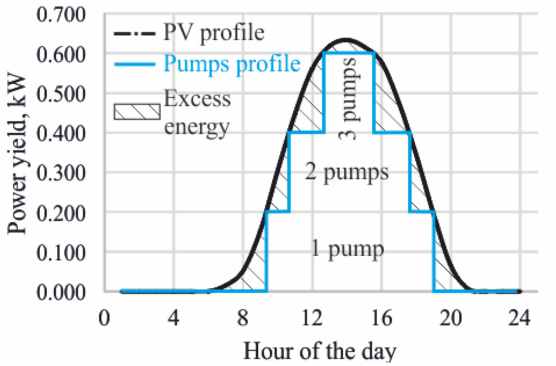

Figure 6 Sample profiles of the generated PV power and the load profile of the pumps

The block-scheme of the algorithm of the irrigation system is presented in Figure 7, where the two subsystems (pumping and irrigation) can be independent of each other. Nevertheless, considering the irrigation control system will require energy to operate, it could as well be part of a common control system. Figure 7a shows the algorithm, responsible for storing the underground water into the reservoir. If PV energy is available (block 1), the number of required water pumps is estimated in block 2, and they are powered in block 3, in order to pump the irrigation water into the reservoir. The control algorithm continues until the system is turned off. Similarly, Figure 7b shows the irrigation algorithm. If irrigation is required, the irrigation valves are opened (block 2) and the reservoir water is used to provide drip irrigation to the orchard (block 3). Upon completion of the irrigation norm, the valve is closed and the system goes into a wait state.

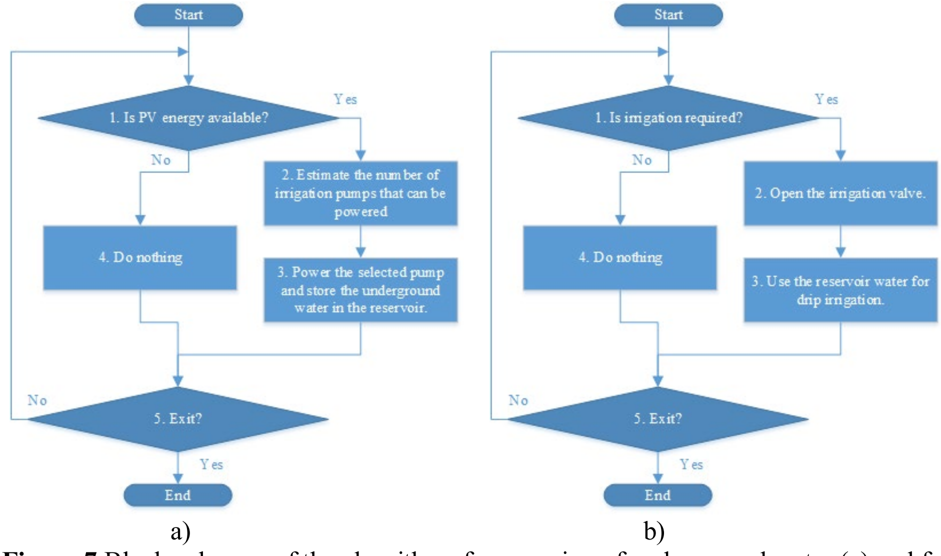

Figure 7 Block-schemes of the algorithms for pumping of underground water (a) and for using the stored water for drip irrigation (b)

Considering the available monthly solar radiation (Figure 2), and the efficiency of the referenced DC and AC pumps from section 2, the maximal amount of water which could be theoretically pumped during the irrigation months with 1 kWp installed PV power, can be observed in Table 2. If for one tree a surface of 5 m^2 is to be irrigated, and an average annual irrigation norm of 350 mm is used, 1 kWp installed PV power could theoretically provide water for more than 900 trees with DC pumps and more than 500 trees with AC pumps. In a real system however, the load profile of pumps will not match exactly the PV generation profile, therefore the actual amounts of pumped water will be lower. A more precise calculation requires a system with specific parameters – installed PV power, number of pumps, their power and efficiency, as well as taking into account the requirements for sizing pump installations.

Table 2 Irrigation water potential

Month of the year	Available energy, kWh kWp^{-1}	Irrigation water at 25 m depth, m^3 kWp^{-1}	
		DC pump: Pn=400 W, Q= 0.75 m^3 h^{-1*}	AC pumps: Pn=450 W, Q= 0.5 m^3 h^{-1}
April	129	241.9	143.3
May	149	279.4	165.6
June	152	285.0	168.9
July	155	290.6	172.2
August	155	290.6	172.2
September	126	236.3	140.0

Total	866	1623.8	962.2

* The reduction in the flow rate of the DC pump is approximate, as this information is not available for the investigated pump.

CONCLUSIONS

In this study was assessed the solar energy potential for the region of Ruse, Bulgaria, in terms of powering an autonomous irrigation system in an orchard. The traditional fruit crops, apple and pear, were investigated and their irrigation norm was analyzed. The results showed that there is a good correspondence between the available solar energy and the irrigation requirements, as the months with the highest energy yield correspond with the irrigation months.

Typical small-scale irrigation pumps were also analyzed in order to assess their applicability for such systems. Even though DC pumps are more expensive, they have better efficiency and don't require a DC to AC converter, therefore seem to be a better choice.

In the study was suggested an autonomous PV powered irrigation system. Its' general scheme, as well as the control algorithm have been also presented. In the study is suggested that the PV system will be used to power numerous pumps and the irrigation control system will decide the number of pumps that should be turned on, depending on the available instantaneous PV power.

A preliminary calculation of the solar potential for the region of Ruse, Bulgaria, shows that 1 kWp installed PV power could be enough to provide irrigation water for a significant number of fruit trees. Further investigations and a cost-benefit analysis are required in order to obtain more specific results.

The study also shows that there is going to be a significant amount of excess energy during the non-irrigation months. Some unused PV energy will also remain during the irrigation months as there can be no perfect match between the pumps and the generator. If the investment payback is to be optimized, the excess energy should be close to zero. Considering the climate of Bulgaria, this should only be possible if it is applied in a different type of process, whose load profiles corresponds with that of the excess energy.

ACKNOWLEDGMENTS

The study was supported by contract of University of Ruse Angel Kanchev, № BG05M2OP001-2.009-0011-C01, "Support for the development of human resources for research and innovation at the University of Ruse Angel Kanchev". The project is funded with support from the Operational Program "Science and Education for Smart Growth 2014 - 2020" financed by the European Social Fund of the European Union.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

UTJECAJ TIPA RASPRŠIVAČA I TEHNIČKIH ČIMBENIKA RASPRŠIVANJA NA DEPOZIT TEKUĆINE

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SAŽETAK

U radu su prikazani rezultati istraživanja utjecaja tehničkih čimbenika raspršivanja na depozit tekućine u krošnji s raspršivačima Agromehanika AGP 200 ENU i Tifone Vento 1500. Istraživanje je provedeno prema ISO normi 22866 (uređaji u zaštiti bilja - metode mjerenja zanesene tekućine u poljskim uvjetima) u nasadu višnje u vlasništvu rasadnika Karolina (Osijek, Osječko-baranjska županija, Hrvatska) tijekom svibnja 2017. godine. Koordinate nasada su 45°31'17,5"N 18°46'39,6"E. Istražen je utjecaj norme raspršivanja (čimbenik A), tip mlaznica (čimbenik B) i brzina zračne struje ventilatora (čimbenik C) na depozit tekućine u krošnji. Sa različitim tretmanima tehničkih čimbenika raspršivanja ostvaren je različit depoziti tekućine u krošnji. Najveća vrijednost depozita u krošnji izmjerena je tretmanom $A_1B_2C_2$ u iznosu od 312 g ha^{-1}, dok je minimalna vrijednost od 274,6 g ha^{-1} ostvarena tretmanom $A_2B_1C_1$ raspršivačem Agromehanika. Maksimalni depozit od 314,20 g ha^{-1} ostvaren je tretmanom $A_1B_2C_2$ dok je minimalna vrijednost od 281,10 g ha^{-1} zabilježena kod tretmana $A_2B_1C_1$ eksploatacijom raspršivača Tifone.

Ključne riječi: *depozit tekućine, norma raspršivanja, brzina zraka, mlaznice, raspršivač*

UVOD

Glavni cilj aplikacije škropiva je ravnomjerna pokrivenost lisne površine s optimalnim depozitom. Loša raspodjela škropiva može smanjiti učinkovitost raspršivanja i povećati opasnost od onečišćenja okoliša (Vercruysse i sur., 1999.). Na pravilnu depoziciju škropiva utječu razni čimbenici kao što su struktura i oblik krošnje, fizikalno-kemijska svojstva pesticida, agroklimatski uvjeti i primijenjena tehnika raspršivanja (Jaeken i sur., 2001.; Nuyttens i sur., 2009.; Catania i sur., 2011.; Rosell i sur., 2012.; Larbi i Salyani 2012.; Dorr i sur., 2013.; Vallet i Tinet, 2013.). Oblik krošnje izravno utječe na depoziciju škropiva, a na taj način i uspješnost raspršivanja. Smanjenjem depozita u srednjem dijelu krošnje povećava se mogućnost ponovne pojave štetočinja (Farooq i Salyani, 2002.; Cross i sur., 2003.; Salyani i sur., 2006.; Zhu i sur., 2006.; Celen i sur., 2009.).

Barčić (1999.) navodi da je za depoziciju kapi od posebnog značaja gibanje stroja i brzina zračne struje. Male kapi u laminarnoj struji slijede strujnice zraka i zaobilaze prepreku, što je važno za pokrivenost površine unutar krošnje.

Velike kapi zbog svoje inercije ne zaobilaze prepreke nego se deponiraju na vanjskim listovima krošnje. Ova tvrdnja govori u prilog malim kapljicama jer prodiru duboko u krošnju i ostvaruju dobar depozit i pokrivenost površine unutar krošnje.

Specifičnost promjene agroklimatskih uvjeta u kratkom vremenskom razdoblju i promjena oblika krošnje tijekom vegetacije dodatno otežavaju istraživanja. Araújo i sur. (2016.) istražuju utjecaj oborina na depozit unutar krošnje, te navode da kiša nepovoljno utječe na optimalan depozit u gornjim dijelovima krošnje gdje gubitak škropiva iznosi od 4 do 5,7 % pri dnevnoj količini oborina od 14,3 do 26,4 mm.

Miranda-Fuentes i sur. (2015) navode da brzina zračne struje utječe na depozit unutar krošnje. Prevelika brzina zračne struje dovodi do loše pokrivenosti i prekomjernog zanošenja pesticida izvan ciljanog prostora zaštite bilja, dok nedovoljna količina zračne struje kao posljedicu ima lošu pokrivenost i depozit u gornjim slojevima krošnje.

Utjecaj vremenskih uvjeta prilikom primjene zaštitnih sredstava proučava Nuyttens i sur. (2005.) te navodi da su najznačajniji meteorološki uvjeti prilikom aplikacije temperatura zraka i brzina vjetra te je poštivanjem preporučenih vrijednosti moguće značajno unaprijediti aplikaciju i smanjiti zanošenje tekućine.

Za evaluaciju neželjeno zanesene tekućine upotrebljavaju se različite metode vizualizacije: fluorescentne i vidljive boje, vodoosjetljivi papirići. Najraširenija je upotreba fluorescentnih i vidljivih boja koje nisu opasna za ljudsku uporabu.

Cilj istraživanja je utvrditi utjecaj različito podešenih tehničkih čimbenika raspršivanja na depozit tekućine u krošnji upotrebom dva različita raspršivača *Agromehanika AGP 200 ENU* i *Tifone Vento 1500* u trajnom nasadu višnje, te na temelju rezultata doći do saznanja koja kombinacija tehničkih čimbenika ostvaruje veći depozit.

MATERIJAL I METODE

Istraživanje je obavljeno u nasadu višnje starom četiri godine, uzgojnog oblika popravljena piramida u vlasništvu rasadnika Karolina (Osijek, Osječko-baranjska županija, Hrvatska) tijekom svibnja 2017. godine. Koordinate nasada su 45°31'17,5"N 18°46'39,6"E, prema *ISO normi 22866* (uređaji u zaštiti bilja - metode mjerenja zanesene tekućine u poljskim uvjetima). U istraživanju su korištena dva različita tipa raspršivača *Agromehanika ENU 200* i *Tifone Vento 1500.*

Raspršivač *Agromehanika AGP 200 ENU* (Slika 1.) opremljen je sa visinskim usmjerivačima zraka visine 117 cm i širine 11 cm. Promjer ventilatora iznosi 585 mm podesiv u pet položaja lopatica ventilatora. Maksimalan protok zračne struje iznosi cca. 32000 m^3 h^{-1}. Izlazna brzina zračne struje kreće se u rasponu od 10 do 35 m s^{-1}. Najveća dopuštena brzina vrtnje ventilatora je 1800 min^{-1}. Na raspršivač su postavljena dva tipa mlaznica *TR 8002* i

ITR 8002 proizvođača *Lechler.* Raspršivač je opremljen sukladno europskoj normi *EN 13790* s tri spremnika tekućine, od kojih je glavni spremnik obujma 200 litara, pomoćnog spremnika veličine 10 % od volumena glavnog spremnika, te spremnika čiste vode za pranje ruku. Na raspršivač je instalirana klipno - membranska crpka proizvođača *Agromehanika* kapaciteta 61 l min^{-1} (model crpke *BM 65/30* s dvije membrane) pri radnom tlaku od 30 bar.

Vučeni raspršivač *Tifone Vento 1500* (Slika1.) opremljen je spremnikom tekućine obujma 1500 litara. Mlaznice *Lechler TR 8002C* i *ITR 8002C* postavljene su polukružno na obodu usmjerivača po šest mlaznica sa svake strane. Ventilator se sastoji od 8 lopatica, a promjer ventilatora iznosi 810 mm. Brzinu zračne struje moguće je podešavati promjenom radnog položaja lopatica ventilatora. Na raspršivač je instalirana klipno-membranska crpka proizvođača *Tifone* kapaciteta 105 l min^{-1} (model crpke 110 *VD* s dvije membrane) a najveći dopušteni radni tlak je 50 bar. Oba raspršivača agregatirani su traktorom *Torpedo 6006K* snage motora 42 kW.

Slika 1 Raspršivači Agromehanika AGP 200 ENU i Tifone Vento 1500
Figure 1 Agromehnaika AGP 200 ENU and Tifone Vento orchard sprayers

Standardna mlaznica *Lechler TR 8002C* formira mlaz s radnim kutom od 80° šuplje konusne izvedbe i koristi se u zaštiti voćnjaka i vinograda. Protok mlaznice iznosi 0,8 l min^{-1} pri radnom tlaku od 3 bar. Mlaznica je izrađena od plastičnih polimera s keramičkim uloškom koji se može izvaditi iz tijela mlaznice radi čišćenja. Ovaj tip mlaznice stvara sitne kapljice koje ostvaruju dobru pokrivenost tretirane površine, ali su osjetljive na zanošenje.

Zračno - injektorska mlaznica konusnog mlaza proizvođača *Lechler ITR 8002C* konstruirana je za smanjeno zanošenje tekućine. Tijelo mlaznice izrađeno je od plastičnih polimera s keramičkim uloškom koji je promjenjiv. Protok od 0,8 l min^{-1}ostvaruje pri tlaku od 3 bar, a kut prskanja je 80°. Ovaj tip mlaznica stvara veći promjer kapljica nego što je to slučaj kod *TR* mlaznica, što u velikoj mjeri smanjuje pojavu zanošenja tekućine

Norma raspršivanja označena je kao čimbenik *A*. Korištena je optimalna norma raspršivanja A_1 (250 l ha^{-1} - izračunava se prema trenutnom stanju nasada i obujmu lisne mase), te A_2 norma raspršivanja, koja se smanjuje za 20 % (200 l ha^{-1}).

Drugi tehnički čimbenik obuhvaća utjecaj tipa standardne mlaznice B_1 (*Lechler TR 8002 C*) i mlaznice sa smanjenim zanošenje tekućine: *Lechler ITR 8002 C – čimbenik* B_2. Treći čimbenik *C* označava utjecaj zračne struje na zanošenje tekućine. C_1 označava brzinu zračne struje ventilatora izračunatu prema obujmu lisne mase i brzinu zračne struje smanjene za 30 % čimbenik C_2.

Vremenski uvjeti tijekom istraživanja praćeni su pomoću meteorološke stanice tvrtke *Hobo*. Najvažniji čimbenici koji imaju izravan utjecaj na tehničke čimbenike zaštite bilja su brzina vjetra, temperatura zraka i relativna vlažnost zraka. Za raspršivanje koristi se 4 % otopina organske boje *Tartrazine*.

Za prikupljanje depozita tekućine u krošnji korišteni su filtar papirići proizvođača *Technofil* (površine 35 cm^2). Depozit unutar krošnje izmjeren je filtar papirićima koji su postavljeni na tri razine krošnje: donjoj, srednjoj i gornjoj razini. Na svakoj razini postavljena su 4 filtar papirića (12 filtar papirića po stablu u četiri ponavljanja).


Slika 2 Filtar papirići u krošnji
Figure 2 Filter papers in treetop

Nakon svakog tretmana filtar papirići su prikupljeni tijekom 15 min i spremljeni u hermetički zatvorene vrećice koje su odložene na mjesto bez pristupa sunčeve svjetlosti. Uzorkovani filtar papirići u laboratoriju ispiru se sa 10 ml deionizirane vode, nakon čega se određuje koncentracija tekućine, pomoću valne duljine očitane na spektrofotometru (*Varian Cary 50 UV-Visible*). Za određivanje koncentracije tekućine pri korištenju organske boje *Tartarzin* korištena je valna duljina od 425 nm. Brzina zračne struje izmjerena je ručnim anemometrom (*Kestrel 4500BT*).

REZULTATI I RASPRAVA

Istraživanje je obavljeno tijekom svibnja 2017. godine, pri preporučenim vremenskim uvjeti za uspješnu aplikaciju pesticida. Pod preporučenim vremenskim uvjetima podrazumijeva se temperatura zraka između 15-22 °C, brzina vjetra manja od 3 m s^{-1} i relativna vlažnost zraka iznad 60 %. U Tablica 1. prikazani su rezultati mjerenja vremenskih uvjeta tijekom raspršivanja raspršivačima *Agromehanika* i *Tifone.*

Prosječna temperatura zraka tijekom eksploatacije raspršivača *Agromehanika* iznosila je 21,9 °C, s vrijednostima od 19,8 do 24,3 °C (Tablica 1.). Vrlo slični rezultati zabilježeni su primjenom raspršivača *Tifone* s prosječnom temperaturom zraka od 21,8 °C (min. od 19,4 do max. 24,8 °C).

Tablica 1 Vremenski uvjeti tijekom istraživanja s raspršivačima *Agromehanika* i *Tifone*
Table 1 Weather conditions during research with *Agromehanika* and *Tifone* orchard sprayers

Tretman/ Treatment		$A_1B_1C_1$	$A_1B_1C_2$	$A_1B_2C_1$	$A_1B_2C_2$	$A_2B_1C_1$	$A_2B_1C_2$	$A_2B_2C_1$	$A_2B_2C_2$	$\bar{x}$	σ	K.V. (%)
Raspršivač / Mistblower Agromehanika												
T_z (°C)		22,3	21,3	19,2	23,4	23,1	19,8	24,3	22,2	21,9	1,8	8,0
R_v (%)		60,2	63,8	70,6	58,4	58,5	68,3	54,2	59,3	61,7	5,5	8,9
v_v (m s^{-1})	Min.	0,5	0,6	0,7	0,5	0,2	0,4	0,4	1,1	0,6	0,3	48,6
	Max.	1,1	0,8	0,8	0,6	0,4	0,6	0,7	1,4	0,8	0,3	39,5
	$\bar{x}$	0,8	0,7	0,8	0,6	0,3	0,5	0,6	1,3	0,7	0,3	41,7
Raspršivač / Mistblower Tifone												
T_z (°C)		19,4	19,6	19,6	20,1	23,4	23,1	24,8	24,6	21,8	2,4	10,9
R_v (%)		70,6	70,1	69,6	65,5	55,2	55,6	50,4	50,2	60,9	1,0	14,8
v_v (m s^{-1})	Min.	0,6	0,8	0,7	0,5	0,4	0,6	0,4	0,8	0,6	0,2	26,7
	Max.	0,9	1,2	0,8	0,9	0,8	0,7	0,9	1,2	1,0	0,2	17,1
	$\bar{x}$	0,8	1,0	0,8	0,7	0,6	0,9	0,7	1,0	0,8	0,2	19,1

T_z - temperatura zraka (°C); R_v - relativna vlažnost zraka (%); v_v - brzina vjetra (m s^{-1})
T_z - air temperature (°C); R_v - relative air humidity (%); v_v wind speed (m s^{-1})

S obzirom na zabilježene vrijednosti može se utvrditi da je utjecaj temperature zraka na ispitivana svojstva bio minimalan i u skladu s preporučenim vrijednostima. Ovakve male razlike u vrijednostima temperature zraka između pojedinog tretmana zabilježene su zbog vrlo male vremenske razlike u obavljanu tretmana koje je iznosilo oko 15 min. Vrijednosti depozita u krošnji s različito podešenim tehničkim čimbenicima raspršivanja prikazane su u Tablici 2.

Tablica 2 Depozit tekućine u krošnji raspršivačima *Agromehanika* i *Tifone*
Table 2 Spray deposit in treetop with *Agromehanika* i *Tifone* orchard sprayers

Tretman/ Treatment	N_r (l ha^{-1})	Tip mlaz./ Nozzle type	v_z (m s^{-1})	Agromehanika			Tifone		
				$\bar{x}$ (g ha^{-1})	σ	K.V. (%)	$\bar{x}$ (g ha^{-1})	σ	K.V. (%)
$A_1B_1C_1$	250	TR	12,00	295,42	0,70	0,57	301,42	0,82	1,04
$A_1B_1C_2$	250	TR	18,00	299,17	1,01	0,81	305,71	0,65	0,50
$A_1B_2C_1$	250	ITR	12,00	297,00	1,29	1,04	305,84	0,76	0,59
$A_1B_2C_2$	250	ITR	18,00	314,20	2,52	0,39	312,02	1,54	1,18
$A_2B_1C_1$	200	TR	12,00	281,10	6,48	5,49	274,63	8,24	7,14
$A_2B_1C_2$	200	TR	18,00	284,00	3,29	2,76	281,72	4,14	3,50
$A_2B_2C_1$	200	ITR	12,00	285,80	2,14	1,78	278,21	8,35	7,14
$A_2B_2C_2$	200	ITR	18,00	287,20	6,08	5,04	285,21	4,67	3,90

A - norma raspršivanja (N_r - l ha^{-1}); B - tip mlaznice; C - brzina zračne struje (v_z - m s^{-1})
A - spraying norm (N_r - l ha^{-1}), B - nozzle type, C - air flow rate (v_z - m s^{-1})

Prema rezultatima prikazanim u Tablici 2. najveća vrijednost depozita u krošnji ostvarena je tretmanom $A_1B_2C_2$ u iznosu od 314,20 g ha^{-1}, dok je minimalna vrijednost od 281,10 g ha^{-1} ostvarena tretmanom $A_2B_1C_1$ raspršivačem *Agromehanika*. Maksimalni depozit od 312,02 g ha^{-1} ostvaren je tretmanom $A_1B_2C_2$ dok je minimalna vrijednost od 274,63 g ha^{-1} zabilježena kod tretmana $A_2B_1C_1$ eksploatacijom raspršivača Tifone. Analiza varijance za ispitivano svojstvo depozita u krošnji prikazana je u Tablici 3.

Tablica 3 Analiza varijance depozita u krošnji
Table 3 Analysis of variance for spray deposit in treetop

ANOVA	Agromehanika		Tifone	
	F-test	p	F-test	p
A	2,81 n.s.	0,11	3,31 n.s.	0,08
B	0,00 n.s.	0,95	0,12 n.s.	0,73
C	2,39 n.s.	0,14	1,37 n.s.	0,25
AB	0,51 n.s.	0,48	0,01 n.s.	0,93
AC	0,90 n.s.	0,77	0,00 n.s.	0,99
BC	0,25 n.s.	0,62	0,02 n.s.	0,90
ABC	0,90 n.s.	0,76	0,02 n.s.	0,90

A - norma raspršivača (l ha^{-1}); *B* - tip mlaznice; *C* - brzina zračne struje (m s^{-1})
A - spraying norm (l ha^{-1}), *B* - nozzle type, *C* - air flow rate (m s^{-1})

Na osnovi rezultata dobivenih analizom varijance prikazanih u Tablici 3. uočeno je da između svih ispitivanih čimbenika i njihovih interakcija nema statistički značajnog utjecaja na svojstvo depozita tekućine unutar krošnje za oba tipa raspršivača (*Agromehanika* i *Tifone*). $LSD_{0,05}$ test za depozit u krošnji prikazan je u Tablici 4.

Tablica 4 $LSD_{0,05}$ test za depozit u krošnji
Table 4 $LSD_{0,05}$ test for spray deposit in treetop

Čimbenici raspršivanja/ Spraying factors		Agromehanika		Tifone	
		$\bar{x}$	$LSD_{0,05}$	$\bar{x}$	$LSD_{0,05}$
A	A_1	1 268,38	32,36 n.s.	1 238,00	17,86 n.s.
	A_2	1 240,88		1 220,13	
B	B_1	1 254,19	33,94 n.s.	1 231,63	18,89 n.s.
	B_2	1 255,06		1 228,75	
C	C_1	1 257,31	32,60 n.s.	1 235,93	18,47 n.s.
	C_2	1 241,94		1 224,87	

A – norma raspršivanja (A_1 – 250 l ha^{-1}; A_2 – 200 l ha^{-1}), B – tip mlaznice (B_1 – Lechler TR 8002 C; B_2 – Lechler ITR 8002 C), C – brzina zračne struje (C_1 -18 m s^{-1}; C_2 – 12 m s^{-1})
A – spraying norm (A_1 – 250 l ha^{-1}; A_2 – 200 l ha^{-1}), B – nozzle type (B_1 – Lechler TR 8002 C; B_2 – Lechler ITR 8002 C), C – air flow rate (C_1 -18 m s^{-1}; C_2 – 12 m s^{-1})

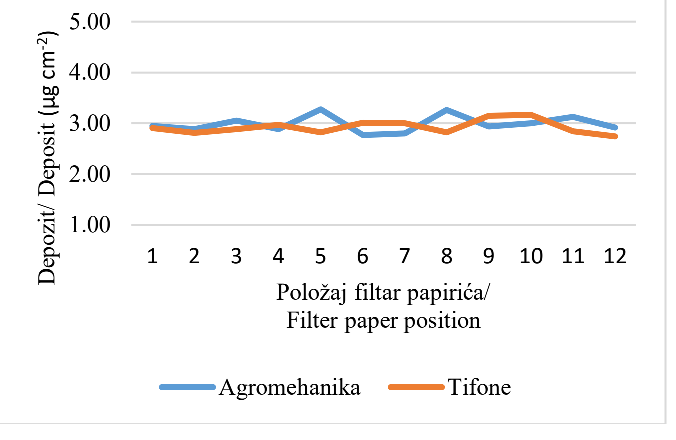
Na osnovu rezultata u Tablici 4. nije utvrđena statistička značajnost između ispitivanih podčimbenika za oba tipa raspršivača. Pošto nema statističke značajnosti za navedena dva slučaja ispitana je razlika u depozitu za tipove raspršivača. Tablica 5. prikazuje $LSD_{0,05}$ test za vrijednosti depozita u krošnji između ispitivanih raspršivača za sve tretmane.

Tablica 5 $LSD_{0,05}$ test za depozit u krošnji između tipova raspršivača
Table 5 $LSD_{0,05}$ test for spray deposit in treetop between sprayer types

Ispitivano svojstvo/ Investigated property	Agromehanika	Tifone	Statističke vrijednosti / Statistical values			
	$\bar{x}$	$\bar{x}$	F-test	p	$LSD_{0,05}$	Otklon/ Deviation (%)
Depozit u krošnji/ Deposit in treetop	1 254,62	1 229,40	7,26*	0,01	18,71	2,01

Na temelju dobivenih rezultata prikazanih u Tablici 5. vidljivo da je primjena raspršivača *Agromehanika* ostvaruje statistički značajno veći depozit tekućine u krošnji u odnosu na raspršivač *Tifone* ($LSD_{0,05}$ = 18,71). Otklon depozita u krošnji između dva navedena raspršivača iznosio je 2,01 %.

Grafikon 1. prikazuje raspodjelu prosječnih vrijednosti depozita u krošnji ostvarenih različito podešenim tehničkim čimbenicima raspršivanja s obzirom na različite raspršivače.



Grafikon 1 Depozit tekućine u krošnji
Figure 1 Spray deposit in treetop

U Grafikonu 1. uočava se da vrijednosti depozita u krošnji uporabom raspršivača *Agromehanika* nisu značajno različite u odnosu na vrijednosti dobivene raspršivačem *Tifone*.

ZAKLJUČAK

Na osnovu dobivenih rezultata u ovom istraživanju mogu se donijeti sljedeći zaključci:

- Prema rezultatima vremenskih uvjeta tijekom istraživanja utvrđeni su vrlo mali otkloni od optimalnih vremenskih uvjeta.
- Najveća vrijednost depozita u krošnji dobivena je s tretmanom $A_1B_2C_2$ u iznosu od 314,20 g ha^{-1}, dok je minimalna vrijednost od 281,10 g ha^{-1} ostvarena s tretmanom $A_2B_1C_1$ raspršivačem *Agromehanika*.
- Maksimalni depozit od 312,02 g ha^{-1} ostvaren je tretmanom $A_1B_2C_2$ dok je minimalna vrijednost od 274,63 g ha^{-1} zabilježena kod tretmana $A_2B_1C_1$ eksploatacijom raspršivača *Tifone.*

Optimiziranje glavnih čimbenika raspršivanja (norme raspršivanja, tip mlaznice, brzina zračne struje) nije značajno utjecalo na depozit tekućine u krošnji s raspršivačima *Agromehanika i Tifone*, ali je zabilježena statistička značajnost za tip raspršivača. U budućnosti je potrebno provesti daljnja istraživanja s ciljem određivanja granice optimizacije čimbenika raspršivanja, a da se depozit tekućine u krošnji značajno ne promjeni. Svakako treba naglasiti da se treba provjeriti i biološka učinkovitost optimizacije čimbenika raspršivanja, tj. do koje granice je moguće optimizirati glavne čimbenike raspršivanje bez narušavanja biološke učinkovitosti sredstva za zaštitu bilja.

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IMPACT OF ORCHARD SPRAYER TYPE AND TECHNICAL SPRAYING FACTORS ON SPRAY DEPOSIT

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SUMMARY

The paper presents, the results of impact of technical spraying factors on the spray deposit in treetop are shown by using Agromehanika AGP 200 ENU and Tifone Vento 1500 orchard sprayers. The research was conducted in Karolina cherry nursery-garden (Osijek and Baranja County, Croatia) according to ISO 22866 norm (devices and machines in plant protection – methods of measuring drift in field conditions) in May 2017. Geographical plant position 45° 31' 17.5" N and 18° 46' 39.6" E. The influence of flow rate is marked as factor A, the type of nozzle as factor B, and air velocity as factor C. With different treatments of technical spraying factors, a different values of spray deposit in treetop are obtained. The highest spray deposit in treetop of Agromehanika sprayer was achieved with $A_1B_2C_2$ treatment with 312.00 g ha^{-1}, while the lowest value of 274.60 g ha^{-1} was achieved with $A_2B_1C_1$ treatment. The highest spray deposit in treetop of Tifone sprayer was achieved with $A_1B_2C_2$ treatment with 314.20 g ha^{-1}, while the lowest value of 281.10 g ha^{-1} was achieved with $A_2B_1C_1$ treatment.

Keywords: *spray deposit, spraying norm, air velocity, nozzles, orchard sprayer*

47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

INFLUENCE OF WORKING PRESSURE ON SPRAYING ANGLE FOR DIFFERENT TYPES OF AGRICULTURE NOZZLES

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ABSTRACT

Ensuring a maximum efficiency of pesticides treatments in field crops is possible by producing spraying machines equipped with spraying systems with superior parameters in the working process.

The spraying angle is an important qualitative index for the quality of phytosanitary treatments, among the factors influencing it being the working pressure and the correlation with the nozzle type.

The paper presents comparative experimental researches on the spraying angle for four pesticides with different physical properties (water, a selective systemic herbicide – S1, a systemic insecticide for fighting larvae and eggs – S2 and a total, nonselective systemic herbicide – S3) at five working pressures (1 - 5 bar) and six types of nozzles (L1 - L6). From the researches it was noticed that the spraying angle increases when increasing the pressure and when reducing the nozzle diameter for any type of nozzle and any of the four pesticides used.

Keywords: *nozzle, spraying angle, pressure, pesticides*

INTRODUCTION

Over the last years were developed a series of construction solutions for plant protection machines that are more modern and performant as to minimize the loss of treatment substances and to conduct high quality works (Stahli et al., 2006).

Our health is indissoluble linked to the health of soil and plants providing us food products. Agriculture represents a vital human activity since ancient times, being the main source of food for a country's population, advances in agriculture having a beneficial effect throughout the country's economy (Boja, 2010; Hilz et al., 2013).

Developing and modernizing agriculture is a natural and necessary process. We cannot imagine raising the quality of life if agriculture is not stimulated to produce as much as possible and at high quality. Agriculture development is influenced by natural, technical and socio-economic factors. Technical factors have an important role in increasing production, through mechanization, use of chemicals, irrigation, etc., phytosanitary protection occupying a very important place (Bran, 2009; Heidary et al., 2014).

An important factor in continuously increasing the quality of products obtained by economic agents is constituted by maintaining the conformity of plant protection equipment. Thus, the purpose of a spraying work is to evenly deposit a maximum quantity of phytosanitary product at the place of combating, respectively on the spayed surface (Popescu, 2007; Mihăiţă, 2003).

In modern working technologies used in plant crops, phytosanitary protection occupies an important place, hereby the spraying machines has a significant role in this work. The spraying nozzles play a very important part in the working process of spraying machines have, by their working characteristics depending in a great measure both the machine’s performances and the phytosanitary treatment quality (Niţu, 2018).

One of the main qualitative indices of spraying works is represented by the distribution uniformity of the droplets of the liquid jet on the working width of the spraying machine’s ramp on which the nozzles are mounted. Characteristics referring to the nozzle’s shape and dimensions, spraying jet angle, maintaining at a constant value the working pressure and the physical properties of phytosanitary substances, represent factors which significantly influence the quality of spraying treatments (Niţu, 2018).

Shafer et. al. (1954) presented the results of experimental researches on the performance of the nozzle for continuous liquid spraying with respect to the average diameter of drops, spraying angle, nozzle size, density, viscosity, superficial tension and liquid pressure.

Barnet et al. (1957) presented an experimental study on the influence of nozzle dimensions and injection conditions on the outlet coefficient and the spraying angle. Twenty simplex nozzles with different geometries were experimented, the parameters followed being the outlet coefficient and the angle of the spraying cone for the pressure swirl nozzles that spray the heavy oil. The dimensions and quality of the surfaces were checked using a microscope, the tested liquid being the heavy oil with its physical properties (density, viscosity, superficial tension) determined depending on temperatures - 100 °, 110 °, 120 ° and 135 °C. 133 experiments were performed with different combinations of variables (the diameter of the outlet orifice, the total inlet slot area, p - injection pressure and Tfo - oil temperature, corresponding to 20 sprayer geometries.

Niţu et al. (2018) presented experimental results obtained from measurements achieved with three different commonly used commercial substances and six types of nozzles used on current machines. As a result of the research, it has been found that the theoretical model proposed for estimating the nozzle jet angle, shows its dependence on working pressure, nozzle diameter and physical properties of the spraying solution.

Also, nozzle manufacturers, based on their own researches on their spraying angle, have come to similar conclusions, namely that the angle of the nozzle and, implicitly, the degree of spraying with a liquid different from water can be influenced by the following factors: density, viscosity, superficial tension, temperature, working pressure and the material used in the nozzle.

From Specifiers Guide - Spray technologies (2018) it results that the spraying angle is usually measured in the immediate vicinity of the nozzle orifice with a tolerance of 5 ° for the spray angles tested. As the spraying distance increases, droplets are affected by gravitational acceleration and by the gas, which reduces the spraying angle. In addition to pressure and flow rate, the spray angle also affects the magnitude of the impact created by the liquid on the surface being sprayed. Also, liquids more viscous than water will also form smaller spraying angles.

In Engineering Information (2018), nozzle flow rate, droplet size, coating degree and spraying angle were studied. In this case was also found that the angle of the nozzle affects the actual coverage degree, not being the same as the theoretical coverage and is depending on the working pressure and on the physical properties of the spraying solutions.

Also, in Spray engineering handbook (2018) was investigated the angle of the spraying jet in relation to the working pressure and the physical properties of the spraying solutions. It has been found that this is one of the main parameters for choosing the nozzles, the size of the spraying angle determining the coverage by spraying and the density of the sprayed liquid in relation to the coverage area. Researches have shown that the theoretical coverage increases faster than the actual coverage, when increasing the distance, therefore the efficiency of coverage and implicitly the quality of phytosanitary treatments decreases.

The paper presents comparative experimental researches on the spraying jet angle for four solutions with different physical properties (water, a selective systemic herbicide – S1, a systemic insecticide for fighting larvae and eggs – S2 and a total, nonselective systemic herbicide – S3) at five working pressures (1 bar, 2 bar, 3 bar, 4 bar, 5 bar) and six types of nozzles (L1, L2, L3, L4, L5, L6).

MATERIAL AND METHODS

Comparative experimental researches on the spraying jet angle were conducted for four solutions with different physical properties (water, a selective systemic herbicide – S1, a systemic insecticide for fighting larvae and eggs – S2 and a total, nonselective systemic herbicide – S3) at five working pressures (1 bar, 2 bar, 3 bar, 4 bar, 5 bar) and six types of nozzles (L1, L2, L3, L4, L5, L6). From the researches it was noticed that the spraying angle increases significantly when increasing the pressure (reaching the maximum value for the pressure of 5 bar) and when reducing the nozzle diameter for any type of nozzle and any of the four pesticides used.

For conducting the verifications, various nozzles were chosen for administrating pesticides and growth regulators and for administrating liquid fertilizers (Stahli, 2006). We chose 6 nozzles with spraying angle of 120°, built from plastic material (POM of PP), with the pressure working domain of 1-6 bar. The nozzles were numbered L1÷L6, depending on their dimension (0.1÷0.6) (Figure 1).

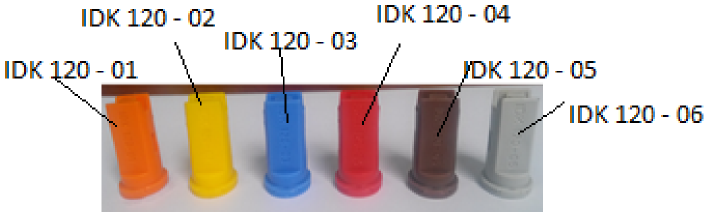

Figure 1 Nozzles used for experiments

The nozzles were equipped on a test stand that simulates the operation of a machine for spraying field crops, with the possibility to adjust the working pressure and to change the nozzles rapidly. The test stand is equipped with manometer, tank, a pump, two nozzle holders with 5 nozzles and anti-dripping device (Figure 2). Also, for measuring the real angle of spraying**,** we used a high-speed recording camera, Phantom V10.0, series V 630, set to record at 80 frames/ second. The software used for recording and off-line processing of the measurements was *PCC-Phantom Camera Control Application*.

Figure 2 Test stand for the nozzles

Video recordings were taken during the operation in the static regime of nozzles, recording 250 frames for each type of nozzle, each working pressure and each type of pesticides and water. Five measurements were made for each recording, from 50 to 50 frames and after that, the average measured value of the angle of the spraying jet was reported for each case. Each video was processed, and the nozzle spray angle was evaluated using the camera's own software (Nitu, 2015).

Figure 3 presents the principle of measuring the angle of the spraying jet (left) and the exemplified result of measurements (right).

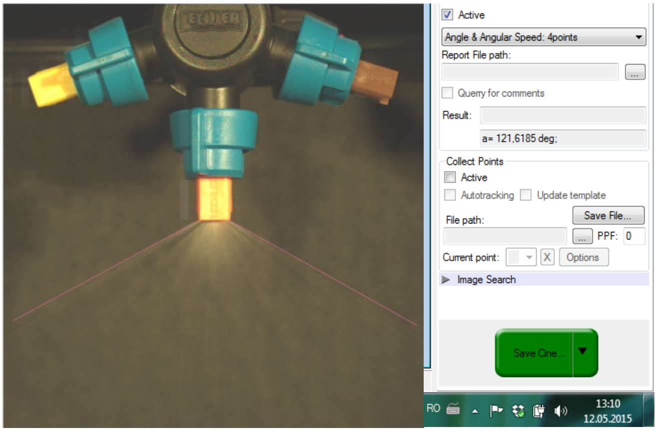

Figure 3 The angle of the spraying jet for the nozzle L 0.1 at a pressure of *1bar*

Physical properties influence the quality of the spraying process, namely the density influences the norm of substance per hectare depending on the temperature. Viscosity has a significant effect on the performances of the nozzles, affecting drop forming, the cone's angle decreasing along with increasing the viscosity.

Also, viscosity, superficial tension and the specific weight of drops are affected by temperature, increased temperatures leading to increased liquid flow rate through the nozzle.

Next, we present the water solutions used, solutions that were prepared according the specification from producers.

SOLUTION S1 is a product formulated as a concentrated oily suspension being a selective systemic herbicide that is absorbed through the leaves and roots. The solution is applied using terrestrial spraying machines, fitted with systems for contiguous stirring/ homogenizing the spraying solution with a concentration of 0.8% (Glăman et al., 2005).

SOLUTION S2 is a systemic insecticide for combating larvae and eggs, having both systemic action and complementary physical action of asphyxiation due to the oil. It has lasting effect ensuring better adherence to the plant surface and a superior contact with the target pests, used with a concentration of 1.5% (Glăman et al., 2005).

SOLUTION S3 is a total, unselective, non-residual herbicide, with action on a wide spectrum of mono and dicotyledonous, annual and perennial weeds, including species resistant to rhizomes. The effect of the treatment is noticed in a 4-14 days interval, depending on local conditions and is used as a concentrated suspension (Glăman et al., 2005).

RESULTS AND DISCUSSION

The stand's tank was fed with the solutions used, first determining the physical properties: density, viscosity and superficial tension, the results are shown in Figure 4.

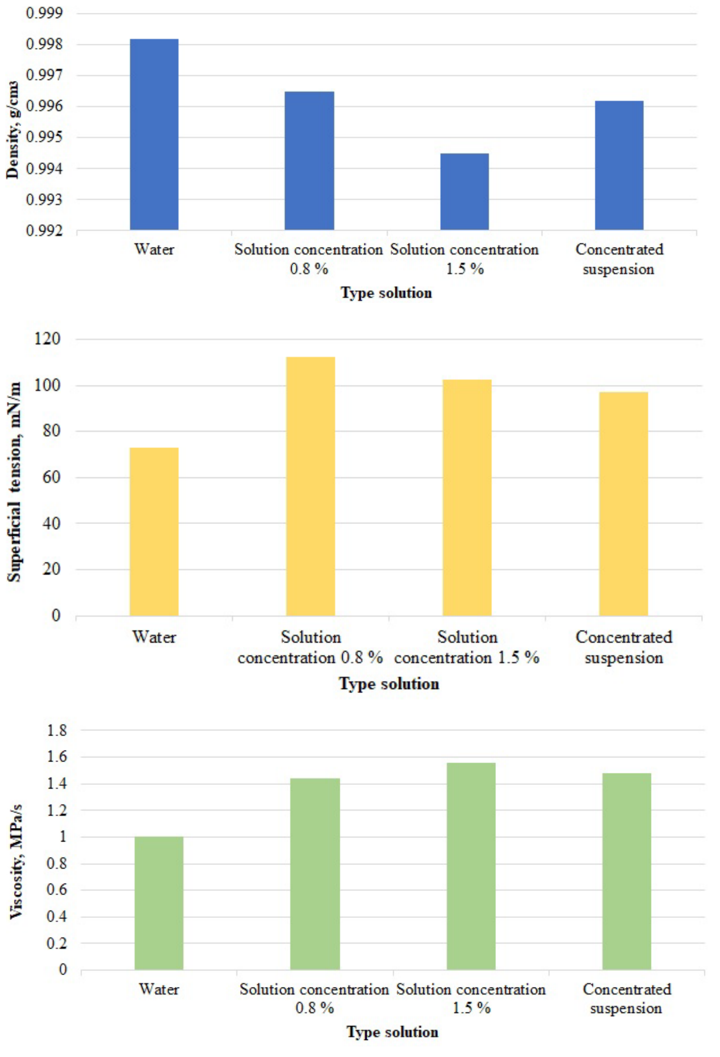

Figure 4 Physical properties of the solution used

From figure 4 is observed that numerically, less than 10% of the values have a coefficient of deviation smaller than 5. This demonstrates the possibility of modelling the angle of the spraying jet depending on the type of solution used (different physical properties), the type of nozzles used and the parameters of the working process.

The data from experiments using water and the three solutions regarding the values of the jet angle at different pressures and the six types of nozzles are synthetically presented in figures 5÷10.

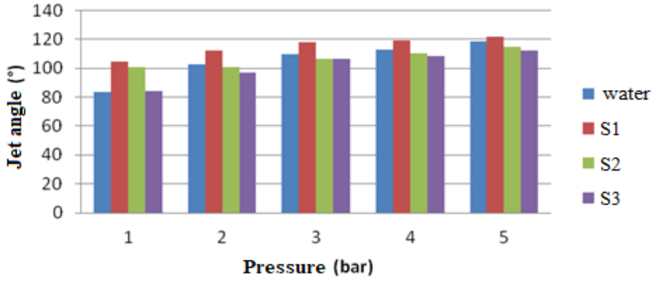

Figure 5 Jet angle for water and S1, S2, S3 depending on pressure, for nozzle L01

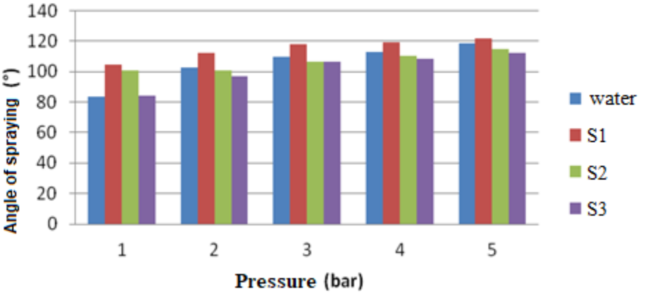

Figure 6 Jet angle for water and S1, S2, S3 depending on pressure, for nozzle L02

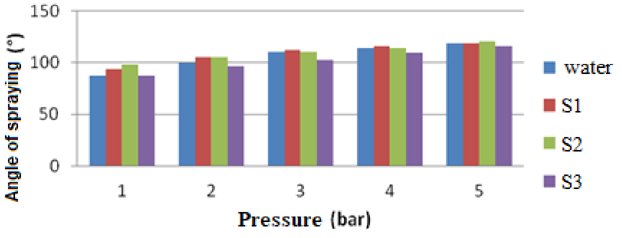

Figure 7 Jet angle for water and S1, S2, S3 depending on pressure, for nozzle L03

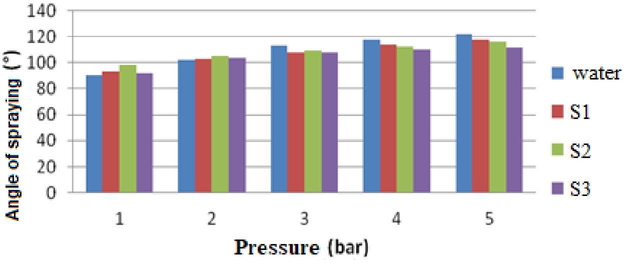

Figure 8 Jet angle for water and S1, S2, S3 depending on pressure, for nozzle L04

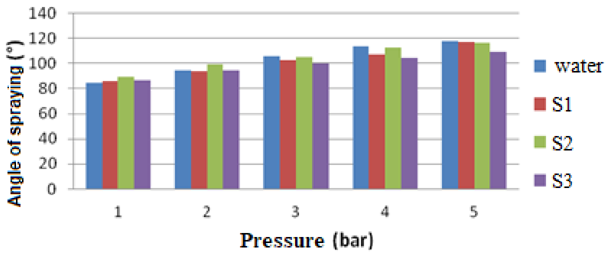

Figure 9 Jet angle for water and S1, S2, S3 depending on pressure, for nozzle L05

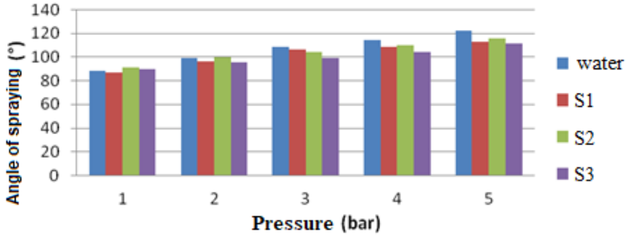

Figure 10 Jet angle for water and S1, S2, S3 depending on pressure, for nozzle L06

The figures present the comparative diagrams for the values of the spraying jet angle depending on the working pressure for each type of nozzles used for water and the three solutions experimented.

A dependence of the spraying jet angle depending on the physical properties of the solutions used is noticed. From the analysis of these data, there is a good approximation between the values of the jet angles for water and the three solutions, both for all researched pressures (1, 2, 3, 4, 5 bar) and for the six types of nozzles. The relative deviations of the values of the three solutions, for all five pressures and the six types of nozzles fall within a ± 10% range, most of them (over 83%) falling within the ± 5,5% range.

On the basis of these data, it can be concluded that, from the point of view of the spraying jet angle, with an acceptable precision, experiments can be conducted using water for all types of researched nozzles, the data being very useful in the activity of engineering design and for an efficient used of the equipment in the field.

The results of experimental researches presented in this paper can be compared with those found in the literature.

As a result of the experimental research, Shafer et al. (1954) concluded that the experimental values of nozzle flow capacity for liquids with different physical properties define a single curve for each nozzle, when are represented graphically in terms of non-dimensional logical variables. Also, the curves presented to indicate the performance of the nozzles are specifically applicable only for certain nozzles that have been experimented, which are used for purposes such as: determining the effects of the individual variables;

analysis correlation and experimental interpretation data; anticipation (prediction) of performance differences due to the use of liquids with different physical properties.

As a result of these researches, it was found that studies according to the theory for non-viscous fluids produce higher values than those obtained from the published correlations and from the results of the present work, the proposed expression providing good estimates for the nozzle spray coefficient $K \geq 0.2$ at Tfo = 100 °C; for $K < 0.2$, the differences between the measurements and those of the theory for non-viscous fluids are less important. Differences observed in the behaviour of small-sized nozzles illustrated in previous studies have been attributed to the significant role of viscous effects (Barnet et al., 1957).

Also, in Engineering Information (2018) it was found that for a 70-degree angle are used nozzles with a 200 mm orifice at a working height of 150 mm from the spraying target. For this case as well was demonstrated that a good quality phytosanitary treatment depends on the spraying angle.

CONCLUSIONS

A particular importance in the process of spraying the liquid through the nozzle is that of the jet angle, which contributes to the covering of sprayed surfaces, to the uniformity of the coverage and the quality of the process.

From the results obtained, the following conclusions can be drawn:

- - tests on the three aqueous solutions reveals that the size of the jet angle is insignificantly influenced by the physical properties of the solutions when they have values in the ranges similar to those specified;
- - the shape, sizes of the nozzle orifice and the constant working pressure are determining factors in achieving the distribution uniformity of drops on the working width;
- - the modelling of the spray jet angle depending on the type of solutions used (different physical properties), the type of nozzles used, and the working process parameters is possible for a coefficient of deviation smaller than 5;
- - distribution deviations during tests on the stand are inherent even for a new nozzle, but these must fall within limits that do not affect the fragmentation distribution on the width of the boom, where the nozzle distributions overlap, and the deviation of the overlapping values do not to exceed ± 20%;
- - the comparative diagrams revealed that there is a good approximation between the values of the jet angles for water and the three solutions, for all 5 working pressures used in the research.

Spraying angles are important in spraying applications in order to prevent jets overlapping on the covered materials.

In the case of spraying machines, the distribution uniformity of droplets on the working width of the nozzle and implicitly on the working width of the spraying equipment is one of the most important quality indices for spraying works.

Ensuring maximum efficiency of treatments with phytosanitary substances in agricultural field crop is possible by building sprayers equipped with spraying systems that have superior parameters for the working process.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Stručni rad
Expert paper

ANALIZA STROJEVA ZA PRIMJENU PESTICIDA PREGLEDANIH U 2017. GODINI U SLOVENIJI

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SAŽETAK

Redoviti pregledi strojeva za primjenu pesticida izvode se radi provjere dali zadovoljavaju određene tehničke uvjete radi postizanja visoke razine zaštite zdravlja ljudi, životinja i okoliša. U radu analizirani su strojevi za primjenu pesticida, koji su bili pregledani u 2017. godini u Sloveniji. Analizirani su proizvođači, starost strojeva, distribucija strojeva po statističkim regijama i broj ispitanih strojeva po danu za pojedinu ispitnu stanicu. Iz baze podataka Uprave za sigurnost hrane, veterinarstva i zaštite bilja Republike Slovenije utvrđeno je da je u 2017. godini ispitano 8.302 stroja za aplikaciju pesticida. Od toga je bilo 66,2 % prskalica i 33,8 % raspršivača. Prskalice su u prosjeku starije od raspršivača. Četvrtina prskalica je proizvedeno u razdoblju od 1986 do 1990 godine. Između proizvođača prskalica i raspršivača slovenski proizvođač Agromehanika ima čak 63,5 % udjela.

Ključne riječi: *prskalice, raspršivači, pregled, broj, starost, proizvođač*

UVOD

Prema podacima Statističkog ureda Republike Slovenije tijekom 2017. godine u Sloveniji je prodano 1.087 tona aktivnih tvari sredstava za zaštitu bilja (pesticida), što je za 6 % manje od prethodne godine 2016. Najviše je bilo prodanih fungicida i herbicida. Prodaja pesticida rasla je od 2014. do 2016. godine, dok je u 2012. i 2013. padala (Maver, 2018).

Sredstvo za zaštitu bilja toliko je efikasno, koliko je dobra njegova primjena. Najčešće kod aplikacije pesticida upotrebljavamo prskalice i raspršivače. Zakonski propisi za strojeve za primjenu pesticida važe za nove proizvode i za strojeve koji su već u upotrebi. Za nove strojeve za primjenu pesticida do 2012. godine u Sloveniji važio je zakonski propis o certifikaciji novih strojeva. Tek sa certifikatom, da je novi stroj sukladan tehničkim zahtjevima, mogao je doći u prodaju (Pravilnik o pridobitvi certifikata o skladnosti za naprave..., 2001). Od 2012. godine na dalje proizvođač strojeva za primjenu pesticida sa CE oznakom garantira, da je prskalica ili raspršivač izrađen prema svim zakonskim uvjetima koji važe u Sloveniji (Direktiva 2009/127/ES…, 2009; Pravilnik o spremembah in dopolnitvah Pravilnika o varnosti strojev. 2010). Ovakav sustav vrijedi i u cijeloj EU.

Za prskalice i raspršivače u upotrebi u Sloveniji provode se redoviti pregledi od 1991. godine. Ovi pregledi provode se zbog provjere da li ovi strojevi zadovoljavaju tehničke zahtjeve radi postizanja visoke razine zaštite zdravlja ljudi, životinja i okoliša (Pravilnik o zahtevah glede pravilnega delovanja naprav…, 2013).

Prema "Popisu poljoprivrede 2010", u Sloveniji je 37.204 strojeva za primjenu pesticida. Od toga je 20.999 traktorskih prskalica i 5.467 traktorskih raspršivača, a ostalo su leđne prskalice. Većina strojeva nalazi se na poljoprivrednim gospodarstvima koja imaju 5 do 20 hektara zemlje. Iz baze Uprave za sigurnost hrane, veterinarstva i zaštite bilja Republike Slovenije utvrđeno je da je 2016. godine pregledano 7.809 strojeva za primjenu pesticida. Kod toga je ustanovljeno, da su prskalice u prosjeku starije od raspršivača (Poje, 2017a). Poje analizira i podatke o pregledanim strojevima za primjenu pesticida za niz godina između 2010. i 2016. U tom razdoblju pregledano je 21.963 strojeva, od toga 68,4% su prskalice, a 31,4% su raspršivači. U Sloveniji prevladavaju prskalice i raspršivači od Agromehanike sa udjelom od 65,4% (Poje, 2017b). Bernik i Vučajnk (2017) su ustanovili da je u Sloveniji bilo između 2005. i 2014. godine pregledano 51.931 prskalica i 22.535 raspršivača. Od toga je bilo tehnički neadekvatno 18,2 % prskalica i 13,4 % raspršivača. Bernik i Kuhar (2017) ustanovili su da se je između 2004. i 2013. kod pregleda strojeva za primjenu pesticida u jugoistočnoj Sloveniji broj neadekvatnih prskalica i raspršivača smanjio iz 49,2 % na 1,6 %.

Cilj ovoga rada je analiza strojeva za primjenu pesticida, koji su bili pregledani u 2017. godini. Analizirani su proizvođači, starost strojeva, distribucija strojeva po statističkim regijama i broj ispitanih strojeva po danu za pojedinu ispitnu stanicu.

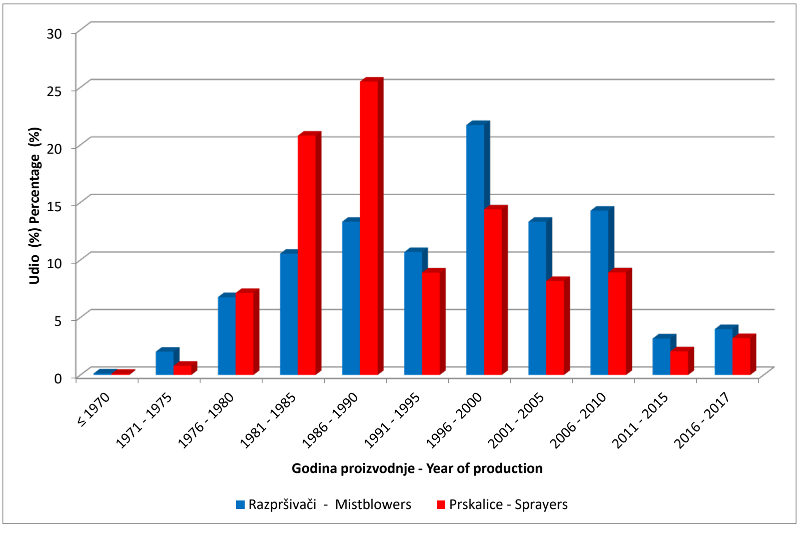
METODIKA

U sastavu Ministarstva za poljoprivredu, šumarstvo i prehranu Republike Slovenije nalazi se i Uprava Republike Slovenije za sigurnost hrane, veterinarstvo i zaštitu bilja. U njihovom radnom području su i pesticidi. Na tom području pokrivaju i strojeve za primjenu pesticida i njihovih redovitih pregleda. Na internetskoj stranici http://spletni2.furs.gov.si/FFS/FFSNaprave/ nalazi se baza podataka o pregledanim strojevima za primjenu pesticida sukladno zahtjevima Pravilnika o zahtjevima za pravilno funkcioniranje strojeva za primjenu pesticida te o uvjetima i načinu obavljanja njihovih pregleda (Pravilnik o zahtevah glede pravilnega delovanja naprav za nanašanje fitofarmacevtskih sredstev in o pogojih ter načinu izvajanja njihovih pregledov, 2013). U ovoj podatkovnoj bazi korišteni su podaci o pregledanim strojevima za primjenu pesticida u 2017. godini. Podaci su statistički analizirani sa deskriptivnom statistikom.

REZULTATI I RASPRAVA

Iz registra Uprave za sigurnost hrane, veterinarstvo i zaštitu bilja analizirali smo strojeve za aplikaciju pesticida pregledane u 2017. godini. Analizirano je 8.302 strojeva, od toga bilo je 5.492 prskalica (66,2 %) i 2.808 raspršivača (33,8 %).

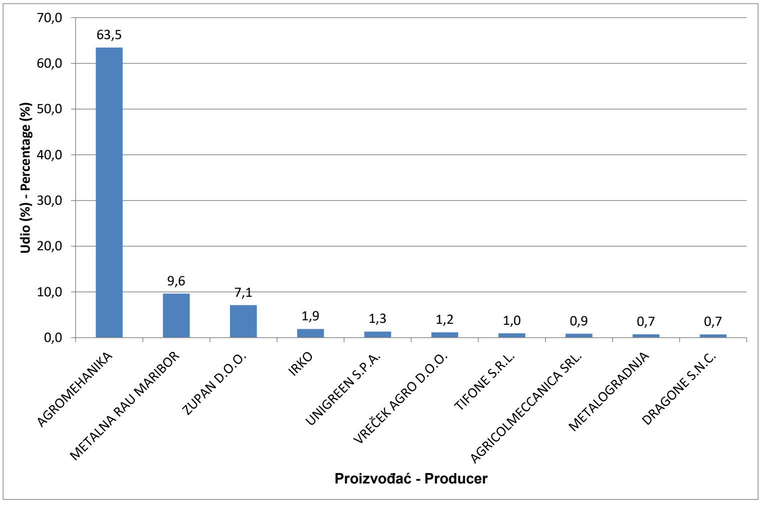
Slika 1 prikazuje udio prskalica i raspršivača pregledanih u 2017. godini prema godini proizvodnje. Modus (najčešće pojavljivana godina proizvodnje) kod raspršivača je godina 1999., a kod prskalica 1988. I iz toga proizlazi da su prskalice u prosjeku starije od raspršivača. Najviše prskalica je proizvedemo u razdoblju od 1986. do 1990. godine i to čak četvrtina svih prskalica pregledanih u analiziranoj godini. Slijede prskalice izrađene između 1981. do 1985. godine sa skoro 20 % udjela. Kod raspršivača imaju najveći udio od 21,7 % strojevi izrađeni između 1996. i 2000. godine. Slijede raspršivači izrađeni između 2006. i 2010. godine sa 14,2 %. Najstarija prskalica izgrađena je 1967. godine, a najstariji raspršivač potječe iz 1970. Ukoliko se pogleda starost strojeva od 2011. do 2017. vidljivo je da s u poljoprviredni proizvođači više nabavljali raspršivače nego prskalice.



Slika 1 Godina proizvodnje prskalica i raspršivača pregledanih u 2017. godini
Figure 1 Year of production of mistblowers and sprayers, which have been tested in the year 2017

Slika 2 prikazuje proizvođače strojeva za primjenu pesticida sa najvećim postotkom strojeva pregledanih u 2017. Godini. Kod pregledanih strojeva u 2017. godini utvrđeno je 109 različitih proizvođača. Od toga 31 proizvođač zastupljen je samo sa jednom prskalicom ili raspršivačem te 102 proizvođača s udjelom manje od 1 % od svih strojeva pregledanih u 2017. godini. Najviše strojeva za primjenu pesticida potječe od Slovenskog proizvođača Agromehanike (kod njih su uključeni i strojevi KŽK, koja je bila prethodnica Agromehanike). Agromehanika ima 63,5 % ili 5.267 strojeva. Slijedi Metalna Rau Maribor sa 9,6 % i Zupan sa 7,1 %. Dakle prva tri proizvođača su iz Slovenije i imaju ukupno preko 80 % strojeva. Ove brojke sukladne su sa rezultatima za 2016. godinu i godine od 2010. do 2016. (Poje, 2017a; Poje, 2017b)

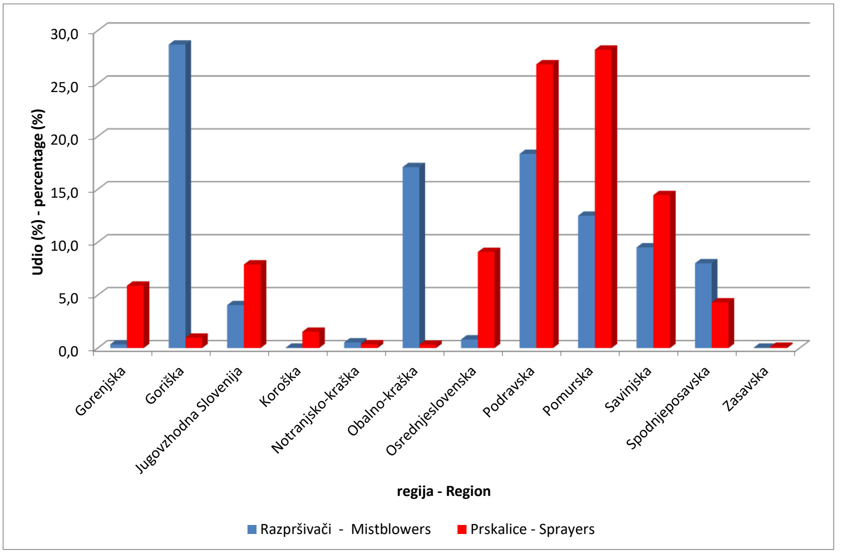
Slika 3 prikazuje udio prskalica i raspršivača u odnosu na statističke regije u Sloveniji. Vidljivo je da statističke regije Jugovzhodna Slovenija, Koroška, Notranjsko kraška i Zasavska ne znače puno u poljoprivredi Slovenije ili je tamo takva poljoprivredna proizvodnja koja ne treba prskanje. Kod raspršivača vidljivo je gdje je najviše vinograda i drugi trajnih nasada (Goriška, Podravska, Obalno kraška regija). Najveći dio prskalica je u regijama sa vrlo razvijenom ratarstvom (Podravska i Pomurska regija).



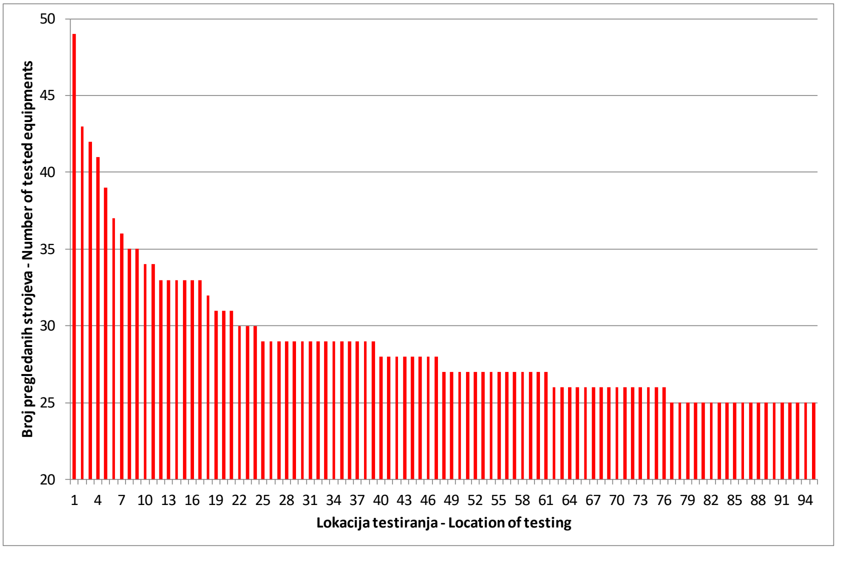
Slika 2 Udio pojedinog proizvođača strojeva za primjenu pesticida (prvih 10) pregledanih u 2017. godini
Figure 2 Share of individual producers (top 10) of pesticide application equipment tested in the year 2017

Slovenija ima 8 ovlaštenih ispitnih stanica za redovite preglede strojeva za aplikaciju pesticida. Rade prema teritorijalnom principu. Datum pregleda i lokacija zna se unaprijed i nalazi se na Internet stranici Uprave Republike Slovenije za sigurnost hrane, veterinarstvo i zaštitu bilja i na internet stranici ispitne stanice. Vlasnici strojeva dobivaju i pismeni poziv na pregled strojeva za primjenu pesticida. Prije nekoliko godina poljoprivrednik nije mogao dobiti subvencije ako nije imao pregledanu prskalicu ili raspršivač. Sustav pregleda je u Sloveniji dobro postavljen i transparentan. Metodika pregleda je propisana, a rad nadgleda Uprava Republike Slovenije za sigurnost hrane, veterinarstvo i zaštitu bilja i dva inspektora za poljoprivredu. Zvanično nema nekih velikih nedostataka kod obavljanja pregleda. Po drugoj strani interesantan je podatak o broju pregledanih strojeva za primjenu pesticida na istoj lokaciji na isti dan. Kod analize broja radnih dana i lokacija pregleda utvrđeno je da su sve ispitne stanice zajedno pregledavale 541 dan. 110 dana bilo je pregledanih do 3 strojeva na dan. Ako pogledamo preostale preglede razvidno je da je najviše pregledanih strojeva u jednom danu na jednoj lokaciji bilo 49 strojeva. Modus – (najviše dana sa istim brojem pregledanih strojeva) je bio 23 stroja pregledanih na dan na jednoj lokaciji.

Na slici 4 prikazan je broj pregledanih strojeva na istoj lokaciji na isti dan. Prikazani su podaci kada je na isti dan na istoj lokaciji bilo pregledanih 25 ili više strojeva. Ovakvih lokacija odnosno dana ima 95, što je 17,6 % sa obzirom na sve lokacije i dane pregleda. Defays i Declercq (2018) ustanovljuju da ispitna stanica u Belgiji kod intenzivnog rada pregleda u prosjeku 10 do 15 strojeva za primjenu pesticida.



Slika 3 Udio raspršivača i prskalica pregledanih u 2017. godini prema statističkim regijama u Sloveniji
Figure 3 Share of mistblowers and sprayers, which have been tested in the year 2017, with regard to statistical region in Slovenia



Slika 4 Broj pregledanih strojeva prema lokacijama i danima. Prikazani su podaci gdje je na istoj lokaciji u istom danu pregledano 25 ili više strojeva.
Figure 4 Number of tested equipment with regard to location and day. Data is displayed where 25 or more equipment were tested on the same day in the same location.

ZAKLJUČAK

Iz podataka Uprave za sigurnost hrane, veterinarstva i zaštitu bilja ustanovili smo, da se je 2017. godine pregledalo 8.302 stroja za aplikaciju pesticida. Više od 80 % prskalica i raspršivača proizvedeno je u Sloveniji. Prva tri mjesta u udjelu strojeva zauzimaju Agromehanika, Metalna Rau Maribor i Zupan. Prskalice su u prosjeku starije od raspršivača. Veliki broj strojeva za aplikaciju pesticida je tehnički zastarjelo, mada još odgovaraju zahtjevima na pregledima. Zato je još značajnija pravilna upotreba strojeva kod primjene pesticida.

Strojevi za primjenu pesticida navedeni u bazi pregledanih strojeva za 2017. godinu ispunjavaju minimalne zakonske zahtjeve. Pravilnom primjenom može se i sa takvim strojevima dosta dobro izvesti aplikaciju pesticida, no aplikacija je puno lakša ako se izvodi suvremenim strojevima. Trenutno postoje komercijalno dostupni strojevi i uređaju koji mogu povećati kvalitetu aplikacije i sigurnost korisnika (dodatni rezervoar za miješnja pesticida, zatvoreni sustavi za pretakanje pesticida, GPS navođenje prskalice, zatvaranje - otvaranja pojedine sapnice itd.).

Kod upotrebe strojeva za aplikaciju pesticida ustanovljeno je da vrlo malo korisnika provodi kalibraciju prskalice ili raspršivača prije sezone prskanja. Ovaj postupak često miješaju sa redovitim pregledima, koje izvode ovlaštene ispitne stanice, a kalibracija je jedan od temelja dobre aplikacije pesticida.

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ANALYSIS OF PESTICIDE APPLICATION EQUIPMENT INSPECTED IN THE YEAR 2017 IN SLOVENIA

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ABSTRACT

Regular inspection of pesticide application equipment is performed to verify whether they meet certain technical requirements to achieve a high level of human, animal and environmental health protection. The pesticide application equipment inspected in 2017 in Slovenia was analysed. Manufacturers, equipment age, equipment distribution by statistical regions and number of equipment tested per day for each test station were analysed. In Slovenia 8,302 units of pesticide application equipment were inspected in the year 2017 regarding the database of the Administration of the Republic of Slovenia for Food Safety, Veterinary and Plant Protection. 66,2 % of them were sprayers and 33,8 % were mistblowers. Sprayers were older than mistblowers. A quarter of sprayers were made between the years 1986 and 1990. Between producers of sprayer and mistblowers the share of Slovene company Agromehanika is 63,5 %.

Keywords*: sprayers, mistblowers, inspection, number of units, age, manufacturer*

47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Stručni rad
Expert paper

TECHNOLOGY FOR A 'BABY LEAF' PRODUCTION OF A CORN SALAD AND RADICCHIO

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SUMMARY

Production potential of Corn salad (Valerianella locusta) and Radicchio (Cichorium intybus var. foliosum Radicchio Group) were studied for a 'baby leaf' young cutting leaves. Research took place in experimental plastic greenhouses, at the University Agricultural Center in Pivola. That is part of the Faculty of Agriculture and Life Sciences, Maribor. Baby leaf-young leaves are used in various salads and in the preparation of a wide variety of dishes. In the good technological conditions young leaves could grow very fast. Experimental treatments included sowing in a plateau of polystyrene with 160 holes. We tested 1 or 2 seeds per hole. Half of the experiment was fertilized with water-soluble fertilizer Rosasol N20:K20:P20, on the other half we used only water. Two different types of Klasmann substrates, tray substrate and bio potgrund were used. We weighed (g) the Radicchio yield 21st day after sowing. On the 30th day after sowing we weighed the Corn salad. Crops in the non-fertilized variant are, as was expected, lower, and the quality of the plants is lower. The higher yield was detected in a tray substrate. It is necessary to make a calculation if the additional yield in two seeds per hole covers the costs of the seeds and the costs of additional work with sowing. High density of the plants causes the greater possibility of fungal diseases, competition for light and nutrition. In this work we present the crop yield, technology that was used and overall conditions.

Keywords: *substrate, greenhouse, 'baby leaf', yield*

INTRODUCTION

Consumer demand for high-quality, fresh-cut vegetables has increased rapidly in the last decades. Fresh cut vegetables contain many vitamins and minerals which are very important in the process of metabolism in the human body. Vegetables are important part of healthy eating and provide a source of many nutrients, including potassium, fibre, folate (folic acid) and vitamins A, E and C. Potassium may help to maintain healthy blood pressure. Dietary fibre from vegetables helps reduce blood cholesterol levels and may lower risk of heart disease (Choose my plate, 2018)

Hymans has been cultivating vegetables for a long time in similar ways that we do today in the hydroponic systems. Plants can grow directly on water or can be precise regulated by the irrigation. An amount of oxygen in the water and an appropriate level of nutrients in the growing medium is very important in production process. By 1519, when the first Spanish conquerors landed in Hernan Cortes in Mexico, the Aztecs controlled the empire in which five to six million people lived. This meant that the exploitation of land for agricultural purposes had to be strengthened. This is evident from the use of the ‘chimpas’ system, the so-called ‘floating gardens’ found on the shallow lakes of the Mexican valley. This is one of the first known hydroponics systems in the world. (Ancient Origins, 2014). In 1948 the English agricultural engineers presented hydroponics to the poor Bengals (Kogoj Osvald and Osvald, 2005).

The corn salad and radicchio production for young cut 'baby leaf' leaves in Slovenia is located in closed, temperature secured rooms on mobile tables or on the ground. The production could be also on the fields outside. The differences are between the production technologies. Glass greenhouses and plastic houses are suitable. The usual size of the production table is 2 m x 10 m. In one greenhouse 20-25 tables are mounted. If the vegetable is grown on the ground, the work is still demanding, and in this case, it is advisable to use machinery and machines adapted to sowing, cutting and picking salad, which represents a big financial contribution. In Slovenia, movable tables are mainly static and can’t be moved and run across rails to another place where they would be driven across the cutting machine and cut all the table at the same time. Since this type of technology represents a great deal of time and a lot of manual work, many other procedures have been invented (figure 1).

Figure 1 Quick cut greens harvester.

There are quite a number of companies involved in the production of cutting machines. It is also necessary to connect the technology of salad production and salad harvesting to work quickly and with the lowest possible costs. To start production, it is necessary to test the growing conditions, harvest and marketing. Investment in machine high technology is very expensive.

Both types of chicory can tolerate fall frosts very well, although growth in very cold weather is slow. Leafier plants and varieties are harder and may be cut even when completely frozen. After thawing slowly, the damaged outer leaves can be peeled away leaving the head itself in usable condition, although not necessarily marketable (Radicchio and Sugarloaf, 2016).

Dalla Costa (2011) reported that soil temperature has a crucial impact on physiological processes and growth of plants with important consequences for plant productivity and food safety including nitrate accumulation in leaf blades of leaf vegetables. The researches made temperature modulation which should help in nitrate concentration control in fresh vegetables, an important trait of product safety. Corn salad plants (Valerianella locusta (L.) Laterr. Cultivar Gala) were grown at three root temperatures (15, 20, and 25 ºC) in a floating system. This experimental setup allowed to directly evaluate the effect of root temperature on yield and plant quality excluding the effect on soil processes and properties. Results showed that growing conditions at 20 ºC of the nutrient solution led to the best plant performance in terms of yield, nitrate content at leaf level, root biomass, leaf area, and greenness with positive effects on postharvest quality, i.e., less rapid leaf loss of greenness and leaf fresh weight (FW) loss during conservation at 4 ºC. Plants grown at 15 ºC showed minor growth, whereas the nutrient solution at 25 ºC caused stress for the plants affecting negatively the quality and yield. Overall, the results obtained showed that root temperature plays a fundamental role in several plant processes that affect yield and its quality; for hydroponic system cultivations, a level of growing-medium temperature close to that of the surrounding air seems suitable.

Petropoulos (2016) reported that there has been a growing trend towards cultivating leafy vegetables in hydroponic systems. Floating system is an alternative hydroponic system suitable for the production of baby vegetable products, ready-to eat salads and minimally processed leafy vegetables. Due to the higher and higher demand of vegetables, various production techniques are tested. Plants grow without the presence of earth. Roots can float in water, above them are polystyrene plate with plants. All nutrients are dissolved in the water and ventilation should be well organized. Often an inert rock wool medium is also used, offering space for the roots. Salad and other vegetables have been used as a sedative for centuries. Successfully cleans and regulates blood pH (reduces acidity). It is highly recommended for heart and kidney patients (Kogoj Osvald and Osvald, 1994). It is also very useful to add carbon dioxide (CO_2) every week. When it is used properly, we can increase the crop by 25%. (Đubrovka et al., 2006).

MATERIALS AND METHODS

An autochthonous Slovenian variety, Radič Tržaški solatnik/Zuccherina di Trieste was chosen. Seeds sprout for 5-14 days. It is a chopper cutter, whose tasty fine, light green leaves are cut all year. Very good wintering. If we root the roots, we produce fine, bright yellow delicious heads. Fresh salad from summer to spring! Light green, smooth and gentle leaves grow well. After thinning, it develops pointed, green heads. We remember that the leaves remain gentle and dressed.

As a corn salad we choose a cultivar Motovilec Ljubljanski. It has dark green, long, bright and very delicious leaves. We maintain a variety in Slovenia. It originates from Ljubljana and its surroundings.

Figure 2 Sowing the seeds in a polystyrene plateau, 160 holes, 1 seed per hole.

Treatment included sowing in a plateau of polystyrene with 160 holes per 1 or 2 seeds per hole (figure 2). After sowing, the plateau was left in the calliper (figure 3) at a temperature of 28 °C, and relative humidity of 96% until the next day. The seeds wait about 20 days for corn salad in the caliper. We have to be in the last days very careful in the calliper, because young germs would quickly 'overgrow'. Half of the plateau was fertilized with water-soluble fertilizers Rosasol N 20: P 20: K 20, the other half of the plateau was only watered. We used two different types of Klasmann substrate, namely tray substrate and Bio potgrund. The yield of the radicchio weight (g) of one hole was weighed on the 21st and 28th day after sowing. At the Corn salad the weighing took place at 30th and 39th days after sowing. For corn salad we have weight the mass of 5 holes. With one seed we sown 4 plates in a tray substrate and 4 plates in a bio potgrund substrate. With two seeds, we also sown 4 plates in a tray substrate and 4 plates in a bio potgrund substrate. Then we split the plateau into half. One half was just watered, the other half was fertilized with Rosasol N 20: P 20: K 20, at a concentration of 3 grams per litter of water. This is 1 g of fertilizer more as we did last year at the cultivar Lettuce Ljubljanska ledenka (Kelc et. al., 2018).

Figure 3 Plateaus stacked in calliper at 28 degrees Celsius.

The first weighing of the Radicchio took place 21 days after sowing and the second 28 days after sowing of Radicchio. At the Corn salad the weighing took place at 30th and 39th days after sowing.

RESULTS AND DISCUSSION

The experiment shows that Radicchio leaves are not commercial developed enough 21 days after sowing for sale, as their weight (g) is too small compared to day 28 after sowing. Crops in the non-fertilized variant (especially in the case of two seeds per hole) are expected to be too low, and the quality of the plants does not reach the market quality. We note that crops are the highest in the case when fertilizer is used. Which means that the use of fertilizers is necessary in the case of commercial growing vegetables for the market. The big difference is in the harvest on the 21st or 28th day after sowing. The two seeds in the fertilized tray substrate 21 day after sowing yield 1.3 g of the crop. Already on the 28th day the yield is 4.1 g per hole. The difference is more than 3 times.

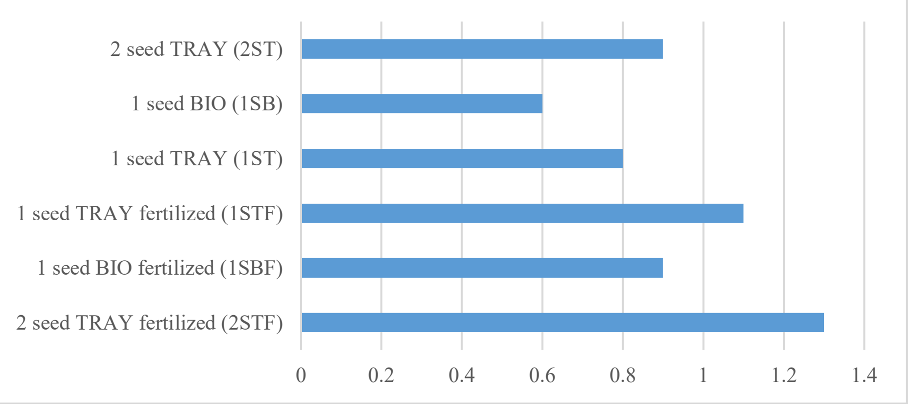

Figure 4 Radicchio production per hole (g) on the 21st day after sowing

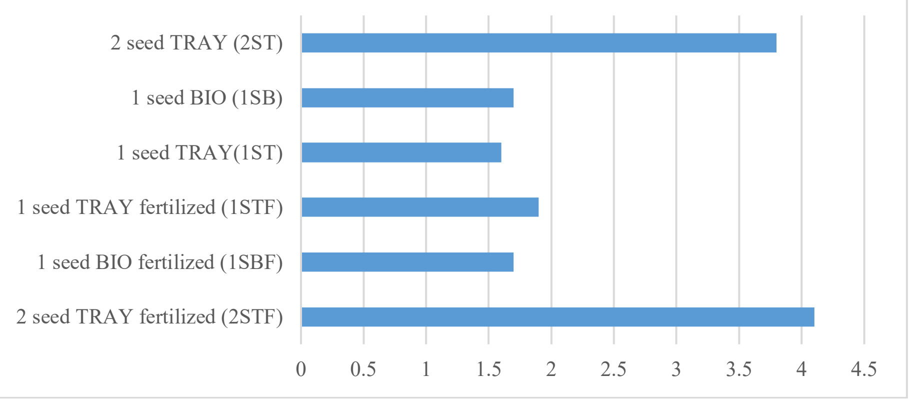

Figure 5 Radicchio production per hole (g) on the 28st day after sowing

A very big difference is also when using 2 or 1 seeds per hole. Day 28 in the fertilized tray substrate and 2 seeds give us 4.1 g of crop to the hole. If we use one seed, the yield is reduced to 1.9 g. There is a very large difference indicating that in the case of Radicchio, sowing of two seeds should be used, because only in this way we can expect competitive crops for the market production. Compared with our previous study on salad (Kelc et. al., 2018), this means that the price of additional seed represents a cost that would be recovered in the production process. At the Radicchio production, we recommend the sowing of two seeds into one hole in a 160-hole polystyrene plate. It is interesting that if the fertilizer is used, the difference in the higher yield is only 7.3%, which is really small and hardly covers the extra work and fertilizer costs. It may be better if we can test the effect of fertilizer after the first cut in the next growing period. The level of fertilizer in the substrate would be significantly smaller and the additional fertilizer would be very welcome. Due to the higher price of the bio substrate and smaller crops, we recommend for a Radicchio tray substrate or some comparable substrate.

Petropoulos (2016) reported that increasing the N application rate resulted in an increase of fresh weight of the above-ground parts of lettuce. Total yield ranged between 12.0 to 41.9 kg m^{-2} of fresh 'baby leaf' leaves. Richardson and Redgrave (1992), reported that not only temperature but also nitrogen fertilizer rate may affect head weight and total yield of lettuce grown in a glasshouse. Kotsiras et al. (2016) find out significantly lower total yields than at the present study. This was 4.0 to 9.0 kg m^{-2} of fresh weight. Difference could be attributed to the different lettuce types (Lollo Rosso and Batavia) and plant densities (20- 30 plants m2), comparing to further study. There was also a clear indication that harvest practice significantly affected storage life (SL), relative fresh weight (RFW) and visual appearance rating (VAR) of all lettuce types.

For corn salad we have 39 days after sowing at least 2 times higher yield than 30 days. The difference in weight is 101 grams. This is high and it is highly recommended to cultivate 39 days after sowing. A very good results were achieved with bio substrate in growing corn salad. In the case of fertilizing the bio and tray substrate and using of 1 seed in the bio substrate and 2 seeds in the tray substrate, the bio-substrate has only 7% smaller yield. Here it is very important to do another experiment with sowing 2 seeds in a bio substrate. It is assumed that the yield in this case would be even better than the tray substrate. This suggests that before starting the production it is advisable to do a search of several different methods of production.

Our sowing plates have a dimension 520 mm x 323 mm. On a table of 20 m^2, lay 120 plates. 590 g can be the best result for corn salad on one cultivation plateau. At 1 m^2, we had 6 plateaus. This represents 3540 g per 1 m^2 of greenhouse surface in 39 days. Price for 1 kg of a Corn salad is at local market 12 €. This would mean 42 € revenue per square meter. If we made a big effort, we could have 9 growth cycles throughout the year. 378 € is a hypothetical profit in one year per 1 m^2 of surface. If we have a medium-sized greenhouse of 10 m x 20 m, we could earn on 180 m^2 of 68 040 € in one year on the assumption that we would sell all the production at the market, or at home for 12 €/kg. Corn salad can't be grown throughout the year, but we could earn a profit, because of the combination in the culture where we can expect the price of 8 € m^{-2}. So, the profits would be reduced by some 30%. For a 'baby leaf' lettuce we can get 8 €/kg and for Radicchio at least 10 € m^{-2}. Earnings would still be very nice, 47,600 € per year. Of this income, the entire family could live. For young families that are thinking of having a Farm, this news is very encouraging.

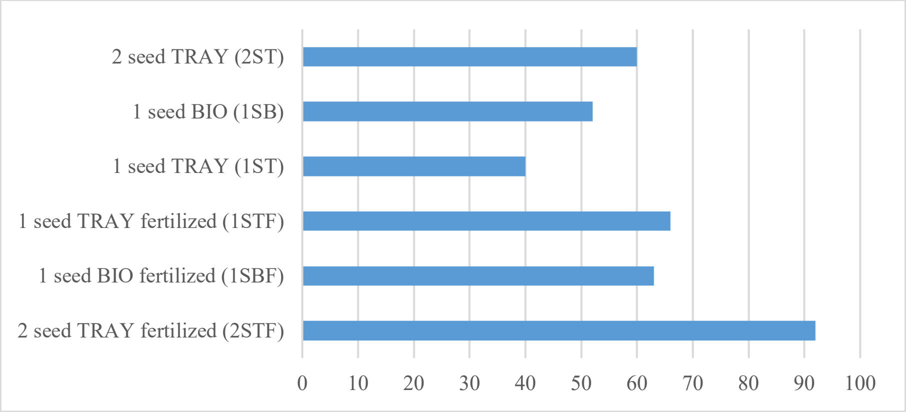

Figure 6 Corn salad production per hole (g) on the 30th day after sowing

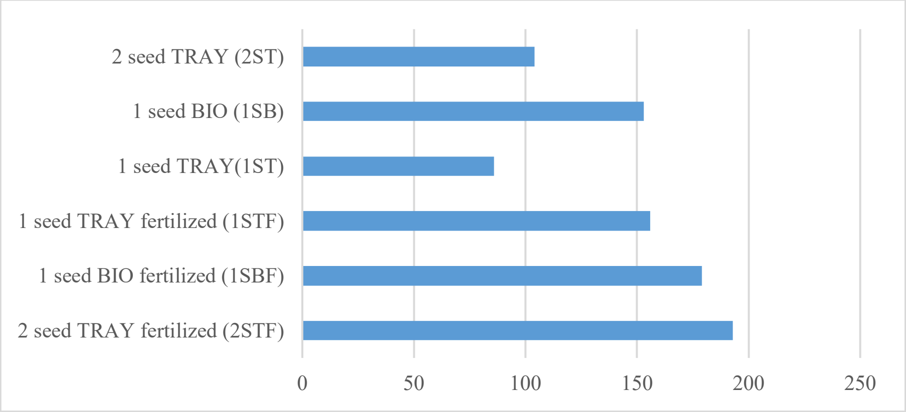

Figure 7 Corn salad production per hole (g) on the 39th day after sowing

CONCLUSIONS

In the research greenhouses of the University Agricultural Center at the Faculty of Agriculture and Life Sciences Maribor, we have tested the production potential of Corn salad *(Valerianella locusta) and* Radicchio *(Cichorium intybus var. foliosum* Radicchio Group*)*. We planted 1 and 2 seeds in a 160-hole plate with polystyrene. Half of the plates were fertilized with Rosasol N20:P20:K20. We used two Klasmann substrates, a tray substrate and a bio potgrund. The yield per hole (g) was weighed on the 21st and 28th day after sowing for Radicchio and at 30th and 39th days after sowing for Corn salad. At the Radicchio production, we recommend the sowing of two seeds into one hole. Leaves are not developed enough 21 days after sowing for sale, as their weight (g) is too small compared to day 28 after sowing. The highest yield we achieved at day 28 with 2 seeds and with use of fertilizer. For Corn salad we have 39 days after sowing 2 times higher yield than 30 days. It is highly recommended to cultivate till day 39. A very good results were achieved with bio substrate in growing corn salad, with almost the same quantity of crop as a tray substrate. We also propose fertilization at each watering in the amount of 3 g of fertilizer per litter of water. We estimated that an additional crop with two seeds does cover the cost of additional seeds. The production of young cutting leaves has potential to be very interesting and a well-accepted strategy on the competitive market. For farms, it can represent significant income as a basic or additional activity.

ACKNOWLEDGEMENTS

The results presented are an integral part of the project CRP V4-1815 entitled "Reducing of draught stress and increasing of soil fertility by introducing conservation (conservation) soil tillage into sustainable agriculture", which is financed by the Slovenian Research Agency and the Ministry of Agriculture, Forestry and Food of the Republic of Slovenia.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

PRELIMINARY RESULTS ON BLOOMING CHARGE ASSESSMENT IN APPLE ORCHARDS FOR AUTOMATIC THINNING ACTIVITIES

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ABSTRACT

The aim of this work is to develop an automatic system able to provide objective information about the bloom charge in apple orchard to be used as managing tool for flower thinning activities. Usually, this procedure is carried out manually, based upon the personal experience of the operator. The paper presents and discusses the use of a mobile lab (ByeLab) to carry out a site-specific bloom charge assessment in apple trees using optical sensors. The Byelab has been equipped with several sensors, such as a GNSS-RTK system, three optical sensors (OptRx) two LiDAR sensors and an Inertial Measurement Unit (IMU). While the OptRx and LIDAR have been used in order to provide Vegetation Index (VI) and to detect the surface profile of the scanned canopy, the GNSS-RTK unit has been used to georeferencing all the data collected by the optical sensor and the LIDARs. Finally, the IMU has been used to correct the acquired dataset filtering noises and distortions due to the vibrations generated by terrain roughness.

LabView application has been used in order to synchronize data collected by sensors. Then, all the acquisitions have been processed by specific algorithm implemented in MatLab.

Three surveys carried on April 2018 in order to cover the whole blooming period: pre-blooming, full-blooming and post-blooming.

Before running ByeLab field tests, thanks to preliminary investigations on flower reflectance signature it has been possible to understand that the NDVI can be the most suitable parameter to be used to discriminate leaves from flowers. Indeed, the NDVI value has a negative correlation with the bloom charge since pure flowers shown NDVI values slightly negative, anyhow very near to 0.

Despite the homogeneous behavior of the flower NDVI response, the use of OptRx sensors, since they give back an average assessment of an area, was not able to highlight significant correlations between the number of flowers and the NDVI values. In the future, further studies will be conducted in order to assess if other techniques based on image analyses can give back better and more sensitive results regarding the bloom charge assessment. Those results can be used as reference for automating machines to be applied in thinning operations according to a site-specific approach.

Keywords: *Optical sensors, Mobile lab, Precision Farming, Ground based sensing, Vegetation Index.*

INTRODUCTION

The flower thinning is one of the most important agronomical operation in apple orchard management. It consists in the removal of a quantity of flowers to ensure an appropriate rate of them as well as of the fruits. This procedure can be done with manually or mechanical methods or, through the spraying of chemicals products (Xiao et al., 2014). The two last methods are done in order to reduce the operative cost of the first methods. In order to perform a correct thinning, it is necessary estimate the density of the blooming charge. Usually, this procedure is carried out by specialized staff, based upon the experience of the operator with an important time spending. The ground remote-sensing technologies can be useful to automate these procedures. Indeed, through the use of optical sensors installed on vehicles (aerial or terrestrial), they are able to provide punctual information, about the crop, such as: bloom-charge, canopy volume, distance between plants, number of trees or healthy status of the monitored crop (Rosell et al., 2009, Ristorto et al., 2017, Gallo et al., 2017). In this paper is described the use of a mobile laboratory equipped with several sensors, called ByeLab, at the aim to evaluate its ability provide objective information about the bloom charge in apple orchard to be used as managing tool for flower thinning activities.

MATERIALS AND METHODS

The testing-area consists of two rows with plants of *Malus domestica* variety Kanzi® located to the "Azienda sperimentale Laimburg", Bolzano, Italy. The single rows are divided in several transept trained with alternate system (2D and Spindel).

First of all, the manual count of the flowers has been made in order to know the real number of flowers per plants. The data obtained were used for data validation of the assessment performed with those collected by the ByeLab.

Three surveys with the ByeLab, in April 2018, were carried out in order detect the blooming charge during the whole blooming period: pre, full and post-blooming (Fig. 1).

Figure 1 From left to right, apple tree in the phases of pre, full and post-blooming.

The experimental design foreseen to carry out three repetitions for each semi-canopy, in every survey day.

The Byelab (Fig. 2) is a modified tracked bins-carrier (NEO Alpin by Windegger S.r.l., Lana, Bolzano, Italy). It is electric-driven and wireless remote-controlled vehicle with compact dimensions and for this experimentation it has been equipped with:

- GNSS system (GEOMAX Zenith 35);
- three OptRx™ AgLeadear optical sensors able to measure the reflectance and calculate VI values;
- two LiDAR (SICK LMS111) sensors used to detect the profile of the canopy;
- an Inertial Measurement Unit (IMU) (LMRK 10 AHRS) able to get data on the mobile robot orientation (to be used to correct sensor data when influenced by relevant vibrations generated by terrain roughness).

Figure 2 The ByeLab

The sensors have different sample acquisition frequency, then, thus collected data are firstly synchronized by a LabView® software, running on the control unit. Then, the recorded data has been processed by dedicated algorithms in MatLab®.

In order to better evaluate the features of the flower reflectance signature some preliminary investigations were performed before running ByeLab field tests. To this aim, a portable spectrophotometer (Jaz Ocean Optics Spectrometers) was used to analyze the different reflectance behavior of different plant organs (petals, corolla, flowers, leaves, trunks) in order to better understand the VI measures got by tools, such as OptRx ™. From the values of the reflectance at the RED, RedEdge and NIR wavelengths several vegetation indexes have been calculated.

The information related to the canopy thickness, collected by the LiDARs mounted on the ByeLab, were validated using a Terrestrial Laser Scanner (TLS) (model CAM2 FARO). The raw-data collected by TLS were elaborated with FARO Scene 7.1.1 software in order to obtain a 3D model to compare with that obtained by LiDARs.

RESULTS AND DISCUSSION

From the analysis of the spectral signature, it is possible to see that for the same plant organ (flowers and leaves), sampled from different trees, spectrums have similar patterns, but they present different values for the same wave length (Fig. 3).

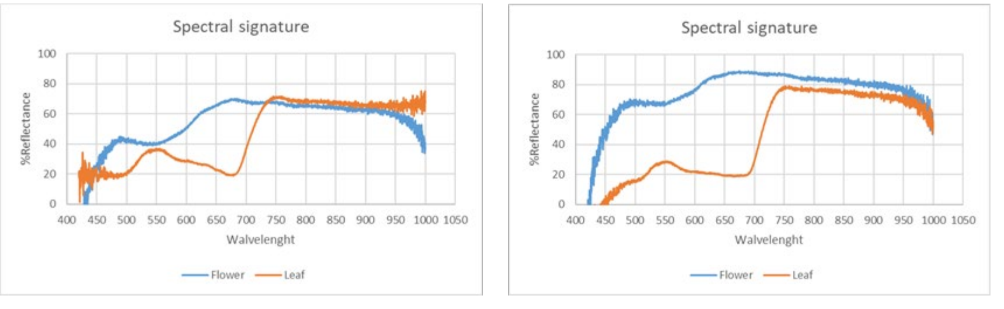

Figure 3 Spectral signature of two pairs of flower and apple leaves collected from different trees.

This issue is overcome through the VI computation, able to confirm the pattern differences while disregarding absolute values on single wavelengths. In addition to the VIs already well known in literature (eg. NDVI), new specific VIs has been tested in order to better consider the specific signature shape of flowers. From the tests done it has been possible to understand that the NDVI can be the most suitable parameter to be used to discriminate leaves from flowers. Moreover, it was observed that low and high NDVI values correspond to the flowers and to the leaves, respectively (Fig. 4).

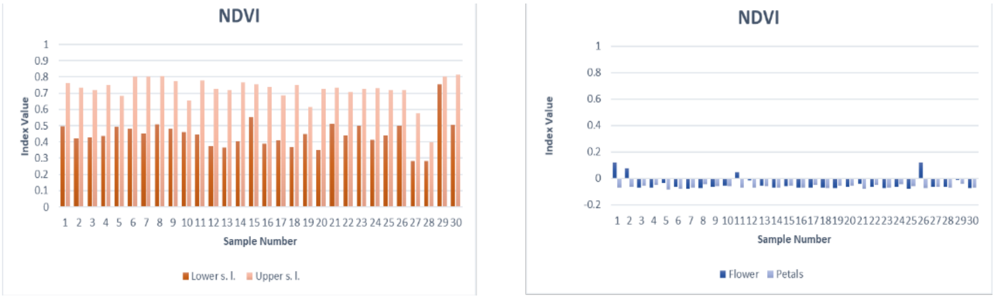

Figure 4 NDVI index associated to lower and upper surface of leaves (on the left) and to flowers and petals (on the right). Pure flowers show NDVI values slightly negative, anyhow very near to 0.

Considering the values of the NDVI associated to the flowers and leaves, from the elaboration of the data collected with the ByeLab we expect a negative correlation between NDVI value and number of flowers: the lower the NDVI value, the higher the charge of blooming. In figure 5 the expected behavior between amount of flower and NDVI value is reported.

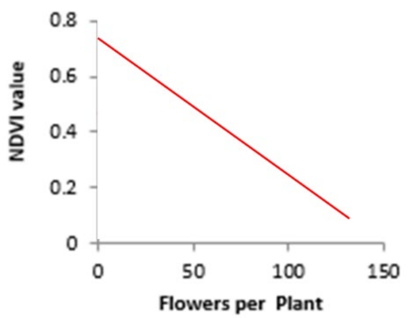

Figure 5 Expected correlation between NDVI value and amount of flowers.

Comparing the TLS and ByeLab (LiDAR) scans there is an evident stretching of the image and consequently measures of the latter when the top view scan is considered (Fig. 6). Reason for that could be a time delay in the communication with LiDAR and GPS, due to a difference in the acquisition frequency as well as the difference characteristics of the two surveys: the TLS carries out static measurements while the ByeLab does dynamic assessments. However, from the images it is possible to get, even if approximatively, important information, such as the change in training, the thickness of the canopy, identification of small plants, gaps between plants, poles of irrigation system and of training system.

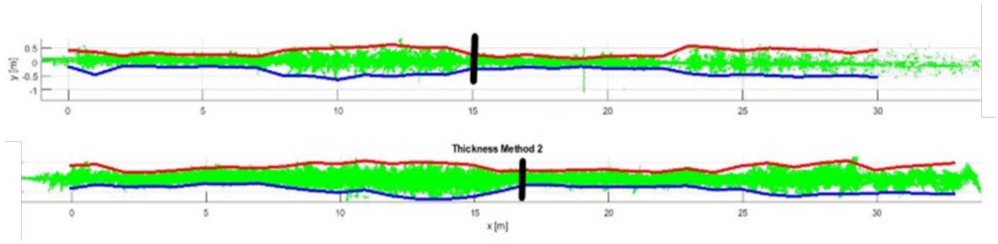

Figure 6 Top-view TLS (above) and ByeLab (below) scan of row. In black the point of change in training system. It is visible the stretching between the two scans.

Another output of the research is the drawing of descriptive maps (Fig. 7) related to the amount of flowers for three different heights of the canopy. This remarkable result was obtained by the merging of LiDAR and OptRx® data providing information about canopy thickness and NDVI index values. White and yellow colors have been associated with low NDVI values, then at a high number of flowers, while cyan and green colors are associated to high NDVI values and then at a low blooming charge. In pre-blooming can be noticed that the predominant colour is not green, as expected. This could be due to the fact that the leaves are still small and cannot be clearly percept by the sensors. In full blooming the white and yellow should increase, instead in the post blooming the cyan and green boxes should be predominant. These supplicative descriptive maps could be used as reference for automatic activation of machines (sprayers) and pruning activities. Taking care of these results a redesign of the system with two-dimensional and multi-parametric scans, which combine more signals would be necessary.

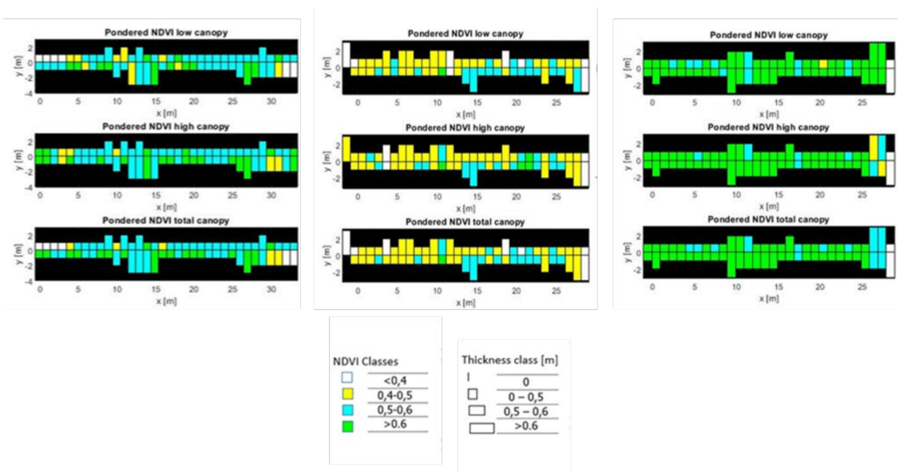

Figure 7 Descriptive maps of one row divided in equal sections along the longitudinal axle, showing NDVI classes (withe and yellow represent high and moderate blooming charge, respectively;while cyan and green represent moderate and high amount of leaves) and thickness classes for the canopy during the blooming period.

From the results obtained by the processing of the collected data with ByeLab it is evident that the NDVI trend in full blooming, compared with pre and post blooming, is always lower. This is due to the higher amount of white provided by the flowers.

However, the variation trend of the NDVI index, between absence of flowers and full blooming period (0.2-0.3), is really too scarce to set vegetative index threshold to be used as reference to estimate the density of blooms.

Considering the information obtained by the elaboration of the ByeLab surveys, is necessary to consider that sensors, such as the OptRx™ was not useful for the focus of the project. Indeed, these sensors perform mono-dimensional scans obtaining an averaged value of reflectance of an entire area dependent from the scan characteristics of the sensor. The obtained value depends by the actual composition (leaves, flowers, and surrounding) of the surveyed area.

The standard mono-dimensional scans, similar to the one used for the evaluation of the vegetative status of plants inside the orchards, results being not enough efficient for reaching the designated aim. This is due to the fact that the regulation gap can be too easily influenced by the background noise levels (variability of the signal) that are normally present. Nevertheless, as already demonstrated in other crop monitoring applications, the utility of these active sensors in Precision Agriculture applications is due to their cheapness, robustness and quick real time response (Maharlooeic et al., 2014).

CONCLUSION

Despite the homogeneous behavior of the flower NDVI response, the use of OptRx™ sensors was not able to highlight significant correlations between the number of flowers and the NDVI values. Thus, one-dimensional sensors - such as OptRx™ - do not seem suitable to be applied to perform an estimation of the flower charge. To increase the reliability of the system, a higher number of sensors per side (4 or more instead of 3) will be investigated in next field tests.

However, the combination of LiDAR and OptRx™ data is already able to improve the quality of the detection. In fact, merging the data collected by the two types of sensors it is possible to build descriptive maps, which provide information about canopy thickness and vegetation index values. These can be used as reference for automating machines to be applied in thinning operations according to a site-specific approach.

To propose future applications of a system, which is able to provide information about the condition of the crop in real time, it is necessary to evaluate the calculation time-consumption, for knowing if it is possible to get this system in practice.

It would be useful to evaluate the use of different algorithms, studying the correlations obtained by setting filters that give greater importance to the lower NDVI values found in the investigated areas.

To overcome the problem of the one-dimensional scan, two-dimensional scans, for example a pixel matrix, such as the one provided by multicameras, should be used. In this case, it could be possible to do a prelaminar classification of the area that should be referred to each specific vegetative part of the plant (flower, leaves, background).

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Pregledni rad
Review paper

SMALL GREENHOUSE ROBOTIZED SOLUTIONS: STATE OF THE ART AND FUTURE PERSPECTIVES

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SUMMARY

Nowadays, precision agriculture means also, the application of high technologies, such as automation, robotics and computing in the agriculture and, particularly in this case, the greenhouse farming. This paper was focused on the state-of-the-art analysis of the main robotized solutions available regarding greenhouse environmental monitoring and control and greenhouse agricultural works. The analysis aims to transfer solutions from general agrobots and cobots to greenhouse farming (GF). Since, one of the biggest encountered problems is the use of low cost robots for small farms greenhouses, the paper try to select the criteria (costs, technical capability, reliability etc.), to find the optimum solutions. The practical reasons involve: cost-efficiency of robotics, use of robots in safe conditions or knowledge transfer problem from farmers to the computer. The most important conclusions after questionnaire on 20 specialists (10 in robotics and 10 in greenhouse farming) were: agricultural tasks could be: transplanting and seeding, plant protection and weed control, harvesting and packaging; supporting tasks must be: guidance and navigation, mapping and location, fruit selecting and grasping; robot structure must include: 4 wheel steering system controlled by ultrasonic sensors, 2 controllers (ARDUINO OR RASPBERRY), binocular stereo vision, power supplying system and optional: 5 DoF harvesting system, 2 linear laser scanner. This work proposes a viable solution given by specialists, which could be implemented in the specified conditions of using the robots in greenhouses in the Romanian Banat area.

Keywords: *agricultural robotics, small greenhouse farming, optimization*

INTRODUCTION

In the last decades, extensive researches have been conducted in agricultural robotic field. Modern agriculture was developed constantly, and the applications on this case allowed the trends in technological advancements.

Increasing of the labor force costs, and decreasing of their disposability, the high volume of seasonal labor, the high quality agricultural products with respect to security, and reducing pollution produced by agricultural activities generates needs for automation (Zujevs et al., 2015; Adamides et al, 2017, Maris et al, 2017; Tucu et al, 2010; Bechar and Vigneault, 2016; Bechar and Vigneault, 2017; Ampatzidis et al., 2017).

According to Straten et al. (2011), the greenhouse industry will show substantial growth, especially in upcoming economies, over open air cultivation. Aravind et al. (2017) consider in their study that agricultural infrastructure is dynamic. Also, complex infrastructure and facilities with costly machines are required to completely automate an agricultural process and to integrate it (Mnerie et al, 2008).

In order not to spend considerable money on infrastructure, intelligent mobile robots (which possess specific task capabilities and that are able to move and adapt in the field) can be developed to reduce production costs, by involving the necessity of new methods in investments dimensions, as life cycle costs, fuzzy, or investments feasibility analysis (Tucu, 2012; Tucu et al, 2010; Tucu and Hollerbach, 2011).

Adamides et al. (2017) evaluated the HRI usability in a tele-operated agricultural robotic sprayer, for an effective and efficient human-robot interaction. They examined the influence of the output devices, the peripheral vision support mechanisms and the control input devices. A modular user interface was constructed and field-tested.

One of the most important tasks of the modern technology is the creation of autonomous machines that do not require constant attention, with small needs of maintenance and administration (Dokin et al., 2016). There are a lot of technologies, methods and algorithms, in exponential incretion, utilized and applied in agriculture for automated and robotic farming that can be transferred (adapted) to small greenhouses. Some of the actual subjects will be summarized in order to have an overall outlook about this subject.

This paper focused on the state-of-the-art analysis of main robotized solutions available regarding greenhouse environmental monitoring and control and greenhouse agricultural works. The object of analysis aimed to transfer solutions from general agrobots and cobots to greenhouse farming (GF). Because one of the biggest encountered problem was the use of low cost robots for small farms greenhouses, the paper tried to select the criteria (costs, technical capability, reliability etc.), to find the optimum solutions. The practical reasons involved: cost-efficiency of robotics, use of robots in safe conditions and knowledge transfer problem from farmers to the computer.

MATERIALS AND METHODS

Initially an overview regarding actual methods used for design and realization of robots in greenhouse was done. The significant ideas were registered. In second step of documentation the study was extended to main robotized solutions available regarding greenhouse environmental monitoring and control and greenhouse agricultural works. Based on such results a synthesis for comparison of the main robotized solutions given in the last three years by scientists, which could be used in greenhouses was accomplished.

The identified concepts were distributed in four sections:

1. Agricultural tasks: F1.1-F1.7;
2. Suporting tasks (functionalities): F2.1-F2.5;
3. Cost of the equipment: F3.1-F3.6;
4. Technical characteristics (robot structure): F4.1-F4.13 (see table 1).

Based on selected indicators a questionnaire was drafted and distributed to 20 specialists (10 in robotics and 10 in greenhouse farming), using the method of correlation of rank (psychological experiment), (Crisan et al., 2017; Gusetoiu et al., 2013; Gusetoiu et al., 2012).

The results were evaluated by statistical analysis, both Microsoft Excel 2016 and STATGRAPHICS Centurion, for correct and find the best solutions (in conditions of differences between specialists' opinions), maximum values and indicators hierarchy.

The most important conclusions of the work will serve to propose a viable structure solution given by specialists, which could be implemented in the specified conditions of using the robots in greenhouses in the Romanian Banat area, according to research cycle presented in figure 1.

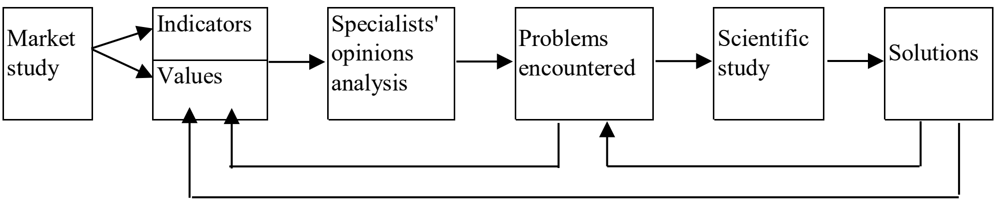

Figure 1 Research cycle

RESULTS AND DISCUSSION

The synthesis of the main robotized solutions given in the last three years by scientists, which could be used in greenhouses is presented in table 1.

Table 1 A comparison of the main robotized solutions given in the last three years by scientists, which could be used in greenhouses

Objective and Destination	**Method / Algorithm**	**Design and Realization**	**Performance / Experimental results**
1	**2**	**3**	**4**
Mobile robot with autonomous navigation inside a greenhouse (Harik et al., 2018)	• Hector Simultaneous Localization and Mapping (SLAM) algorithm • Artificial potential field (APF) method	• four wheels drive platform • four motors (max. 285rpm) • two 12V 18Ah batteries • 168MHz Cortex-M4F • Industrial grade embedded computer (ARK-1123H) with Linux OS • two GNSS receivers • an RGB camera • a LIDAR sensor	The robot is able to adapt to the structural changes due to the growth of crops while being safe to operate in the presence of humans

Table 1 cont.

Objective and Destination	**Method / Algorithm**	**•Design and Realization**	**Performance / Experimental results**
1	**2**	**•3**	**4**
Transplanting work cell for greenhouse seedlings (Han et al., 2018)	Dynamic accuracy test	• transplanting system (with multiple grippers) • 2 conveyors • filling unit • control system (with PLC)	90% overall success ratio 960 plants/h/gripper
Water irrigation in greenhouses for family farming (Batista et al., 2017)	3 axes Cartesian geometry	• Bosch motors • OEM drivers • Goldentec power supply • 2 controllers: ARDUINO Mega and One • JNG sensors	No statistical difference - manual irrigation vs robot
Selective spraying with pesticide in grapevines canopy (Oberti et al., 2016)	Integrated disease-sensing system	• Industrial PC with CAN interface • R-G-NIR camera • Precision-spraying end-effectors •Robotic arm 9 DoF	85%-100% of the diseased area, 65%-85% reduced pesticide area
Weed detection in sugarcane fields (Sujaritha et al., 2017)	Fuzzy real time classifier based on Image acquisition system	• Motors with power systems •Raspberry Pi microcontroller • Cameras • Small light sources	92.9% accuracy over a processing time of 0.02 s
Nitrogen fertilizing in hydroponic greenhouses – cucumber crop (Vakilian and Massah, 2017)	Autonomous machine vision-based robot with algorithm implemented in MatLab R2016b	• Robotic-based framework with 2DC motor-gearboxes • Computer • data acquisition kit (Arduino Mega) • CCD color camera • GPS module	Reduction of nitrogen fertilizer consumption - about 18% without lowering the fruit yield
Spraying in greenhouses (Gao et al., 2017)	● Dynamic sliding mode control ● D'Alembert's principle	• Motion subsystem: walking support chassis, units for: power energy and interface, sensory system, control system and peripheral loading • Control system: host comp ThinkPad X220, single-chip microcomp AT xmega64A3, DC motors and encoders	Good stability and precise tracking capability without understeer or oversteer. Turning right-angled successfully
Harvesting sweet-pepper in greenhouse (Bac et al., 2016)	• Collision detection • Selecting the azimuth angle	• Platform using the heating pipes as a rail system • 9DoF manipulator • Grasp end-effector	From 63% to 83% improved rate of success
Harvesting tomato in greenhouse (Wang et al., 2017)	• PID algorithm • Otsu algorithm • Elliptic template method • C-space method	• 4 wheel steering system • Binocular stereo vision • 5DoF harvesting system	99.3% success rate of ripe tomato recognition 86% rate of pitching
Automated harvesting of sugar snap peas in greenhouse (Tejada et al., 2017)	• Spectral reflectance analysis • Visual servoing method	• platform Superdroid • four 24V DC motors • onboard nCArbotiXRobo controller • IR sensor VishayVCNL4000 • USB3 vision CCD camera (NIR), Theia SY110M lens • 5 DoF robotic arm	54% success rate of the visual servoing trials on 22 untouched environments

Table 1 cont.

Objective and Destination	**Method / Algorithm**	**•Design and Realization**	**Performance / Experimental results**
1	**2**	**•3**	**4**
Monitoring environ-mental variables in green-houses (Roldan et al., 2016)	GNC algorithm based on sensors and ROS navigation stack	• 4-wheeled sensor platform controlled with embedded computer • 2 linear lasers scanners • Pan-tilt-zoom camera	8%-23% improved performance of the ground robot
Prototype mobile manipulator for different crops (Bascetta et al., 2017)	Model of a skid steering robot	• 4 in-wheel electric AC brushless motors • 12V lead acid deep charge batteries • STM32F405 microcontroller • CrustCrawler robotic arm	Valid design on a realistic agricultural trajectory, based on motor power and battery energy consumption simulation
Modular agricultural robot used in a wide variety of environments for seeding, weeding, liming, crop scouting (Grimstad et al., 2017)	• Ansys computer analysis tests for frame flexibility in the agricultural terrains • Robotics Operating System (ROS)	• re-configurable aluminum frame with different interchangeable modules • wheel drive modules (500W propulsion motor) and wheel steering modules with passive suspension • 48VDC Li-I batteries • on-board computer with Linux Ubuntu • VelodyneVPL-16 3D LIDAR • Xsenns MTi-G-710 GNSS/INS	The robot performs well in vastly different environments

Other significant elements can be noted. Thereby, Zaidner and Sapiro (2016) developed an algorithm for vineyard sprayer robot, by state estimation and localization for mobile robots with a method that can also be adapted to other navigation platforms. Four different sensors were tested (Global Positioning System, Inertial Navigation System, Visual Odometry and Wheel Odometry) and were considered suitable for a low cost navigation system. The results proved the feasibility of the MSPI (Maximum sum of probabilities intersections) algorithm. Another application using Visual Odometry as a tool for agricultural robotic navigation was proposed in Arbo, M. (2017), where the Bayesian formulation of fusing delayed displacement measurements is presented, with a solution based on unscented Kalman filter (UKF). Yin and Noguchi (2013), developed a target following system for a field robot, using as navigation sensor a 3D camera. The steering angle was calculated using the pursuit-strategy following method and the space keeping was realized using a PID controller. Sousa et al. (2013) presented a methodology for generating and implementing a complex row crop following behavior for a mobile agricultural robot by the use of Fuzzy rules to compose and coordinate the simple moves in a specific agricultural context and to perform the path tracking.

In Zaho Y.S. et al. (2016) a method for tomato recognition for robotic harvesting is proposed by the use of low-cost camera. Another paper is developing a real-time turning acquisition method based on tri-axial acceleration sensor for an agricultural robot (Zaho S.L. et al., 2016).

Table 2 contains the results regarding ranking of factors for all four groups: agricultural tasks, suporting tasks (functionalities), cost of the equipment and technical characteristics (robot structure).

Table 2 Results regarding ranking of factors for all four groups

Criteria	Code	Factors	Sum	Average	Median	Share, [%]	Variance	Standard Deviation	Average Absolute Deviation
1. Agricultural tasks	F1.3	harvesting and packaging	**116**	5.80	6	20.71	1.432	1.196	0.960
	F1.2	plant protection and weed control	**114**	5.70	6	20.36	1.379	1.174	0.960
	F1.1	transplanting and seeding	**95**	4.75	5	16.96	3.671	1.916	1.600
	F1.4	environmental monitoring and management	**80**	4.00	4	14.29	3.789	1.947	1.600
	F1.5	watering and fertilizing	**58**	2.90	3	10.36	2.200	1.483	1.210
	F1.7	wide-variety of tasks	**51**	2.55	2	9.11	2.155	1.468	1.205
	F1.6	manipulator	**46**	2.30	2	8.21	1.274	1.129	0.960
2.Supporting tasks *(functionalities)*	F2.1	guidance and navigation	**85**	4.25	4	28.33	0.408	0.639	0.525
	F2.3	fruit selecting and grasping	**79**	3.95	5	26.33	1.629	1.276	1.160
	F2.2	mapping and location	**59**	2.95	3	19.67	1.524	1.234	0.965
	F2.5	obstacle avoidance	**41**	2.05	2	13.67	0.892	0.945	0.765
	F2.4	vehicle dispatching for transportation	**36**	1.80	1.5	12.00	1.011	1.005	0.800
3. Cost of the equipment	F3.2	maintenance costs	**97**	4.85	5	23.10	1.608	1.268	1.010
	F3.1	total investment costs	**95**	4.75	5	22.62	1.355	1.164	0.925
	F3.3	availability	**85**	4.25	4	20.24	1.987	1.410	1.125
	F3.4	flexibility	**57**	2.85	2.5	13.57	2.134	1.461	1.250
	F3.5	Up-grade	**44**	2.20	2	10.48	1.432	1.196	0.960
	F3.6	knowledge transfer	**42**	2.10	2	10.00	1.463	1.210	1.020
4. Technical characteristics *(robot structure)*	F4.1	4 wheel steering system	**229**	11.05	11	12.58	2.892	1.701	1.455
	F4.2	ultrasonic sensors	**222**	11.10	11.5	12.20	3.147	1.774	1.500
	F4.3	2 controllers (Arduino or Raspberry)	**221**	11.05	11	12.14	2.892	1.701	1.455
	F4.4	binocular stereo vision	**206**	10.30	10.5	11.32	3.589	1.895	1.600
	F4.5	power supplying system	**186**	9.30	9.5	10.22	3.379	1.838	1.600
	F4.6	5 DoF harvesting system	**176**	8.80	9	9.67	2.274	1.508	1.220
	F4.7	2 linear laser scanners	**148**	7.40	7	8.13	1.832	1.353	1.120
	F4.8	2/4 motors	**116**	5.80	6	6.37	2.905	1.704	1.320
	F4.9	drivers	**87**	4.35	4.5	4.78	2.555	1.599	1.350
	F4.10	industrial/on-board computer	**74**	3.70	4.5	4.07	2.958	1.720	1.530
	F4.11	camera	**66**	3.30	4	3.63	2.537	1.593	1.370
	F4.12	GNSS receiver	**51**	2.55	3	2.80	1.103	1.050	0.895
	F4.13	end-effector	**38**	1.90	2	2.09	0.937	0.968	0.810

The analysis of rank and standard deviation (figure 2), demonstrated different perceptions: the specialists had a concordant opinion regarding the use of robots in greenhouses for harvesting and packaging and plant protection and weed control, and not for wide-variety of tasks and manipulator. Regarding supporting tasks all opinions agreed better and consider more importance to guidance and navigation, fruit selecting and grasping and mapping and location. Similarly, regarding costs (more for maintenance, investments and availability). Regarding technical criteria, best concordance is for non-necessity of GNSS receiver.

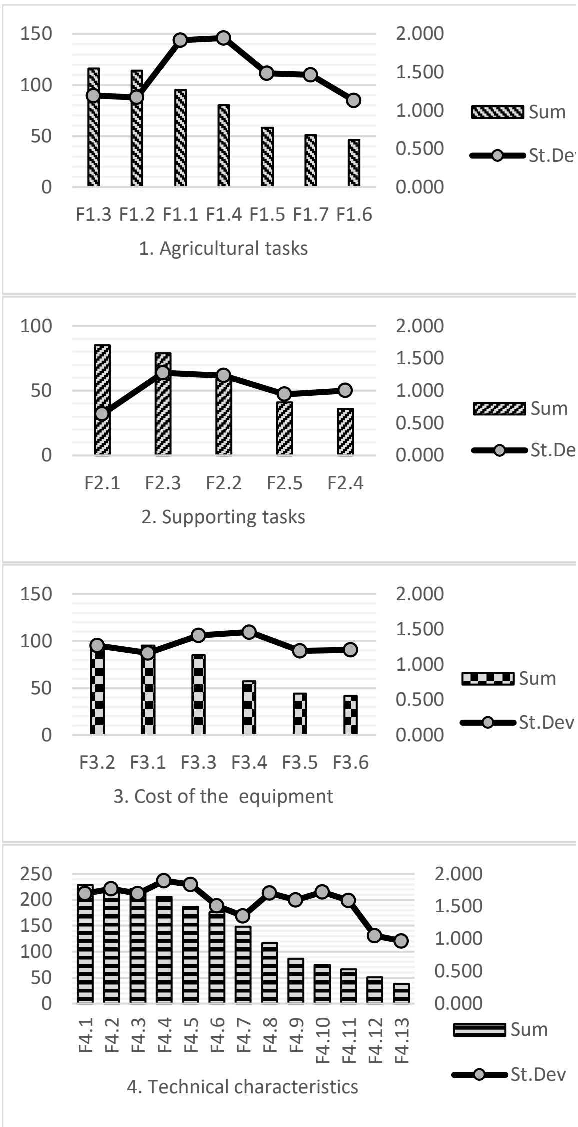

Figure 2 Rank of factors and standard deviation

CONCLUSIONS

Robotic solutions have not yet been successfully implemented for field operations and only a few developments have been adopted and introduced into practice (Xiang et al., 2014). But under no circumstances can be a talk about serial production at this moment. Realization of robots adapted on greenhouses conditions from Romania involve different aspects depending on more factors (human resources, financial, clime, culture etc.). For Romania the most interesting fields could be the cultivation of tomatoes in greenhouses for harvesting and packaging and plant protection and weed control. Based on identified solutions a robot concept will be designed, specialized in greenhouse works and it will be structured in two parts: one as tractor (movement and energy resource), and other which will be applied special for each activity.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

SMALL AGRIBOT FOR MONITORING ENVIRONMENTAL VARIABLES IN GREENHOUSE

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SUMMARY

Our study presents the design, construction and validation of an agricultural robot for greenhouse monitoring. The complete system consists of a sensory system on board a small chassis (i.e., a four-motor small-UGV). The system was designed based on the Arduino Nano V3 development platform, a NDIR CO_2 sensor, a SHT10 digital air temperature and humidity sensor and open source software. The sensors have been selected by considering the climate and plant growth models and the requirements for their integration onboard the mobile robot. The goals of this system include taking measures of CO_2 concentration, air temperature and humidity and plotting maps of these variables. The tests have shown that the measurements made with the chosen sensor are suitable for obtaining local data for production monitoring, problem detection and local climate control. All components of the system have been developed, integrated and tested through a set of field experiments in a real greenhouse. The primary contributions of this paper are the validation of the agribot as a platform for autonomous agricultural monitoring duties.

Keywords: *precision agriculture, robots, monitoring systems*

INTRODUCTION

More and more modern farms in Europe use high tech solutions such as those that allow digital control or those using remote controlled machines (without a driver). There are already fully or partially automated equipment that performs much of the farm work, from grafting to sowing, planting, harvesting, sorting, packing, etc.

The theoretical foundations of agricultural robots and their role in precision farming have already been investigated in numerous research papers (Blackmore et al. 2005; Pedersen et al.

2008; Yaghoubi et al. 2013; Kushwaha et al. 2016), but the first real tests have been conducted recently (Gonzalez-de-Santos et al., 2017).

Ruiz-Larrea et al. (2015) studies variables that influence the climate in greenhouses or plant growth with the help of a mobile platform vehicle. They implement path planning and tracking algorithms in the Robot Operating System (ROS) to move the robot into a closed and obstructed space. Roldán et al. (2018), in their study, used an unmanned aerial mini-vehicle to measure environmental variables in a greenhouse. Validation of the quadrotor as a mobile platform for monitoring crop growth and determining the optimal position of sensors on a quadrotor was achieved through practical experiments.

Tokekar et al. (2013) studied the problem of coordinating an Unmanned Ground Vehicle (UGV) used for estimating nitrogen (N) levels on-demand across a farm in the context of a precision agriculture application. They demonstrate the utility of the system and concluded that applying the right amount of fertilizer at the right time can drastically reduce fertilizer usage. In last years, numerous researches have focused on the use of image sensors to monitor plant physiology and morphology. LiDAR scanners mounted aboard ground vehicles and tractors have been used to extract morphological properties such as canopy volume and leaf area (Das et. al, 2015).

Considering the above, it is obvious that the implementation of the concept of precision agriculture at a broad level implies a more advanced research on products that allow them to know exactly what is happening on the farm at any time, as well as investing in innovative technologies.

The main objective of this paper is to develop an agriculture robot system for obtaining local data for production monitoring. The system can collect and submit data in a cloud database, which enables agronomic managers to problem detection and local climate control. The basic tasks of the prototype are: (i) a rigid mechanical structure; ii) the ability to move in well-defined directions; iii) optimal energy consumption; (iv) the capability to monitor environmental factors.

SYSTEM OVERVIEW

The proposed mini-farm robot is intended to be integrated into a greenhouse management system, and primarily carries out the acquisition of environmental data in the greenhouse. (Figure1) The system has a centralized architecture based on a microcontroller that receives data from detection devices, compiles data, makes decisions, and sends commands to drive devices.

The robot has a mass of 0.9 kg, symmetric weight and form factor, so it can transport the sensors and the components required for their work. The robot chassis is made of PVC profiles to get as little weight as possible. The mobile platform components are: base plate and lower cover, 4 DC drives with reducers and 4 easy wheels with good ground adhesion. The engine chosen is a 48:1 drive shaft with a diameter of 5.5 mm perpendicular on the wheel. This brushless DC motor has a low current consumption and provides power and speed comparable to a servomechanism. Plastic rubber tires have a width of 26.6 mm and a diameter of 66 mm. Inside the tires there is a sponge insert on the entire circumference that causes superior behavior during the run.

Figure 1 Views during experimental tests inside the greenhouse

To drive the robot, the motor torque must exceed at least the torque external force of the friction force acting on the wheel radius. To determine the required torque the following equation is used:

$$M_m = \mu \cdot F_R \cdot D/2 \tag{1}$$

where: M_m is the motor moment [N·mm]; μ is the coefficient of friction (depends directly the wheel material and the contact surface state); F_R is the reaction between the surface and the wheel [N]; D is the diameter of the wheel [mm].

Mobile robots need to generate enough traction to get themselves moving to perform different tasks (monitoring, inspection, intervention). The tractive force F_t exerted by a drive wheel of the assembly - depending on the variation of the motor torque - M_m, the speed of the drive wheel - v and the efficiency of the transmission used - η is determined from the relationship:

$$P_e = F_t \cdot \frac{v}{\eta} \tag{2}$$

where: P_e is the power of the motor [W].

The power supply of the robot is made using 2-4 Li-ion batteries, type 18650, 4000 mAh. The motor is powered by an integrated circuit, commonly known as the "motor driver", of the type L298 N that supports no more than 2 A. The basic electronic schema for the robot control, driven by four DC motors, is shown in Figure 2.

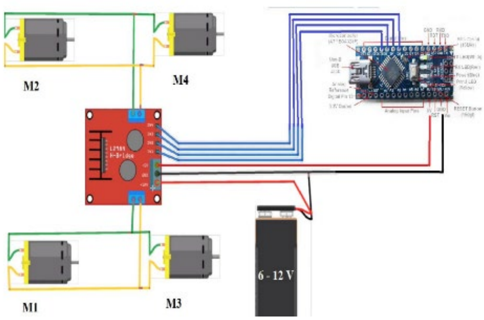

Figure 2 Basic electronic schema for robot control

The Tinius Olsen mechanical test bench (model H10kS, Hounsfield) is used to measure the traction force of the robot motor module according to the diagram illustrated in Figure 3. At a supply voltage of 7.5 V and a current of 1.4 A, a maximum traction force of 4.83 N was recorded, as can be seen in Figure 4.

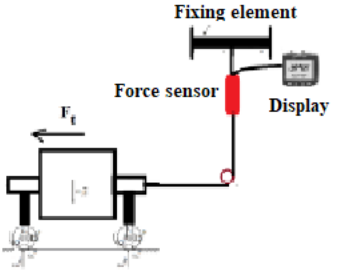

Figure 3 Determination of traction force

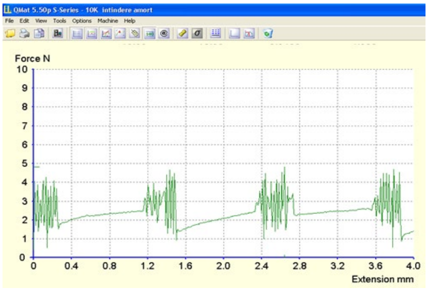

Figure 4 Variation of traction force at the voltage of 7.5V

The sensors are connected to a controller that reads the signals, computes the values and stores the information. In this work an ATmega328 microcontroller has been chosen for its compatibility with the sensors (the air temperature and humidity sensor are connected by two-wire interface and the CO_2 sensor is connected directly) and its ease of use. The sensors selected in this work are described below.

For monitoring the air quality in the greenhouse, the high-precision sensor for CO_2 with the measuring range from 0 to 5000 ppm is used. This sensor is a non-dispersive infrared sensor (NDIR) compatible with all types of microcontrollers and supports temperature compensation. This low-cost in comparison to other sensors available in market is shown in Figure 5.

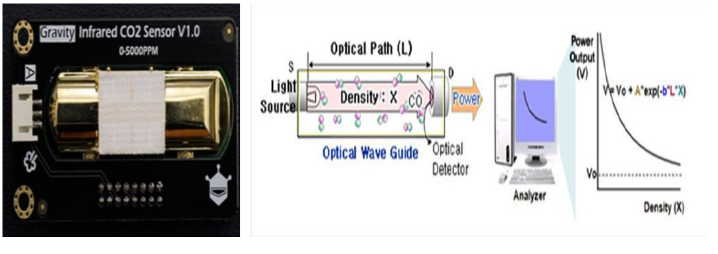

Figure 5 Infrared CO_2 Sensor

CO_2 has a maximum absorption and a minimum interference at the wavelength of 4.3 µm and therefore this frequency band is generally used for NDIR sensors. Radiation at these wavelengths is associated with the CO_2 concentration by the Law of Beer-Lambert which is given by the following equation:

$$I_d/I_0 = e^{\alpha \cdot c \cdot l} \tag{3}$$

where, I_d is the radiation intensity at 4.3 µm, I_0 is the reference radiation intensity, α is the CO_2 absorption coefficient, c is the CO_2 concentration, and l is the distance between the light source and detector light.

The SHT10 digital humidity sensor provided by Sensirion AG Switzerland is chosen to measure the air temperature and humidity. The two-wire serial interface and internal voltage regulation allows to obtain correct measures and avoid potential noises. The sensor includes a waterproof, sintered metal housing that prevents sensor damage. When calibrated at 25C, the SHT10 has typically less than 1°C error over a 100°C temperature range.

The UGV is equipped with an ultrasonic sensor to avoiding the obstacles and a Global Positioning System (GPS) receiver for performing navigation.

The robot will be remotely operated and monitored to perform the tasks for which it was created. Manual control of the mobile robot using wireless Bluetooth technology is achieved through a touch screen with a graphical interface (Nadvornik, 2014). By developing the application to Android operating system, we can monitor the current robot and sensor data through a Bluetooth device. The main Android app screen shown in Figure 6 shows the values of the sensors sent through the Arduino board and the Bluetooth device and the robot control buttons. Android App Mobile App was developed in App Inventor, a visual programming environment implemented by Google and currently supported by the Massachusetts Institute of Technology (MIT).

To integrate the mobile robot into a cloud-based Smart Farm Management System (Figure 7), a web application has been developed in the Google Fusion Table that allows to record, store, query and view online measurement data by connecting the Android device to the internet.

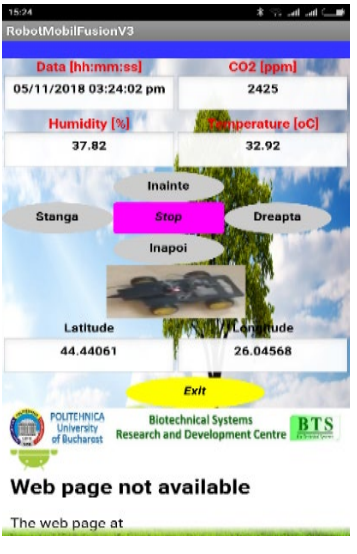

Figure 6 Main screen of Android app

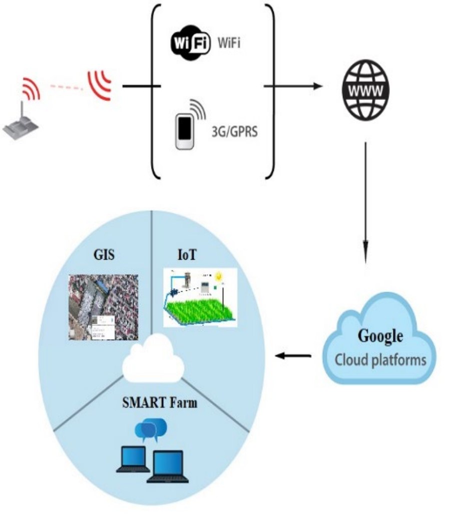

Figure 7 Farm Management Information Systems

Implementing such a system meets the need for farmers to have access to more unsophisticated services, and so we can understand how precision farming can lead to possibility to improve the cost control of farms.

RESULTS AND DISCUSSION

The experimental work has deployed in the rectangular greenhouse (160x64 m) with glass roof, available in the location of Institute for Research and Development for Industrialization and Marketing of Horticultural Products "HORTING" Bucharest to monitor the environmental climate conditions. The height of the greenhouse is 3.5 m. Horting Greenhouses with an average area of 20,500 m^2 have a front entrance with two doors for entry and exit of agricultural machinery and a set of main corridors with a width of about 2 meters. In these experiments, a cloud database of carbon dioxide concentration, temperature and humidity in a greenhouse have been created using the small robot based sensory system. The monitoring panel can be displayed on any computer connected to internet, indicating the address of the web page:

https://fusiontables.google.com/DataSource?docid=1I4QjFGFiUKZ9UaJpkER8ntbNYuFtrIMJQ7BQBwgV#rows:id=1.

The agribot followed a pre-planned path of 70 points (Figure 8), following a line and stopping at intervals of around 10.75 m and measurements were taken from the ground. In line with those found by Ruiz-Lazarrea et. al. (2015), we have found that there are some differences between theoretical and real paths. The robot covered the path in around 75 minutes.

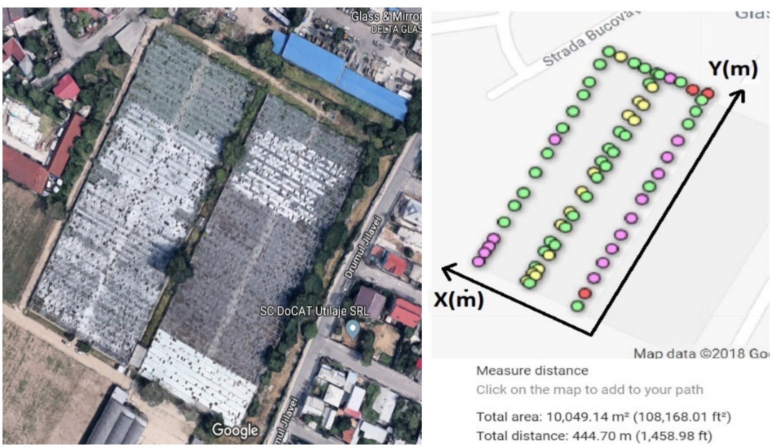

Figure 8 Google maps views of the greenhouse location and points of measurements

The results obtained of this experiment are shown in Figure 9 and 10. The maps of carbon dioxide concentration obtained in the greenhouse are shown in Figure 9. The points show the measurements of the sensors, and the surfaces show interpolations between these points. As can be seen, there are variation between the measurements. In accordance with the observations of Omid and Shafaei (2005), fluctuations in the relative humidity and temperature profile within the series are caused by natural conditions such as outdoor ambient temperature and meteorological changes during the experiment. The standard deviation in temperature (0.7594), humidity (1.5871) and carbon dioxide concentration (161.99) can be acceptable. Regarding to carbon dioxide data the errors in measurement can be associated with the response time of the sensors, particularly.

As shown, the temperature growth from the first measurement (30.7 °C), located at (Lat = 44.3749741, Long = 26.1300914), to the last measurement (33.6 °C), located at (Lat = 44.375243, Long = 26.1293852). This event is described by considering the time differential of these measurements, which began at 12:00 and ended at 13:15; these measurements corresponded to the overall warming of the greenhouse.

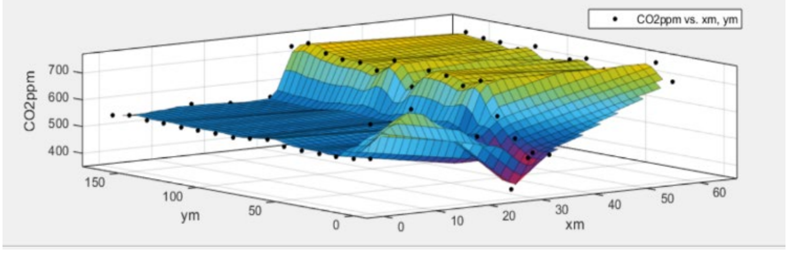

Figure 9 Maps of CO_2 evolution during the study period

It can also be seen in Figure 10 that the air temperature at the ground was between 30.71 and 34.91 °C, while the relative humidity with mean 23.68 %, was low but not uniform due to the season and the absence of irrigation.

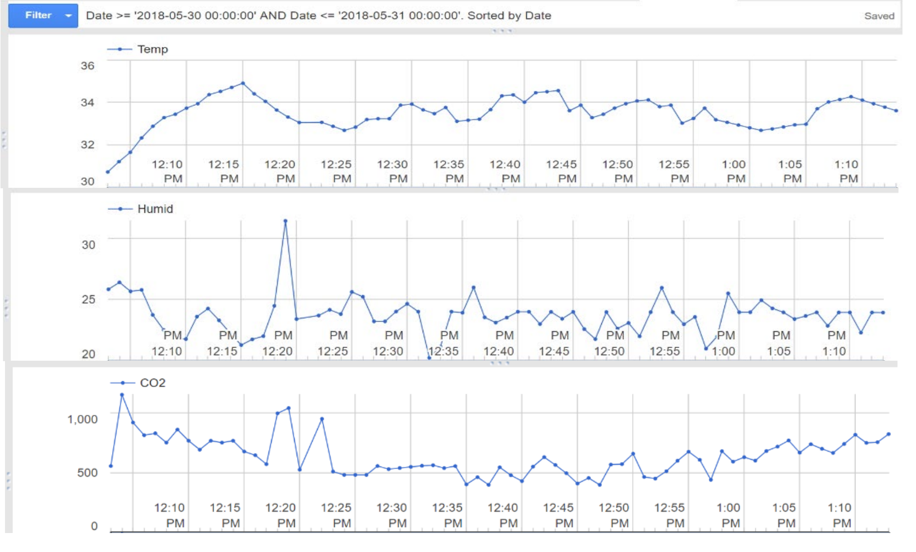

Figure 10 Temperature, relative humidity and carbon dioxide profile obtained in experiments

In summary, data from accurately characterized and calibrated, instruments can provide reasonably measurement in real time of relevant environmental variables levels. This makes them useful for a valuable tool to prevent diseases in greenhouses, like Humidity management control, as a part of overall Smart Farm Management. The acquisition of data from the NDIR sensor can be considerably ameliorate; however, the size, weight, and costs of mobile agribot can provide growers with actionable intelligence and help them interpret the resulting data products efficiently. Even though the entire system has functioned correctly, there are several specific features and many improvements that could be mentioned. For example, the current control system for the robot, sometimes shows smaller lateral oscillations.

Other highly desirable improvements would be related to the battery innovations to increase the mission time for robot. Depending on the size of the greenhouse, the coverage time required is small enough to monitor the complete greenhouse and obtain more homogeneous measurements and build maps more efficiently. Furthermore, the overall performance of the system proposed is satisfactory.

CONCLUSIONS

This paper proposes a small mobile robot for measuring environmental variables of a greenhouse at nearly any point in the two-dimensional space. The proposed agricultural robot has been tested and improved over an extended period but are still designed with a very limited payload. A set of field experiments was performed in a greenhouse to validate the small-UGV sensory system. Experimental data were recorded with elemental sensors (analog NDIR CO2, digital SHT10 air temperature and humidity and GPS location sensors). The flexibility of the system may allow, if necessary, the inclusion of other sensors for the measurement of other environmental factors such as atmospheric pressure, light intensity and UV radiation, or the concentration of CO and CH4. The information collected by the mobile robot and recorded in a database allows agricultural managers to take the most appropriate decisions to optimize crop growth.

ACKNOWLEDGEMENT

The work has been funded by the Institutional Development Fund of the Ministry of National Education through the Financial Agreement CNFIS-FDI 2018-0086.

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ENERGY EFFICIENCY OF THE TOMATO AND LETTUCE GREENHOUSE PRODUCTION SYSTEMS

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ABSTRACT

In this paper the influence of greenhouse construction type on energy efficiency of tomato and lettuce production was analysed. Influence of greenhouse construction on energy consumption was estimated for four different double plastic covered greenhouses. Specific energy input, energy output-input ratio and energy productivity were estimated in the tomato and lettuce production. Results show that there are differences in energy efficiency regarding the production as well as regarding the type of construction. The average energy input in greenhouse tomato production was 24.13 MJ m^{-2} while in lettuce it was 3.19 MJ m^{-2}. Results also showed that the type of greenhouse construction has a significant influence on the energy efficiency of the greenhouse tomato and lettuce production. Greenhouses with the higher specific volume, in both cases had the higher energy output, higher energy efficiency, higher energy ratios and higher energy productivity.

Keywords: *tomato, lettuce, plastic covered greenhouses, specific volume, energy efficiency*

INTRODUCTION

Greenhouse plant production is still among the most energy consuming branches in agriculture (Pahlavan et al., 2011, Castoldi et al., 2011). In Serbia region, greenhouse energy consumption is 15 to 20% higher compared with to the countries with the warmer climate. Apart from the energy and production intensity, greenhouse production involves high investments and costs (Canakci and Akinci, 2006, Sethi and Sharma, 2007, Singh et al., 2007). In order to reduce the costs and save the energy, various greenhouse constructions and different coverings are offered to the farmers (Nelson, 2003, Hanan, 1998). Greenhouse production can be used to exploit market conditions in periods where supply is limited and prices are high. Thus, the most important vegetable crops grown in greenhouses are those that have a strong market throughout the entire year, such as melon, tomato, and salad greens (Castoldi et al., 2011). One of the biggest problems is in winter production when additional heating and light are needed (Damjanovic et al., 2005, Sethi and Sharma, 2007). During that period construction and coverings fully show their qualities.

Tomato is one of the most widely grown and consumed vegetables in many parts of the world (Cengiz et al., 2018). Global tomato production increased from 27.6 million t in 1960 to 177 million t in 2016, with corresponding increases in production areas of 1.68 million ha in 1960 to 4.78 million ha in 2016 (Ya-Dan Du et al., 2018). Lettuce World production accounts for 26.78 Mil ton 1,22 ha surface (FAO statistics).

Most common greenhouse vegetables in Serbia are lettuce (Ilic et al, 2017) and spinach (winter crops), and tomato and cucumber (summer crops) since, together, they are covering a year-round production. At the same time, these crops have different demands regarding the production condition and energy input. Winter crops have lower energy output and are less energy demanding if additional heating is not used. Summer crops have the higher yields but in the same time have high demands for nutrients, water and plant protection chemical. The most common greenhouse structures in Serbia are tunnels covered with the double PE UV AD folia. However, lately there is a tendency of introducing gutter connected and multi-span greenhouses. This tendency is motivated by the fact that crop rotation is more viable in these structures (Djevic and Dimitrijevic, 2009).

The aim of this paper was to estimate greenhouse energy consumption and the energy efficiency for the lettuce and tomato production in order to see if the different types of greenhouse construction can influence energy consumption for a given plant production. paper combines results from the previous research and publications (Dimitrijevic et al., 2015)

MATERIAL AND METHOD

Influence of greenhouse construction on energy consumption in tomato and lettuce production was analysed for four different double plastic covered greenhouses. For the research a tunnel type, 5.5 x 24 m covered with 180 µm PE UV IR outside folia (GH1), a gutter connected plastic covered greenhouse 21 x 250 m and with 50 µm inner folia and 180 µm outside folia (GH2), a multi-span greenhouse 4 x 8 m wide and 51 m long with 50 µm inner folia and 180 µm outside folia (GH3) and a multi-span greenhouse 13 x 12 m wide and 67.5 m long, with 50 µm inner folia and 180 µm outside folia (GH4) were used. The parameter needed for the statistical analysis, was covering material /production surface ratio. For the tunnel structure this value was 1.91, for GH2 structure it was 1.62, for the GH3 type of construction it was 1.44 and for the GH4 type of construction it was 1.30.

The experiment was carried out at a private property near Novi Sad (Serbia) on 19°51E altitude and 45°20N latitude and at a private property near Jagodina (Serbia) on 21°16E altitude and 44°1N latitude.

The method used for the energy efficiency analysis (Djevic and Dimitrijevic, 2009, Hatirli et al., 2006, Ozkan et al., 2007, Mani et al., 2007, Canakci and Akinci 2006, Pahlavan et al., 2011, Bajkin et al., 2014) is based on the energy input analysis (definition of direct and indirect energy inputs), calculation of the energy consumption for a given plant production and the energy efficiency. On the basis of tomato and lettuce production output and the energy input, specific energy input, energy output-input ratio and energy productivity were estimated.

Energy inputs were calculated by multiplying the material input with the referent energy equivalents. Energy equivalents for different material inputs as well as for the lettuce and tomato output were obtained from different sources (Badger, 1999, Ozkan et al., 2007, Pahlavan et al., 2011).

Statistical analysis, used for the greenhouse construction type influence on the energy efficiency, included the linear regression model. The parameter that was used to describe differences in constructions was the greenhouse covering / production surface ratio. The obtained data and the calculated values were imported in Microsoft Excel 2000 for the statistical analysis.

RESULTS AND DISCUSSION

Table 1 shows previous results on how much energy was needed for tomato production in the selected greenhouse construction types (Dimitrijevic et al., 2015). The lowest value was calculated for gutter-connected greenhouse, GH2 (21.96 MJ m^{-2}) and the highest for the tunnel greenhouse (26.87 MJ m^{-2}).

Table 1 Energy consumption for the greenhouse tomato production, MJ (Dimitrijevic et al., 2015)

	Tunnel structure, GH1	Gutter-connected structure, GH2	Multi-span structure, GH3	Multi-span structure, GH4
	Energy consumption, MJ			
Diesel, l	189.29	3346.00		
Electricity	168.69	8971.50	2788.85	17994.17
Straw		17294.00		
Nutrients				
Nitrogen	2000.55	49206.00	20251.08	135741.80
Phosphorus	200.97	5702.90		
Potassium	411.41	11198.00	8126.84	54010.88
Plant protection chemicals				
Pesticides	5.97	115.42	280.59	1623.84
Fungicides	24.84	299.92	784.76	3269.68
Water	203.67	8104.50	396.00	2223.00
Technical systems	7.84	67.91		
Human labor	333.20	10976.00	7389.20	28894.32
Total, MJ	3546.43	115282.00	40017.32	243757.67
Total, MJ m^{-2}	26.87	21.96	24.52	23.15

Table 2 Energy consumption for the greenhouse lettuce production, MJ

	Tunnel structure, GH1	Gutter-connected structure, GH2	Multi-span structure, GH3	Multi-span structure, GH4
	Energy consumption, MJ			
Diesel	66.92	3346.00	507.16	2322.12
Electricity	55.08	4485.74	1394.42	8997.08
Nutrients				
Nitrogen	10.23	974.31	611.50	3976.71
Phosphorus	2.26	65.25	272.48	1758.62
Potassium	3.56	334.01	378.81	2447.23
Plant protection chemicals				
Pesticides	0.39	1661.65		
Fungicides	138.00	184.00	22.08	142.60
Water	18.09	810.00	48.42	312.39
Technical systems	6.53	50.54	44.14	281.44
Human labor	102.25	3221.99	1442.56	11540.48
Lettuce crates	18.00	1180.20	420.60	2926.50
Total, MJ	421.33	16313.68	5142.17	34705.18
Total, MJ m^{-2}	3.19	3.11	3.15	3.30

Care should be taken when selecting the greenhouse construction type also in the lettuce production since different energy consumption was measured for different greenhouse structures (Table 2, Figure 1). The lowest amount of energy was needed in gutter-connected greenhouse, GH2 (3.11 MJ m^{-2}) and the highest amount was needed for the multi-span greenhouse with 13 bays, GH4 (3.30 MJ m^{-2}).

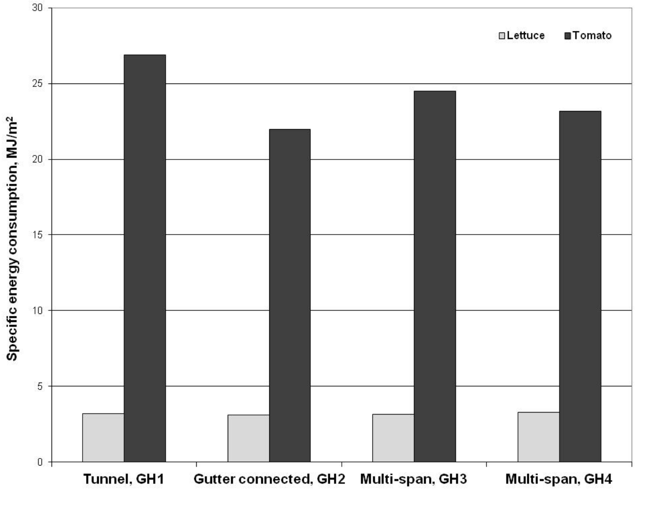

Figure 1 Specific energy consumption in lettuce and tomato production

Energy output was calculated based on the energy value for tomato and lettuce and their yield (Tab. 3). In case of tomato (Dimitrijevic et al., 2015) the highest yield was calculated for multi-span greenhouse GH4 (35.81 kg m^{-2}) and the lowest for the tunnel structure GH1 (17.00 kg m^{-2}). It can be seen that there is a tendency of having higher yield with the lower covering material / production surface ratio. In the case of lettuce (Tab. 3) the highest yield was obtained in the multi-span greenhouse GH4 (6.08 kg m^{-2}) while the lowest yield of 3.30 kg m^{-2} obtained in the tunnel structure GH1. As in the case of tomato production there is a clear tendency of having higher yield with the lower covering material / production surface ratio.

Table 3 Lettuce and tomato yield and energy output

	Specific yield, kg m^{-2}		Specific energy output, MJ m^{-2}	
	Lettuce	Tomato	Lettuce	Tomato
Tunnel structure, GH1	3.30	17.36	1.52	13.89
Gutter-connected structure, GH2	4.94	24.76	2.27	19.81
Multi-span structure, GH3	5.44	31.39	2.50	25.11
Multi-span structure, GH4	6.08	35.81	2.80	28.65

Based on the measured energy inputs and the energy output, parameters for energy analysis were calculated (Tab. 4). It can be seen that different values were obtained for tomato and lettuce regarding the basic energy parameters.

Lower values of the specific energy inputs and higher values of energy ratio and energy productivity were obtained for the multi-span greenhouses.

In the case of lettuce, the highest amount of energy per kg of product is needed in the tunnel structure greenhouse, GH1 (0.97 MJ kg^{-1}). The lowest specific energy input was measured for the multi-span greenhouse GH4, 0.54 MJ kg^{-1}. In tomato production (Dimitrijevic et al., 2015) the highest amount of energy was needed in the tunnel greenhouse structure, GH1 (1.54 M kg^{-1}) and the lowest specific energy input was needed in the multi-span greenhouse GH4 (0.65 MJ kg^{-1}). If the values are compared, it can be seen that lettuce production is less energy demanding, having the 17–37% lower specific energy input. It can also be seen (Tab. 4) that the differences in the specific energy input for tomato and lettuce production, are smaller as the specific volume of the greenhouse is growing and the covering material / production surface ratio is decreasing. In some point these differences in specific energy consumption in tomato and in lettuce will not be significant.

Values of the energy ratio are also showing the differences regarding the greenhouse construction type and also the plant production type (Tab. 4). In case of lettuce production, the highest energy ratio was calculated for multi-span greenhouse GH4, 0.85, while the lowest value was obtained for the tunnel structure GH1, 0.47. In case of tomato production similar tendencies were observed (Dimitrijevic et al., 2015). The lowest energy ratio was calculated for the tunnel greenhouse structure GH1, 0.52 and the highest value was calculated for multi-span greenhouse GH4, 1.23. It can be seen that in tomato production 9% to 31% higher energy ratio can be expected compared to the lettuce production. In both cases there is a tendency of having higher energy ratio in the greenhouse structures with the lower covering material / production surface ratio.

Table 4 Energy analysis for the lettuce and tomato greenhouse production

	Specific energy input, MJ kg^{-1}		Energy ratio		Energy productivity, kg MJ^{-1}	
	Lettuce	Tomato	Lettuce	Tomato	Lettuce	Tomato
Tunnel, GH1	0.97	1.55	0.47	0.52	1.03	0.65
Gutter connected structure, GH2	0.63	0.89	0.73	0.90	1.59	1.13
Multi-span structure, GH3	0.58	0.78	0.79	1.02	1.73	1.28
Multi-span structure, GH4	0.54	0.65	0.85	1.23	1.85	1.55

Energy productivity in both cases (lettuce and tomato) showed different values for the different greenhouse structures. In the lettuce production, the lowest value of the energy productivity was determined for the tunnel structure greenhouse, GH1 (1.03 kg MJ^{-1}) while the highest value was measured for the multi-span greenhouse, GH4 (1.85 kg MJ^{-1}). Similar tendency was observed in the tomato production when the lowest energy productivity was calculated for the tunnel greenhouse structure, GH1 (0.65 kg MJ^{-1}) while the highest value was calculated for the multi-span greenhouse, GH4 (1.55 kg MJ^{-1}). It can be concluded that 16-37% better energy utilisation can be expected in the case of lettuce production, if compared to tomato production. These differences have a tendency to be smaller when greenhouses with the higher specific volume are used.

In order to see if the previously showed differences in energy parameters, in case of greenhouse production, are influenced by the greenhouse construction, statistical regression analysis was used. The covering material surface / production surface ratio was used as a parameter for describing the greenhouse construction (Hanan, 1998). After importing these data in Microsoft Excel data analysis tool pack, Eqs. 1-3 were obtained that are describing relations between the calculated energy parameters for lettuce production and the specific volume of the selected greenhouses.

In case of lettuce, linear regression model showed a strong correlation between specific energy input and greenhouse construction type (92.4%). Equation 1 gives the relation between these two parameters leading to the same conclusion as in the case of tomato production.

$$y = -0.35 + 0.65\ EI \tag{1}$$

In case of tomato (Dimitrijevic et al., 2015) a strong correlation between specific energy input and greenhouse construction type was observed.

Energy ratio analysis showed that there is a strong correlation between energy ratio in lettuce production and the greenhouse construction type (97%). Equation 2 shows that higher values of energy ratio can be achieved with the use of gutter-connected greenhouse structures.

$$y = 1.67 - 0.57\ ER \tag{2}$$

Similar results were obtained for the tomato production energy ratio (Dimitrijevic et al., 2015).

When energy productivity was analysed it can be seen that there is a tendency of having higher productivity within the gutter connected greenhouses with the lower covering material / production surface ratio. Linear regression showed that there is a strong correlation between energy productivity of lettuce and type of greenhouse construction (97%). Regression equation (3) shows that better energy productivity can be expected when using the gutter connected greenhouse structures.

$$y = 3.5 - 1.23\ EP \qquad (3)$$

Similar results were presented for the tomato production energy productivity (Dimitrijevic et al., 2015)

Presented results lead to the conclusion that in the sense of lowering specific energy input and having energy productivity higher, greenhouse structures with lower covering material surface / production surface ration should be used. The reason for this kind of tendencies can be searched in the more uniform microclimatic conditions in the gutter connected and the multi-span greenhouse. Also, the tunnels in this area were more susceptible to wind and there were more damaged lettuce heads in the tunnels near the side walls.

The obtained results can be helpful in suggesting producers what kind of greenhouse structures should they use in order to have a better energy efficiency, energy productivity and lower energy input per kg of product.

CONCLUSIONS

In this study, the energy input and output for different production technologies and different greenhouse construction in the tomato production was analyzed. The specific energy consumption showed different values for different greenhouse constructions and in the open filed. Lowest value was obtained for the gutter-connected greenhouse and the highest for the multi-span greenhouse with the thirteen bays. Higher yields were obtained in the gutter and multi-span greenhouses compared to tunnel structures, due to better climatic conditions and better utilization of the fertilizer. The multi-span greenhouses also showed lower energy input per kg of product compared to the tunnel structure and the open field production.

The linear regression models were estimated as significant and had shown that the greenhouse structure has a significant influence on energy input, energy efficiency and productivity. The results show that lower covering material surface / production surface ratio can influence a lower energy input per kg of product, higher energy ratio and better energy productivity. Additionally, it can be concluded that the energy efficiency can also be higher with gutter-connected and multi-span greenhouses.

ACKNOWLEDGEMENT

This paper presents results from national Project “The improvement and Preservation of the Biotechnology Procedures for Rational Energy Use and Improvement of Agricultural Production Quality“. Project is financed by Ministry of Education, science and technology development, Republic of Serbia, project number TR 031051.

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***http://www.fao.org/faostat/en/

47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

SHADING METHODS FOR CROP PROTECTION UNDER GREENHOUSE IN MEDITERRANEAN AREAS

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ABSTRACT

Mediterranean areas are characterized by hot summers, which can determine unfavorable environment for the growth and quality of the crops which are cultivated inside a greenhouse. In order to control the greenhouse air temperature raise, one of the most common traditional solutions utilized by growers is the shading of the greenhouse against excessive solar radiation through the use of calcium hydroxide (i.e., slaked lime) or other paints applied on the greenhouse cover (so-called, whitening) with the aim to reduce the incoming solar radiation and limit the inside air temperature. More recently, the use of plastic shading nets is progressively affirming due to their cheaper price and photo-selective properties, as a way to effectively control the micro-climatic conditions inside greenhouses and tunnels. Thanks to a specific formulation of their chemical and physical properties, plastic nets may indeed combine the shading effect with some specific features useful for creating more favorable microclimatic conditions for the crop growth. With the aim to analyze the efficacy of the shading effect of plastic nets in different climates, two experimental trials have been carried out by comparing five identical small-scale tunnels; two installed in Southern Italy, and three in an arid climate (Saudi Arabia), in which the inside air and soil temperatures have been measured. The two tunnels were covered with EVAC plastic film, one of them also covered with plastic net, in contact with the external side the film. The three tunnels were covered with PE film; two of them were covered with two different plastic nets, fixed at 20-cm apart from the film cover. The radiometrical characteristics of the plastic films and nets were determined. The results obtained through these experimental trails enabled to start a comparative analysis of the performances of the tested net, highlighting the role that a selective filtering of solar radiation may play on crop protection from high temperatures and quality of light arriving to the crops.

Keywords: *plastic film, plastic nets, crop shading, radiometric characteristics, micro-climatic effect.*

INTRODUCTION

Agricultural production is progressively influenced by extreme meteorological phenomena, accompanied by big changes on a global scale, such as the increasingly sudden and frequent appearance of new types of insects, the transformation of food habits (*e.g.*, "*smart/super foods*"), *etc*. Thus, the concept of crop protection under a greenhouse, intended as a mere passive defense (from hail, sun, insects, wind, birds, *etc.*), is gradually being overcome: no longer an "*against*" or "*defending*" shelter, but rather a "*for*" or "*proactive*" smart structure. This building would be suitable to create ideal cultivation conditions thanks to a favourable microclimate, together with a greater diffusion of light, thanks to a more effective exploitation of solar radiation, as well as a better control of the general environmental conditions, enabling a reduction in use of pesticides as well. The plant and/or the fruits thus become healthier, more vigorous and characterized by higher concentrations of elements beneficial for human health (*e.g.*, antioxidants) thanks to a greater efficiency in the valorisation of natural resources and energy deriving from the sun.

Cladding materials employed for covering a greenhouse destined to protect crops may play a crucial role on the quality of light arriving to the crops, reducing in different ways the radiation, mostly within the Photosynthetically Active Radiation - PAR (400–700 nm) wavebands. Combination of wavebands in the incident light mixture may affect indeed plant growth, development, metabolism and morphology. This aspect may be at the base of the observed different agronomic results and antioxidant activity of the plant, since different cladding materials may influence the crop performance through a selective filtering which modifies the incoming radiation (Schettini et al. 2011; Vox et al., 2016). Mostly the UV-B component of the solar radiation may play a crucial role, as well as the green wavelength. This last component of the sun radiation in several cases may work against plant development, promoted conversely by the red and blue components (Folta and Maruhnich 2007).

Cladding materials and shading strategies may be proactively selected and implemented in many Mediterranean areas, as well as in other hot regions (*e.g.*, arid regions) in which the solar radiation levels arriving during spring/summer season are often too high for a correct management of the greenhouse, even to avoid undesirable effect on the crop, *e.g.*, sunburn. Sunlight can affect indeed more than the opening and closing of plant stomata. While some plants have specialized proteins that protect them from sunburn, others do not, and intense solar radiation can damage their leaves. Plants that are not adapted to full or intense sunlight can develop heat stress. Many plants are susceptible to leaf scorch, where parts of the plant die due to excessive water loss through transpiration. In addition to slowing or halting photosynthesis, heat stress and leaf scorch can make plants more susceptible to disease or insect infestations. Most of these negative effects may be avoided, mostly in the case of crop protection under greenhouse, when some suitable shading devices are properly employed (Castronuovo et al., 2015; Dehbi et al., 2017). In order to control air temperature inside greenhouse, one of the most common traditional solution utilized by growers in Southern Europe is the shading of the greenhouse against excessive solar radiation through the application of calcium hydroxide (*i.e.*, slaked lime) or other chemicals on the cover of the greenhouse (so-called, *whitening*) to create some shade and then limit the raising of the air temperature (Castellano et al., 2008).

More recently, the use of plastic shading nets is progressively affirming, thanks to a cheaper price and improved photo-selective properties, as a way to more effectively control the late spring and summer micro-climatic conditions inside close greenhouse and tunnel (Picuno et al., 2008). Plastic nets are usually characterized by a shading factor, ranging from 10% to 90%, which represents the capacity of the net to reduce the incoming solar radiation, related to the average value of the transmissivity of the net in the solar wavelength band from 200 nm to 2500 nm (Schettini et al., 2012). A plastic net performs indirect effects as well, when it is employed to cover close greenhouse and tunnel. Due to its influence on the values of the main microclimatic parameters (temperature, relative humidity, carbon dioxide concentration, solar radiation, *etc.*), it could play, if used as standalone cover or even in synergy with a cladding plastic film, a fundamental role on creating more favourable microclimatic conditions during the crop growth (Picuno & Abdel-Ghany, 2016; Dehbi et al., 2018). Thanks to a specific formulation of their chemical and physical properties, plastic nets may indeed combine the shade effect with some specific features useful for creating suitable conditions for the crop growth and to guarantee healthy conditions for workers. Each plastic net modifies the solar radiation that arrives on the crop, by reducing the light flow and varying the available radiant spectrum. Apart from the net structure, the spectrum of the transmitted radiation is also influenced by the diameter of the thread, color and thickness of the net, and the radiometric properties (absorbance, transmittance and reflectance) of the plastic material (Sica & Picuno, 2008). Plastic covers play a critical role not only towards the internal environment, influencing the crop growth, but also towards the external surrounding landscape, strongly influencing the visual aspect of the rural land (Tortora et al., 2015). From this point of view, a suitable landscape planning approach appears necessary, in order to consider in a holistic way all aspects connected to the use of plastic nets in agricultural application (Statuto et al., 2016). Despite their widespread use, however, neither growers nor net producers have clear ideas about the relationship between the net typology optimization for a specific application and the technical characteristics of the net. The choice often depends on empirical or economic criteria, not on scientific considerations (Castellano et al., 2008; Shahak, 2008).

The analysis of different shading strategies was performed by Abdel-Ghany et al. (2015), who showed through experimental tests that the internal position of the shading net drastically increases the generated thermal radiation within the greenhouse and the internal air temperature during the day, so the outside position for the shading net should anyway be preferred from a general thermodynamic point of view (Abdel-Ghany et al., 2016). Despite the importance of the spectral radiative properties during the lifetime of a plastic material used to crop protection, very few studies have been performed so far to analyse the degradation behaviour of these materials, in terms of their spectro-radiometrical characteristics (Emekli et al., 2016). Particularly Abdel-Ghany et al. (2018) have investigated the degradation behaviour of spectral transmittance and reflectance in the solar spectrum range of a 200 μm thick, PE-LD film-covered greenhouse model, resulting that the 1-year exposure drastically reduced the spectral and total transmittance of the cover film to global and PAR solar radiation by about 32% and increased the spectral and total reflectance by about 19% compared to new film. Degradation of the radiative properties of the film did not affect the light quality or the transmission ratios of light into the greenhouse.

In this paper, the results of an experimental trial carried out on the basis of some previous experimental tests (Statuto & Picuno, 2017) are reported. This new analysis was performed in order to start a systematic approach aimed to analyze the effect of a shading net on the internal microclimate of a greenhouse depending on its radiometrical properties, as well as to analyze different shading strategies on a selective filtering effect of the solar radiation.

MATERIALS AND METHODS

Two identical small tunnels (Fig. 1) were realized in the experimental area of an agricultural farm located in the municipality of Acerenza (Southern Italy - 40° 82′ N latitude; 15° 96′ E longitude). These small-scale tunnels, both covered with an EVAC plastic film, were left without any cultivation inside. One of them was covered with a plastic shading net overlapped on the external side, in contact with the plastic film. The tested plastic net was a BIORETE 50 MESH, 100% PE-HD monofilament net produced by the Italian industry Sachim-Arrigoni. It was a semi-transparent milky-white colour woven net, with a hole dimension of 0.27-mm × 0.83-mm and a weight equal to 130g/m^2. The producer declares a shading effect for this net of 13%. Both the shading plastic net and the EVAC plastic film were analyzed in the UV-VIS-NIR wavelength ranges by using a Jasco V-570 spectro-radiometer, at the Laboratory of Material Tests of the SAFE School of the University of Basilicata, Italy.

The temperature of the external and internal air and soil were recorded by CS500-L probes (modified version of Vaisala's 50Y Humitter, Campbell Scientific Inc, Utah, USA). The relevant data were recorded by a CR10X data-logger (Campbell Scientific Inc, Utah, USA).

Figure1 Small-scale tunnels covered with plastic film (left) and plastic film+net (right).

In parallel, another experiment was conducted in an arid climate (at King Saud University campus, Riyadh, Saudi Arabia - 24° 39′ N latitude; 46° 47′ E longitude) using three identical small tunnels, having the same dimensions as those two in Figure 1. These three tunnels were covered with a PE-LD plastic film, 200-µm thick. One tunnel as a control and the other two include an additional frame used to fix a plastic net cover at a distance of 20 cm apart from the film cover. The nets colors were white and black, each one of 50% nominal shading factor, as they were provided by the supplier. The radiometric properties of the PE-LD plastic film and of the white and black nets used in Riyadh experiment have been reported by Abdel-Ghany et al., (2018) and Abdel-Ghany & Al-Helal (2012).

RESULTS AND DISCUSSION

The results of the spectro-radiometrical analysis of the materials used in the experimental trials performed in Acerenza are reported in Tables 1 and 2, in terms of the main characteristics measured in different significant ranges within the solar spectrum, both for the plastic film and for the joint combination (coupling) plastic net + EVAC film. From the results of this spectro-radiometric analysis performed in the solar range, it could be deduced that the shading effect that was detected (*i.e.*, the complement to 1 of the transmissivity coefficient) into the different wavelength ranges (UVB, UVA, PAR, *etc.*) may give further information about the effective capability of the net to protect the crop from excessive solar radiation. The overlapping of the plastic net in contact with the cladding film has indeed increased the shading effect in the solar range of around 11% (from 33,86% to 44,8%) that is, somewhat, lower than the shading effect of the net alone (13%), as it is reported by the net producer.

Table 1 Results of the spectro-radiometrical analysis on the plastic EVAC film.

Range	Wavelength	Transmittance	Reflectance	Absorptivity	Shading effect
	nm	%	%	%	%
Solar	200 - 2500	66,14	8,75	25,11	33,86
PAR	400 - 700	67,14	12,19	20,67	32,86
Solar IR	700 - 2500	72,06	8,53	19,41	27,94
UV	280 - 380	10,45	4,86	84,69	89,55
UVA	320 - 380	16,78	5,26	77,96	83,22
UVB	280 - 320	0,64	4,24	95,12	99,36

Table 2 Results of the spectro-radiometrical analysis on the coupling plastic net + EVAC film used in the Acerenza experimental trials.

Range	Wavelength	Transmittance	Reflectance	Absorptivity	Shading effect
	nm	%	%	%	%
Solar	200 - 2500	55,20	15,72	29,08	44,80
PAR	400 - 700	57,54	20,33	22,13	42,46
Solar IR	700 - 2500	60,03	15,98	23,99	39,97
UV	280 - 380	7,01	5,87	87,12	92,99
UVA	320 - 380	11,34	6,91	81,75	88,66
UVB	280 - 320	0,30	4,25	95,45	99,70

In figures 2 and 3, the diagrams of the solar transmittance and reflectance respectively of the plastic EVAC film and the joint combination (coupling) plastic EVAC film and the shading plastic net along the whole UV-VIS-NIR wavelength [200–2500 nm] are illustrated. The difference did not seem to have significant influence on the air and soil temperature within the two different small-scale tunnels located in Acerenza during the testing period. As shown in figure 4, in fact, temperatures within these close small structures were almost the same, but it is possible to notice a lower air temperature (difference about 1°C) in the tunnel shaded with the plastic net.

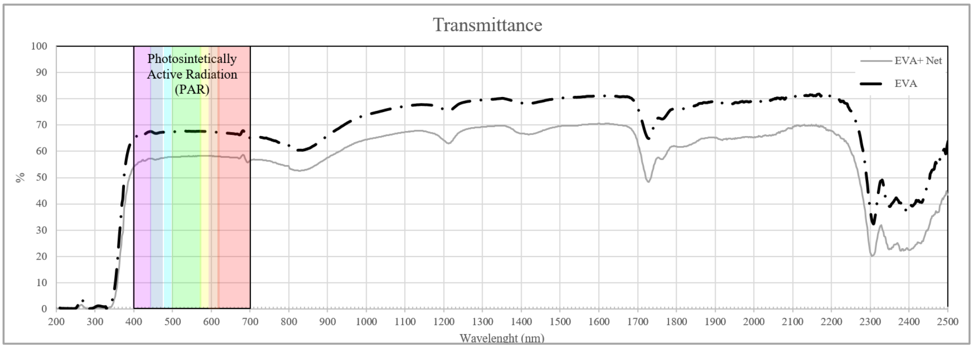

Figure 2 Transmittance in the UV-VIS-NIR of plastic film and coupling film + net.

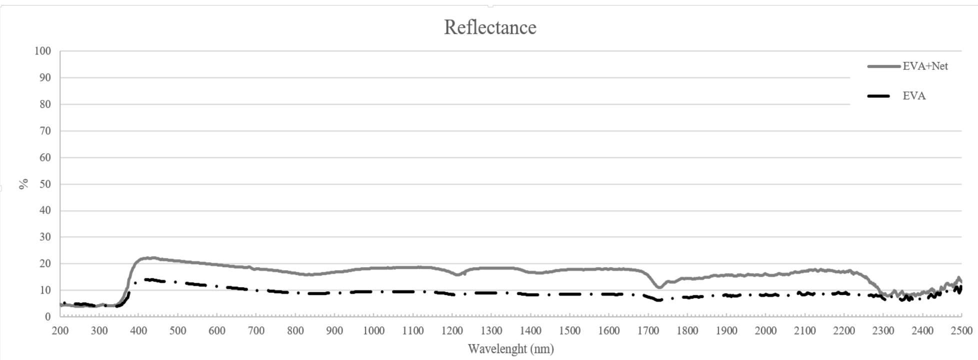

Figure 3 Reflectance in the UV-VIS-NIR of plastic film and coupling film + net.

In the case of the experimental trials performed in an arid climate on the identical experimental tunnels, however, a reduction of around 5-7ºC was observed when the shading nets installed apart from the film cover (Fig. 5). Despite of the nominal shading factor is the same (50%), the black net showed higher shading effect than the white net because the white colour increases the forward scattering of solar beam and consequently enhances the transmitted solar radiation into the tunnel.

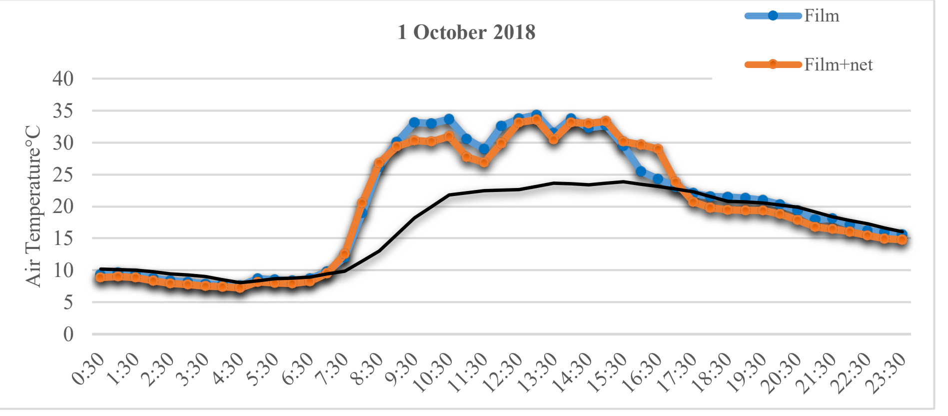

Figure 4 Air temperature detected in the trial tunnels installed in Southern Italy.

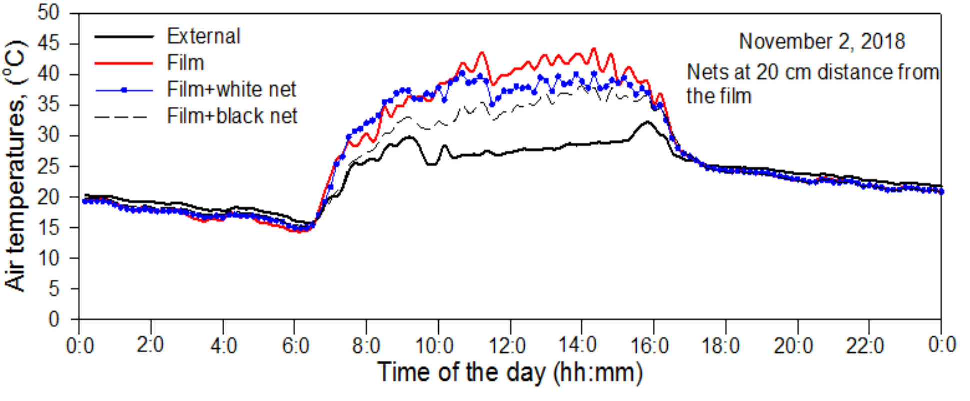

Figure 5 Air temperature detected in the trial tunnels installed in the arid climate.

In the Acerenza experiment, the same situation appears when considering the soil temperature at the centre of each tunnel, at a depth of 10 cm. Also, in this case the temperature recorded in the case of film with net is slightly lower, during the day, than in case of plastic film only (Fig.6). This observation is mainly attributed to the low shading power of the net (≅11%) and its colour which enhances the transmitted radiation into the tunnel and reduces the shading effect.

Under arid climatic conditions and existing a sandy soil below the three tested tunnels, however, the effect of shading reduced the in-depth (at 10-cm) soil temperature by about 3°C lower than that under the un-shaded tunnel (Fig. 7). The maximum reduction in Figure 7 was shifted from solar noon to 4:00 PM due to the thermal inertia of soil, which delayed the response of soil to the environment over the soil surface. During night time, shading is expected to warm up the microclimate and the soil below the tunnels; however, this effect is not clearly recognized in the present study because the size of the tested tunnels was small. Significant effects are expected with full scale and commercial greenhouses.

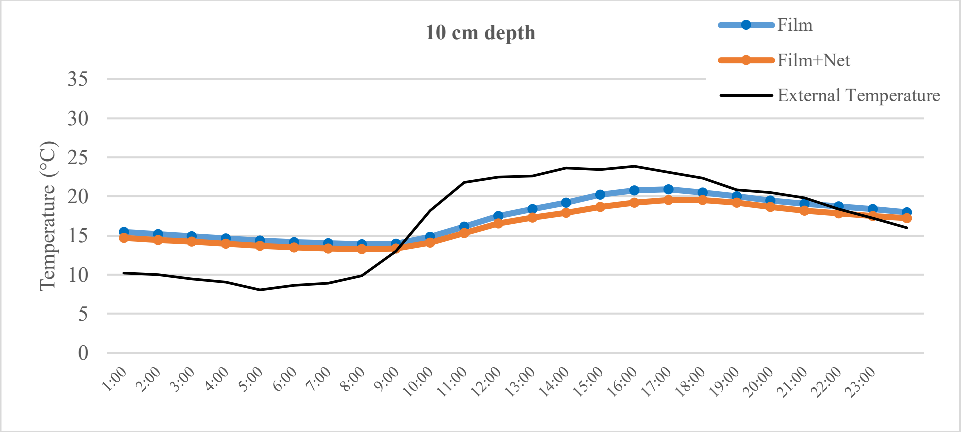

Figure 6 Soil temperature detected in the trial tunnels at 10 cm depth (Acerenza).

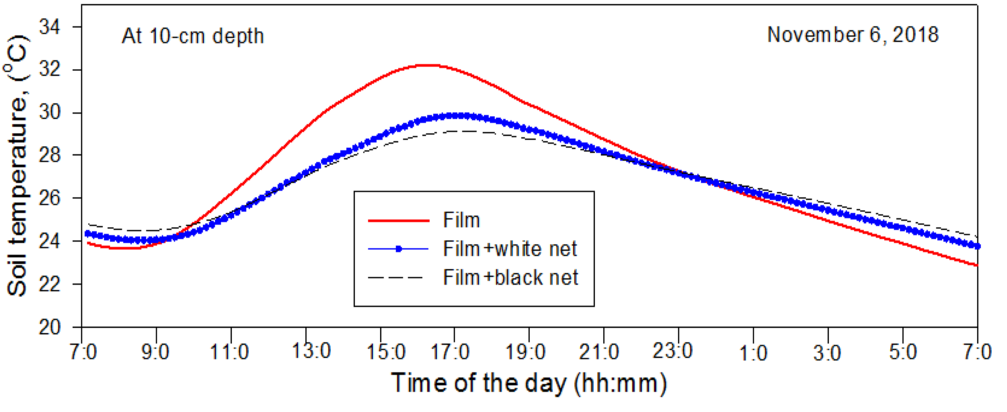

Figure 7 Soil temperature detected in the trial tunnels at 10 cm depth (arid climate).

From the results of these first trials, it can be concluded that an accurate evaluation of shading effects of a plastic net for different wavelength ranges (e.g., UVA, UVB, PAR, etc.) may give useful hints for the evaluation of the technical performance, in terms of real efficacy in protecting the crops from excessive sun radiation and possible consequent damages to the crop, *e.g.*, sunburn, scorch, *etc.* Transmittance coefficients, detailed at the different wavelength ranges playing a role in the crop growth, appear as an indispensable tool, able to classify the covering material in relation to the micro-climatic parameters of the protected environment, the quality of the radiation, the temperature and the air flow.

CONCLUSIONS

Nets are currently often employed as covering elements without any proper design, only basing on the knowledge of some technical characteristics. The lack of a specific Standard for determining the spectro-radiometrical characteristics of agricultural nets - with the consequence that laboratory test may be conducted on the basis of Standards applicable to different materials (*e.g.* glass, or transparent film) - still asks further investigations aimed to support an improvement of the technical properties of the plastic nets, in order to make them more finalized to the biological necessities of the crop.

From the present research, it can be concluded that nets should be accompanied by technical information about the shading factor along the whole solar range even when they have a different function than the shading. This specific information about the shading factor in the principal wavelength ranges - mostly in the Phosynthetically Active Radiation and UVA/UVB bands - seems very meaningful, taking into account the different effects on the crop as well as on the protected environment. More research is anyway needed to characterize different types of nets for specific purposes, as well as to quantify the effects of the shading effect on the greenhouse internal climate and crop response. Also, the duration of a plastic net, depending on the site and condition of application still needs further investigations.

ACKNOWLEDGEMENTS

The Authors wish to thank the net producer SACHIM-ARRIGONI for the kind supply of the plastic net that was tested in this experimental trial.

Many thanks to Mr. Cosimo Marano - technical staff at the SAFE School of the University of Basilicata - for his support into performing the spectro-radiometrical laboratory analysis and field tests.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

UTJECAJ ROKA BERBE I NAČINA SUŠENJA NA KVALITATIVNA SVOJSTVA RUŽMARINA

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SAŽETAK

Ružmarin (Rosmarinus officinalis) je grmolika višegodišnja vazdazelena biljka, koja se zbog atraktivnog mirisa i okusa koristi u farmaceutskoj, prehrambenoj i prerađivačkoj industriji. Osim u svježem stanju, ružmarin se može termički doraditi kako bi mu se očuvala kvalitativna svojstva. Upravo zbog toga, od velike je važnosti prilikom postupka termičke dorade odrediti optimalnu kombinaciju temperature i vremena sušenja kako bi se očuvala kvaliteta.

Za potrebe ovog istraživanja korišten je ružmarin ubran u zimskoj i proljetnoj berbi. Navedeni biljni materijal sakupljen je na području Istre gdje ružmarin u divljini raste kao samoniklo bilje. Ružmarin je sušen zagrijanim zrakom u konvekcijskoj sušari (dehidratoru) na dvije različite temperature (40 °C i 50 °C) te zrakom okoline. Utvrđena su kvalitativna svojstva ružmarina prije te nakon tretmana sušenja u svrhu bolje iskoristivosti ružmarina kao sirovine u prehrambenoj industriji.

Provedenim istraživanjem zabilježeno je brže otpuštanje vode kod ružmarina ubranog u zimskoj berbi u odnosu na proljetnu. Najbrže se sušio ružmarin (bez obzira na godišnje doba) pomoću temperature od 50 °C. Bolji sadržaj kvalitativnih svojstava zabilježen je kod konvekcijskog sušenja bez obzira na rok berbe.

***Ključne riječi**: ružmarin, sušenje, kvalitativna svojstva*

UVOD

Ružmarin je višegodišnja biljka koja tvori kruti grm, vrlo razgranatog i gustog oblika s karakterističnim aromatičnim mirisom (Ghrabi, 2005). Uzgaja se uglavnom u mediteranskim zemljama: Španjolska, Maroko, Tunis, Francuska i Italija (Szumny i sur., 2010).

Svakim danom u Svijetu postoji sve veći interes za očuvanje prehrambenih tvari u prirodnim antioksidansima, u koje se ubraja i ružmarin (Bruni i sur., 2004; Hras i sur., 2000; Williamsi sur., 2004; Frutos i Hernandez-Herrero, 2005; Erkan i sur., 2008; Ribeiro-Santos i sur., 2015) koji se koristi u fitoterapiji i ima veliki potencijal zahvaljujući različitim aktivnostima sekundarnih biomolekula, posebno eteričnih ulja (Bozin i sur., 2007). Eterično ulje i ekstrakt ružmarina prepoznati su i opće prihvaćeni zbog njihovih antimikrobnih i antioksidativnih svojstava (Ribeiro-Santos i sur., 2015). Međutim, mnoga istraživanja ukazala su na varijabilnost te kvalitativni i kvantitativni sastav i prinos eteričnog ulja zbog unutarnjih (genetike i biljne dobi) ili vanjskih čimbenika kao što su uvjeti klime i uzgoja ili metode izolacije (Flamini i sur., 2002).

Trenutno je ružmarin široko istražen kao dodatak jelima koji se može dodati izravno ili ugraditi u pakiranje hrane. Koristi u prehrambenim proizvodima i bezalkoholnim pićima, a haidrolat ružmarina prodaje se kao osvježavajuće piće.

Kako bi se produljilo vrijeme korištenja začinskog bilja, pa tako i ružmarina, najbolji način konzerviranja je sušenje zrakom okoline ili zagrijanim zrakom.

Svrha sušenja je omogućiti dulje razdoblje skladištenja za očuvanje i stavljanje na raspolaganje potrošačima tijekom cijele godine (Maroulis i Saravacos, 2003). Sušenje zrakom okoline je najstarija i najjednostavnija metoda sušenja. Sirovina se izlaže toplom i suhom zraku na tamnom mjestu, a voda evaporira iz njih (Raghupathy i sur., 2000). Da bi se neka tvar sušila mora se zagrijati do temperature pri kojoj će parcijalni tlak vodene pare na površini sušene tvari biti veći od parcijalnog tlaka vodene pare u plinu. Ako je taj tlak manji, vlaga iz plina će se apsorbirati u tvari (Krička i sur., 2009). Sušenje ljekovitog bilja može se izvesti različitim metodama koje će utjecati na kvalitativni sastav, a najpoznatija metoda je konvekcijsko sušenje (Jałoszyński i sur., 2008). Međutim, ova metoda ima nekoliko nedostataka i ograničenja (učinci razine vakuuma i mikrovalne snage na volatilni sastav ružmarina tijekom sušenja) (Calín-Sánchez i sur., 2011). Temperatura je najvažniji čimbenik u kontroli gubitka kvalitete jer utječe na fiziološke procese razvoja i starenje, kao i na fizičke procese zbog kojih dolazi do gubitka kvalitete.

Stoga je cilj ovog rada je utvrditi utjecaj roka berbe (zima i proljeće) i načina sušenja na kvalitativna svojstva listova ružmarina u svrhu bolje iskoristivosti ružmarina kao sirovine u prehrambenoj industriji.

MATERIJALI I METODE

Istraživanje je provedeno u laboratoriju Zavoda za poljoprivrednu tehnologiju, skladištenje i transport na Sveučilištu u Zagrebu Agronomski fakultet na ružmarinu ručno ubranom u zimskoj i proljetnoj berbi na području Istre. Sve provedene analize rađene su na svježim, a zatim na sušenim uzorcima. Konvekcijsko sušenje provedeno je u dehidratoru Exalibur dehydrator 4926T, USA s dvije temperature zraka (40 i 50 °C) te sušenje zrakom okoline. Uzorci su vagani svakih 15 minuta, te se pratila promjena gubitka mase, odnosno otpuštanja vlage do 12%.

Od kvalitativnih svojstava prema standardnim metodama određen je sadržaj vode u laboratorijskoj sušnici (HRN ISO 6540:2002), pepela u mufolnoj peći (HRN ISO 2171:1999), ulja na ekstraktoru Soxhlet (HRN ISO 6492:2001), te ugljika (C), vodika (H), dušika (N) i sumpora (S) prema metodi za C, H, N (HRN EN 15104:2011) i S (HRN EN 15289:2011) metodom suhog spaljivanja pomoću Vario CHNS analizatora.

REZULTATI I RASPRAVA

Rezultati otpuštanja vode iz ružmarina, odnosno eksponencijalne jednadžbe otpuštanja vode prikazane su u tablici 1.

Tablica 1 Eksponencijalne jednadžbe otpuštanja vode iz ružmarina
Table 1 Exponential equations of water release from rosemary

Rok berbe Harvest time	Početna vlaga Initial moisture (%)	Temperatura sušenja Drying temperature (˚C)	Eksponencijalna jednadžba Exponential equation	Koef. korelacije Correlation coefficient
Zima Winter	66,06	40°C	$w = 62{,}025e^{-0{,}01\tau}$	0,996
		50°C	$w = 61{,}953e^{-0{,}011\tau}$	0,983
		Sušenje zrakom okoline Ambient air drying	$w = 64{,}305e^{-0{,}002\tau}$	0,917
Proljeće Spring	55,28	40°C	$w = 53{,}157e^{-0{,}005\tau}$	0,955
		50°C	$w = 51{,}739e^{-0{,}006\tau}$	0,944
		Sušenje zrakom okoline Ambient air drying	$w = 54{,}144e^{-0{,}004\tau}$	0,817

Legenda: w – količina vode (%), τ – vrijeme (min)
Legend: w - water quantity (%), τ - time (min)

Analizom dobivenih rezultata istraživanih rokova berbe te načina i temperatura sušenja prikazanih u tablici 1. uočava se da postoje razlike u brzini otpuštanja vode.

Prema dobivenim podacima može se utvrditi da je ružmarin zimske berbe brže otpuštao vodu u odnosu na proljetnu berbu. Najbrže se sušio ružmarin bez obzira na rok berbe na temperaturi od 50 °C. To se potvrđuje kraćim vremenom koje je bilo potrebno za otpuštanje vode do vlažnosti od 12% te većom vrijednošću eksponenata. Kod svih istraživanih eksponencijalnih jednadžbi utvrđen je koeficijent determinacije između 0,817 do 0,996 koji potvrđuje da su istraživanja otpuštanja vode iz ružmarina vođena precizno te da su dobiveni rezultati međusobno usporedivi.

Nadalje, u svrhu odrađivanja kvalitativnih svojstava ružmarina u tablici 2. prikazan sadržaj pepela i ulja, dok je u tablici 3 prikazan sadržaj ugljika (C), vodika (H), sumpora (S) i dušika (N), izraženih na suhu tvar, u prirodnom uzorku te nakon termičke dorade.

U svrhu što bolje iskoristivosti ružmarina za prehrambenu industriju određen je sadržaj pepela koji je u namirnicama važan kao mjerilo biološke vrijednosti (makro i mikroelementi u pravilnoj prehrani), ali i kao mjerilo kakvoće i higijenske ispravnosti namirnica. Ulja ili masti su važne i nužne u ljudskoj prehrani, a s prehrambenog stajališta, ulja u odnosu na druge hranjive sastojke predstavljaju bolji izvor energije sagorijevanjem. Sadržaj pepela i ulja povisio se nakon termičkih tretmana bez obzira na rok berbe što znači da je ružmarin dobra sirovina za daljnju preradu bez gubitka najvažnijih komponenata sastava. Rezultati su u suglasju s USDA National Nutrient Food Composition Databases (2015) prema kojem ružmarin u svježem stanju sadrži 5,8% ulja, a nakon sušenja oko 15%.

Tablica 2 Sadržaj pepela i ulja u prirodnom uzorku te nakon termičke dorade
Table 2 Content of ash and oil in natural sample and after thermal processing

Rok berbe Harvest time	Temperatura sušenja Drying temperature (˚C)	Pepeo Ash (%)	Ulje Oil (%)
Zima/Winter	Prirodni uzorak Raw material	4,48	4,76
Proljeće/Spring		6,63	6,42
Zima/Winter	40°C	8,04	14,85
Proljeće/Spring		7,64	15,99
Zima/Winter	50°C	7,83	15,21
Proljeće/Spring		6,74	17,13
Zima/Winter	Sušenje zrakom okoline Ambiant air drying	7,91	5,77
Proljeće/Spring		6,65	14,47

Ljudskom organizmu je za njegovo normalno funkcioniranje neophodan čitav spektar raznih hranjivih elemenata, a neki od najvažniji su analizirani u tablici 3. Ugljik (C) je važan za fotosintezu i stanično disanje, a obzirom da ljudski organizam izgrađuje oko 60-70 % vode, vodik (H) je element koji je važan dio molekule vode u ljudskom organizmu. Sumpor (S) u prehrani nije samo dio aromatičnih spojeva ugodna ili neugodna mirisa, već važan prehrambeni esencijalni faktor za organizam, a u metabolizmu čovjeka igra vrlo važnu, dok je sadržaj dušika (N) vezan uz sadržaj proteina koji je važan za sve procese rasta i razvoja te je stoga vrlo poželjna komponenta u prehrambenoj industriji.

Tablica 3 Sadržaj ugljika, vodika, sumpor i dušik u prirodnom uzorku te termički dorađenim uzorcima
Table 3 Carbon, hydrogen, sulphur and nitrogen content in the natural sample and thermaly processed samples

Rok berbe Harvest time	Temperatura sušenja Drying temperature (˚C)	Ugljik Carbon (%)	Vodik Hydrogen (%)	Sumpor Sulphur (%)	Dušik Nitrogen (%)
Zima/Winter	Prirodni zorak Raw material	38,58	4,48	0,37	1,69
Proljeće/Spring		41,92	4,37	0,21	1,79
Zima/Winter	40°C	52,18	5,96	0,42	2,03
Proljeće/Spring		49,98	5,86	0,40	1,99
Zima/Winter	50°C	51,32	6,00	0,24	1,86
Proljeće/Spring		50,49	5,99	0,20	1,91
Zima/Winter	Sušenje zrakom okoline Ambiant air drying	47,86	5,90	0,47	1,73
Proljeće/Spring		48,75	4,83	0,47	1,74

Analizom podataka iz tablice 3 vidljivo je da nakon obje termičke dorade bez obzira na temperaturu sušenja i vrijeme berbe vrijednost istraživanih hranjivih elemenata raste. S obzirom da navedeni elementi predstavljaju važnu komponentu svakog organizma, sukladno tome važna su komponenta i za prehrambenu industriju. Istraživanje slično ovome na mineralnom sastavu ružmarina proveli su Ożcan i sur., 2008 te su u svoj istraživanju dobili slične rezultate.

ZAKLJUČAK

Usporedbom načina sušenja ružmarina različitom termičkom doradom zabilježeno je brže otpuštanje vode kod ružmarina ubranog u zimskoj berbi u odnosu na proljetnu. Najbrže se sušio ružmarin (bez obzira na godišnje doba) pomoću temperature od 50 °C.

Praćenjem promjena kvalitativnih svojstava, odnosno sadržaja vode, pepela i ulja te ugljika, vodika, sumpora i dušika tijekom upotrebe različite termičke dorade utvrđeno je da proces sušenja utječe na povećanje nutritivnih svojstava ružmarina bez obzira na visinu temperature.

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INFLUENCE OF HARVEST TIME AND DRYING METHOD ON THE QUALITATIVE PROPERTIES OF ROSEMARY

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SUMMARY

Rosemary (Rosmarinus officinalis) is a perennial herbaceous plant, which is used in the pharmaceutical, food and processing industry due to its attractive smell and taste. Except in the fresh state, rosemary can be thermally processed to preserve its qualitative properties. For this reason, it is essential in the process of thermal processing to determine the optimal combination of temperature and drying time in order to preserve quality.

For the purpose of this study rosemary harvested in the winter and spring was used. The mentioned herbal material was collected in the Istria area where rosemary grows in the wild as self-propagating herbs. The rosemary was dried with heated air in a convection dryer (dehydrator) at two different temperatures (40 ° C and 50 ° C) as well as with ambient air (natural drying). The qualitative properties of rosemary were determined before and after drying for the purpose of better rosemary utilization as feedstock in the food industry.

This research observed faster release of water in the winter harvested rosemary compared to the spring harvested rosemary. The fastest rosemary drying is observed (regardless of season) with a temperature of 50 °C.

A more favorable content of qualitative properties was observed after convection drying irrespective of the harvest period.

***Keywords**: rosemary, drying, qualitative properties*

47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

HARVEST AND QUALITY OF HYSSOP (*HYSSOPUS OFFICINALIS* L.)

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SUMMARY

Countries in the elite of European medicinal plants growers, use technologies that involve a high degree of mechanization/automation of operations based on modern machines in order to increase productivity and obtain quality vegetable material. Hyssop (Hyssopus officinalis L., fam. Lamiaceae) is a perennial Mediterranean plant, well acclimatized in Romania. The quality of the hyssop vegetal production obtained is influenced by a series of pedoclimatic factors, the quality of the material used for the establishment of a crop (seedlings, cuttings, etc.), the varieties and the chemical used, etc. In addition, agricultural practices such as spacing and harvesting have a critical effect on the quantitative and qualitative characteristics of this species, resulting in plant growth and development as well as yields.

This paper presents, on the one hand, the experimental researches carried out within INMA Bucharest regarding the mechanized harvesting technology of hyssop (Hyssopus officinalis L., fam. Lamiaceae), using low-capacity equipment for small plots. On the other hand, it is presented the technology of processing the obtained raw material, to evaluate the possibilities of use, to find new directions of application and exploitation (e.g.: ecological agriculture, plant protection, etc.).

The proposed method of efficiency for the exploitation of hyssop is based on the application of a process based on pressure water to produce essential oil and hydrosol (floral water), products with high market value.

Preliminary tests on oil and hydrosol (floral water) obtained from hyssop have shown their antimicrobial capacity on phytopathogenic bacteria and/or fungi.

The results obtained allow the evaluation of the working performances of the hyssop harvesting equipment and also the premises for the obtaining of new products, which can be applied for the protection of vegetable crops in greenhouses and solariums.

Keywords: *hyssop, harvest, essential oil, quality.*

INTRODUCTION

Hyssop - *Hyssopus officinalis* L., *fam. Lamiaceae,* originates in the Mediterranean and Caspian Sea regions, naturally growing in southern Europe, the Middle East, Central Asia, North Africa and North America. The plant cultivated for medicinal and culinary purposes is used in many countries around the world (Judžentienė A., 2016).

Hyssop is a perennial herbaceous plant, which has a pleasant smell. The plant grows like a shrub, with the height of the bush up to 0.6-0.7 m. The stems are straight, woody, branched at the base. The leaves are lanceolate, 2-4 cm long, covered with thin bristles bearing on their surface the glands producing volatile oil. The colour of the flowers can be blue, pink, violet and (more rarely) white or purple. They are scented and appear grouped in the axil at the base of the upper leaves, forming a spike at the top. The flowers are hermaphrodite; they are pollinated by insects (mainly bees). The flowering period ranges from mid-May to June (crop of the 2nd year of vegetation), until October-November (when frosts fall). It propagates generative or vegetative. The plant prefers sunny and warm climate and well-drained soils (clays, sands, etc.). Fields cultivated by Hyssop can be exploited 8-10 years, 2 harvest per year are obtained: spring (May) and early autumn. The plants are harvested at flowering stage. The production of Hyssop volatile oil and hydrosol (flower water) is obtained by distillation with water vapour under pressure, with extraction yields of about 0.5-1%. Under average climatic conditions, yields range from 8.0-15.0 t/ha of fresh plant, what results with one quarter of dried.

The volatile oil obtained from Hyssop is a clear yellow liquid with herbaceous odour, like camphor with warm and spicy tones. The chemical composition of this type of volatile oil comprises a long list of compounds, the most important of which are: *izopinocamphone* (sin. cis-, (3)-pinanone), *pinocamphone* (syn- trans-, (3) -pinanone) and their precursor *β-pinene*. Other important compounds include pinocarvone, sabinene, germacrene, α-, β-phellandrene, 4-carvomenthenol, thymol, carvacrol, camphor, linalool, 1,8-cineole, α-terpinene, myrtenol, eugenol and other compounds (Fathiazad et Hamedeyazdan, 2011; Ogunwande et al., 2011).

This paper presents the experimental research carried out within INMA Bucharest on Hyssop crop and mechanized harvesting technology, using low-capacity equipment for small areas. Following the processing of plant raw material, high value added products were obtained (Grigore et al., 2016), such as volatile oil and hydrosol (flower water), the antimicrobial activity of which was tested on a bacterium with phytopathogenic potential.

MATERIAL AND METHODS

In order to obtain the plant material necessary for the extraction of volatile oil and hydrosol (flower water), on the experimental plots of INMA Bucharest, under the climatic conditions of 2017 (the extremely dry summer, with temepratures over 33ºC) on a reddish-brown forest soil, the experimental lots were set up. Hyssop harvesting was performed special inflorescence collection appliance. The field of use of the harvesting equipment comprises the majority of medicinal and aromatic plants which are harvested as herbs.

Figure 1 Equipment for medicinal plant harvesting in a Hyssop culture

Experimentation of the medicinal plant harvesting equipment (figure 1) was carried out on a culture of Hyssop (Table 1), which was in the second year of exploitation on the experimental plots of INMA Bucharest. The main subassemblies of the equipment are: mower; rolling chassis; collecting bag; collecting bag support. As the harvesting of the aerial parts of medicinal and aromatic plants is achieved by cutting, at a certain height from the ground, determined by species, the equipment was tested in the previous season in a culture of Tagetes (*Tagetes patula* L.). During the work, an operator directs the rolling chassis in the culture, while another executes the repeated commands necessary to start/stop the heat engine that drives the mower. The collected material is directed by a blower into the collecting bag. (Muscalu et al., 2018).

Table 1 Agrotechnical parameters of field trials

Culture	HYSOP (Line 1)
Area of the experimental plot	approx. 200 m^2
Row spacing	80 cm
Plant spacing/row	50 cm
Bush height	60-70 cm
Bush diameter	60 cm
Number of branches	10-12
Inflorescence shape	spiciform inflorescence
Harvesting time	May-June – until frosts fall
Degree of weed encroachment	approx. 5%
State of the surface	plane

Testing the antimicrobial activity of volatile oil and Hyssop hydrosol was evaluated "*in vitro*" on *Pseudomonas marginalis* phytopathogenic bacterium. The study was performed in sterile Petri dishes in which agarose medium was distributed. After solidification, the medium was seeded in the turf by flooding with bacterial suspension from a 24h culture obtained in liquid LB medium. Subsequently, four spots of essential oil were placed equidistant at 2 cm from the dish centre. The oil was used both undiluted and diluted in proportion of 3/4, 2/4 (or ½) and 1/4 respectively, using as a solvent a mixture of 10% DMSO and 0.5% Tween 80 (Prabuseenivasan et al., 2006). Also, control dishes were prepared, in which no essential oil spots were placed. Samples were incubated at 28°C, and due to the cultural features of the bacterium, biometric determinations were performed only 24 hours after seeding, respectively after 7 days. Antibacterial activity was determined by measuring mycelial growth in the test dishes.

RESULTS AND DISCUSSION

The plant material used in these experiments comes from a Hyssop culture (second year of exploitation), set up under the climatic conditions of 2017, on the land belonging to INMA Bucharest - Baneasa area. The culture was established by planting seedlings in mid-May following the scheme: 80 cm between rows/50 cm between plants in a row, resulting in a planted area of approx. 200 m^2. This scheme was preferred to mechanize the maintenance works necessary for this culture.

The *maintenance works* that were applied to the culture consisted of: a manual hoeing, superficial, for crust destruction and then mechanical hoeing for the destruction of weeds between the rows. Avoid covering the plants with earth. In the first year and the next ones, hoeing is done as often as necessary to keep the land clean of weeds and free of crust.

Watering (dripping) was also applied during the summer when there is a danger of drought at soil level. In order to stimulate the inflorescence production, it is recommended, in spring, before the start of the vegetation, to cut the bushes.

Harvesting was performed during blooming, in sunny weather, mechanically, using equipment for harvesting medicinal plants, created by INMA Testing Department. The qualitative working and energy indices determined in the tests and the results obtained are presented in table 2.

Table 2 Qualitative working indices of Hyssop harvesting

Name of qualitative working and energy indices	U. M.	Average value
Number of rows harvested	pc.	2
Cutting height (working)	mm	300
Working speed	km h^{-1}	1.43
The efficiency of the cutting process	%	94.7
Losses (uncut plants)	%	5.3
Efficiency of collecting process	%	95.1
Losses (uncollected cut plants)	%	4.9
Fuel consumption	l h^{-1}	1.5

In the climatic conditions, 2 crops were obtained, the first in May and the second in September, with a total production of approximately 125 kg green plant / 200 m^2 (6t/ha).

The harvested plant material was used to obtain essential oil and hydrosol (flower water), from inflorescences and top parts of the upper branches, by the method of hydrodistillation - water vapour distillation under pressure, using a medium capacity installation of French origin.

The principle of this method is based on the fact that highly volatile substances are entrained by water vapour, even if they have high boiling points. But before, there is a process of diffusion of the volatile oil from the plant cells depending on the location in the plant or on its chemical composition. When oil diffusion becomes more difficult, or when components have high viscosity and remain on the vessel walls, organic solvents (2-3%) such as benzene, hexane, etc. are also used. Clevenger type apparatus is used in the laboratory, where the water recirculates, the plant being in constant contact with water. In industrial distillation plants there are fixed boilers installed on special platforms or mobile boilers so that plant loading can be made directly from the harvesting site. After condensation, the volatile oil is collected in the Florentine vessels, where decanting and separation of the oil is done. (Stan Tudora et al., 2018) The volatile oil and hydrosol (flower water) obtained were subsequently used for a series of tests regarding antioxidant and antimicrobial activity.

Antimicrobial activity of Hyssop volatile oil and hydrosol on Pseudomonas marginalis bacterium

This is a Gram negative bacterium with phytopathogenic potential for leguminous (Kůdela et al., 2010) and floriculture (Krejzer et al., 2008) plants. It can cause damage both in culture and during harvest storage (Li et al., 2007). In the case of vegetables, during storage, Pseudomonas marginalis infections manifest as wet rot, and in culture, the attack is manifested by burns on the edges of the leaves.

In the previously clear area (no bacterial growth one day after treatment) after a week of incubation, the appearance of small isolated colonies of bacteria, more or less abundant depending on the dilution tested, was observed. The more diluted the oil tested, the higher the bacterial colony weight. As seen in Figure 2, in experimental variants where the oil and hydrosol were tested undiluted (after 7 days of incubation), the bacteria completely or nearly completely covered the agar in the previously clear areas, suggesting that they present rather bacteriostatic activity, not bactericidal.

By measuring areas of bacterial growth inhibition after one day, respectively 7 days of incubation, we can say that bacterial growth inhibition zones were slightly diminished, predominantly by 0.7÷0.8 mm and rarely by 1.2 mm, suggesting the bacteriostatic effect of Hyssop oil and hydrosol.

After 24h of incubation, there was a better inhibitory efficacy as the Hyssop essential oil concentration increased.

After 7 days of incubation, it was observed that in variants where the solvent was used, colony density was lower in the previously clear areas. Colonies developed in that area were rarer compared to dishes in which the oil was tested undiluted. The more diluted the tested oil, the higher the bacterial colony weight.

The results obtained in this test confirm a series of experimental results. Hyssop antimicrobial activity was evaluated "*in vitro*" by the method of volatile discs (Nedorostova et al., 2009) against 5 bacteria (2 Gram-positive: Listeria monocytogenes and S. aureus, 3 Gram-negative bacteria: *Escherichia coli*, *Pseudomonas aeruginosa, Salmonella enteritidis*). Also, tests carried out by Mazzanti et al. (1998) showed that Hyssop volatile oil was almost inactive against Gram-negative bacteria, including *P. aeruginosa*, *E. coli, Salmonella typhi*.

Despite all its advantages, a number of toxic properties of Hyssop oil must be discussed. Its chemical composition is regulated at global level by ISO (9841: 1991 Hyssop oil - *Hyssopus officialnalis L. ssp. officinalis*). In this document, 13 compounds are recognized as standards; *pinocamphone, izopinocamphone* and *β-pinene* are declared as the most abundant (40-90%) constituents identified in Hyssop volatile oil. Several published papers have shown that high dose of Hyssop oil has convulsive, epileptogenic and neurological effects in animals undergoing experiments. These properties of volatile oil are related to the highly reactive monoterpene ketone (e.g., izopinocamphone, pinocamphone and 1,8-cineole). Carcinogenic properties may be due to the presence of methyl eugenol, but the Hyssop oils rich in this constituent are quite rare (Judžentienė A., 2016).

Figure 2 *Pseudomonas marginalis* culture on agarose LB medium in the presence of Hyssop oil and hydrosol (observations after 1 day of incubation)

CONCLUSIONS

By the qualitative working indices and energy ones obtained, the equipment for harvesting medicinal plants has also demonstrated its effectiveness in a Hyssop culture cultivated on small areas, from which the inflorescences have been collected. The equipment is a prerequisite both for obtaining quality crops and for developing a specialized machinery system for small surface medicinal and aromatic plant cultures.

The tests showed the bacteriostatic rather than bactericidal activity of Hyssop volatile oil and less of hydrosol (flower water) (*Hyssopus officinalis* L., *fam. Lamiaceae*) on the phytopathogenic bacterium - P*seudomonas marginalis*.

The use of volatile oils (such as Hyssop oil) for disease control in organic farming can be promising, but these natural oils act quickly and their effectiveness is limited by the fact that they volatilize relatively quickly.

The strategy for sustainable use of medicinal and aromatic plants aims to promote the cultivation of these plants to meet demand and provide new income opportunities for farmers.

ACKNOWLEDGMENTS

This work was supported by one founding source the NUCLEU Program, carried out with the support of ANCSI, Project PN 18 30 02 03 "Technology for the establishment and superior utilization of herbal raw material obtained from medicinal plants".

This work was supported by one founding source the NUCLEU Program, carried out with the support of ANCSI, Project PN 5N/07.02.2019 "Research on the superior valorization of some new plants species cultivated in Romania".

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

UTJECAJ FAO GRUPE HIBRIDA KUKURUZA NA BRZINU OTPUŠTANJA VODE SUŠENJEM I HRANIDBENU VRIJEDNOST ZRNA

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SAŽETAK

Najvažnije energetsko krmivo u Republici Hrvatskoj je zrno kukuruza, a kao posljedica velikog broja hibrida upravo se kod njega javljaju najveće varijacije u pogledu kemijskog sastava. Zrno kukuruza mora se sačuvati od jedne berbe do druge. U vrijeme ubiranja ono ima veću vlažnost od ravnotežne te se, kako bi se moglo skladištiti, mora konzervirati. Jedan od načina konzerviranja je konvekcijsko sušenje. S obzirom da se prilikom sušenja u sušari istodobno suše različiti hibridi zrna s različitom početnom vlažnošću, morfološkom građom i veličinom, dolazi do različitog ponašanja zrna u procesu sušenja. Otpuštanje suvišne vode do ravnotežne vlažnosti (14%) različito je za svaki hibrid, stoga je cilj rada odrediti brzinu otpuštanja vode iz zrna prezentiranih pomoću eksponencijalnih jednadžbi za 4 različite FAO grupe kukuruza 300, 400, 500 i 600. Također, odrediti će se lom zrna nakon procesa sušenja, koji predstavlja simulaciju pada zrna u silosnu ćeliju, te hranidbena vrijednost zrna istraživanih hibrida kukuruza nakon procesa sušenja, kao i nakon godinu dana skladištenja u pothlađenim uvjetima (5 °C). Najsporiju tendenciju sušenja imao je hibrid FAO grupe 500, dok je najbržu imao hibrid FAO grupe 400. Brzina sušenja utjecala je na lom zrna te je najsporije osušen hibrid FAO grupe 500 ostvario najmanji postotak loma (24,0%), dok je najbrže osušeni hibrid FAO grupe 400 ostvario najveći postotak loma (48,4%). Hibridi su imali slične hranidbene vrijednosti te se skladištenjem one nisu značajno promijenile, što konvekcijsko sušenje i skladištenje u pothlađenom prostoru čini kvalitetnom metodom čuvanja zrna kukuruza.

Ključne riječi*: zrno kukuruza, sušenje, lom, nutritivne vrijednosti, skladištenje*

UVOD

Kukuruz je jedan od najraširenijih žitarica u svijetu i jedan je od najvažnijih poljoprivrednih proizvoda u Republici Hrvatskoj. Neizbježan je i najvažniji sastojak krmnih smjesa u hranidbi životinja te se osim za potrebe skladištenja, zrno dorađuje i s ciljem povećanja njegove probavljivosti u hranidbi životinja (Voća i sur., 2008). Kukuruz je bogat vitaminima, posebice A i E, i ima veliku nutritivnu vrijednost (Tuncel i sur., 2010). Kukuruzno zrno sadrži veliku količinu škroba i donosi više od 85% škroba proizvedenog u Svijetu (Eckhoff, 2004; Malumba i sur., 2009). Globalno doprinosi sa 42 Mt bjelančevina godišnje, što odgovara približno 15% svjetske godišnje proizvodnje proteina iz hrane (Li i Vassal, 2004; Malumba i sur., 2009).

Većina hibrida kukuruza trenutno se bere s 22 do 30% vlažnosti kako bi se olakšalo korištenje kombinacijskog skladišta (Wall i sur., 1975). U koliko se brzo ne osuši, visoko vlažni kukuruz podložan je brzom propadanju, i iz tog razloga kukuruz mora biti osušen ispod kritične razine, odnosno između 13% i 14% (Wilcke i Hellevang, 2002; Tuncel i sur., 2010; Kričká i sur., 2018).

Sušenje kukuruza je složen proces koji tradicionalno ovisi o iskustvu korisnika i hibridima te postoji mogućnost za poboljšanje procesa u smislu očuvanja kvalitete, smanjenja troškova i/ili optimizacije procesa (Islam i sur., 2004). Prilikom prirodnog sušenja kukuruza na zrnu mogu se razviti plijesni te je zrno kontaminirano aflatoksinima, štetnim mikotoksinima za životinje, ali i za ljudsko zdravlje (Doymaz i Pala, 2003). Dakle, kako bi se osigurao higijenski i kvalitetni proizvod koristi se sušenje vrućim zrakom, koje je brzo i osigurava ujednačeno osušen proizvod (Doymaz i Pala, 2003).

Da bi se postigli najbolji mogući rezultati procesa sušenja, bitno je prikupiti veliki broj informacija o različitim hibridima i utjecaju njihovih fizičkih i kemijskih svojstava na kinetiku sušenja (Gely i Santalla, 2000). Brzina i kvaliteta sušenja poljoprivrednih proizvoda ovise o fizikalnim svojstvima okoline sušenja, fizikalnim svojstvima materijala koji se suši i debljini sloja kroz koji se voda ispušta u sušenju (Kričká i sur., 2007).

Sušenje osigurava proizvodu određeno vrijeme čuvanja bez promjene i mogućnost njegovog korištenja tijekom cijele godine (Kričká i Pliestić, 1994; Kričká i sur., 2001; Kričká i sur., 2003; Matin i sur., 2013). Sušenje je jedan od najvažnijih procesa nakon žetve, što ne samo da povećava rok trajanja proizvoda već i povećava njegovu vrijednost kao hrane (Mohapatra i Rao, 2005; Kričká i sur., 2018). Kod kukuruza se zagrijavanjem zrna povećava udio želatiniziranog škroba i glutena (Kričká i sur., 2001).

Sušenje vrućim zrakom obično se primjenjuje za očuvanje kukuruznog zrna smanjujući njihovu dostupnost vode (Kričká, 1993; Malumba i sur., 2010). Tijekom tog procesa zrno se podvrgava različitim promjenama. Važno je uzeti u obzir proces zagrijavanja zraka, temperaturu sušenja koja ovisi o specifičnoj upotrebi zrna i predloženom vremenu zadržavanja zrna u sušari (Jayas i White, 2003; Malumba i sur., 2010).

Sušenje može započeti tek onda kada je razlika parcijalnih tlakova vodene pare između zrna i zraka tolika da voda prelazi iz zrna u zrak. Za postupak sušenja mora postojati mogućnost kretanja vode i vodene pare unutar zrna. Kretanje vode u kapilarama uvjetuju osmotski tlak i površinska napetost meniskusa vode u kapilari. U procesu sušenja vlaga se kreće iz unutrašnjosti zrna prema površini i zatim s površina zrna prelazi na zrak kojim se suši (Katić, 1997; Mujumdar, 2000).

Međutim, da bi se u potpunosti opisala kinetika sušenja, potrebno je poznavati velik broj parametara. Osim tipa sušare, njegove geometrije i načina zagrijavanja, tu su u prvom redu svojstva materijala koji se suši. Važno je poznavanje geometrijskih čestica materijala kao što su veličina čestica i raspodjela veličina čestica, raspodjela veličina pora, oblik čestica.

Tijekom procesa sušenja određeni broj kvalitetnih značajki može se značajno promijeniti (Kocsis et al., 2011). Povećana temperatura zraka za sušenje smanjuje razinu vlage u zrnu, pa povećana razlika u parcijalnim tlakovima između zrna i zraka poboljšava sušenje (Kričkа i sur., 2003). Visoke temperature korištene tijekom sušenja mogu utjecati na fizikalno-kemijska svojstva zrna (Altay i Gunasekaran, 2006; Hardacre i Clark, 2006; Chung i sur., 2009;).

Sušenje zrna na povišenim temperaturama uzrokuje pukotine usred napora i lomljivost (Wall i sur., 1975), a isto tako i sušenje pri niskim temperaturama obično ima utjecaj na čimbenike kakvoće kukuruza, kao što su pukotine uslijed otpornosti na stres, gustoća, osjetljivost lomova ili klijavost (Peplinski i sur., 1994).

Budući da povećano zagrijavanje zrna tijekom sušenja omogućuje veći kapacitet sušenja s istom količinom zraka, svakodnevno se nastoji postići veće temperature sušenja zraka. Previše zagrijavanja smanjuje kvalitetu zrna jer postaje krhko i prekida se s lagano povećanim opterećenjem (Kričkа i sur., 2003) te je takvo zrno podložnije lomovima (Martins, 1988).

Sušenje u sušari se istodobno odvija s različitim hibridima zrna kukuruza različit početne vlažnosti, različitom morfološkom građom i veličinom te zbog toga dolazi do različitog ponašanja zrna u procesu sušenja. Otpuštanje suvišne vode do ravnotežne vlažnosti (14%) različito je za svaki hibrid, stoga je cilj rada odrediti otpuštanje vode iz 4 različite FAO grupe zrna kukuruza pomoću eksponencijalnih jednadžbi. Također, će se odrediti hranidbena vrijednost zrna istraživanih hibrida kukuruza nakon procesa sušenja te nakon godinu dana skladištenja u pothlađenim uvjetima (5°C). Uz navedeno istražiti će se utjecaj sušenja na lom zrna hibrida različitih FAO grupa.

MATERIJALI I METODE

Istraživanje je provedeno na 4 različite FAO grupe kukuruza 300, 400, 500 i 600. Hibrid FAO grupe 300 po svojim karakteristikama bio je dvolinijski, rani hibrid kukuruza, po podvrsti zuban, svjetložute boje zrna. Hibrid FAO grupe 400 bio je dvolinijski, srednje rani hibrid kukuruza, po podvrsti zuban, svjetložute boje zrna. Hibrid FAO grupe 500 bio je dvolinijski, kasni hibrid kukuruza, po podvrsti zuban, krupnog zrna zlatnožute boje. Hibrid FAO grupe 600 bio je dvolinijski, kasni hibrid kukuruza, po podvrsti zuban, krupnog žutog zrna. Neposredno prije sušenja pomoću pomičnog mjerila izmjerene su dimenzije zrna (dužina, širina i debljina).

Za eksperimentalno sušenje kukuruznog zrna upotrijebljena je laboratorijska konvekcijska sušara izrađena na Zavodu za poljoprivrednu tehnologiju, skladištenje i transport, Sveučilište u Zagrebu Agronomski fakultet. Zrno svih hibrida sušeno je na temperaturi od 130 °C te je brzina strujanja zraka iznosila oko 2 m/s. Uzorak se suši u stacionarnom sloju i njegova masa, tj. gubitak vlage, mjerio se svakih 5 minuta na vagi smještenoj u neposrednoj blizini sušare. U tablici 1 prikazane su srednje vrijednosti faktora sušenja 4 različitih hibrida kukuruza. Vrijednosti temperature i relativne vlage zraka mjerene su pomoću psihrometra i higrometra, a ostali parametri (x_0, h_0, h_1) računski h-x diagramom. Brzina zraka na izlazu iz sušare mjerena je pomoću anemometra.

Tablica 1 Srednje vrijednosti zraka pri sušenju zrna
Table 1 Average values of air during grain drying

Hibrid/Hybrid	t_0 (°C)	φ_0 (%)	x_0 (g kg^{-1})	h_0 (kJ kg^{-1})	t_1 (°C)	h_1 (kJ kg^{-1})	v_2 (m s^{-1})
FAO 300	23,9	41,5	0,007800	43,74	130,6	151,97	1,93
FAO 400	22,0	65,6	0,010880	49,64	130,0	159,80	2,10
FAO 500	23,4	62,3	0,011276	52,08	131,2	162,11	2,10
FAO 600	24,9	58,9	0,011662	54,59	130,9	162,86	2,10

Legenda: t_0- temperatura zraka okoline; φ_0- relativna vlaga zraka; x_0- apsolutna vlaga zraka okoline; h_0- specifična entalpija zraka; t_1- temperatura vrućeg zraka; h_1- specifična entalpija vrućeg zraka; v_2- brzina zraka na izlazu iz sušare

Legend: t_0- ambient air temperature; φ_0- relative air humidity; x_0 - absolute ambient air humidity; h_0- specific air enthalpy; t_1- hot air temperature; h_1- specific hot air enthalpy; v_2- air velocity at the dryer exit

Kako bi se simulirao pad zrna u silosnu ćeliju određen je lom zrna u centerifugalnom bubnju pri 1000 okretaja u minuti. Uzorci zrna su bili izbrojani i izvagani te propušteni kroz bubanj. Po prestanku djelovanja opterećenja u centrifugalnom bubnju cijela i polomljena zrna su skupljena u posudicu i nakon toga opet izbrojana i izvagana. Iz dobivenih rezultata dobiven je odnos cijelih i izlomljenih zrna. Ujedno na osnovu mase 250 zrna dobivena je i apsolutna masa 1000 zrna.

Određivanje početne vlage zrna kukuruza određena je prema protokolu HRN ISO 6540:2002. Sadržaj proteina, masti, pepela i vlakana u kukuruznom zrnu, nakon sušenja te skladištenja u trajanju od godinu dana u pothlađenim uvjetima (5 °C), određen je prema Weende metodi. Slijedeći prijedloge Ensminger i Olentine (1978) dobivene vrijednosti su zatim pretvorene u vlagu od 14% i suhe tvari.

REZULTATI I RASPRAVA

Prije početka sušenja izmjerene su dimenzije zrna (tablica 2). Obzirom na približno jednake veličine zrna istraživanih kultura proces sušenja odvijao se u ujednačenim uvjetima te je usporedba sušenja između hibrida pravilnija.

Tablica 2 Fizikalne karakteristike zrna
Table 2 Physical characteristics of grain

Hibrid/Hybrid	Dužina/Length (mm)	Širina/Width (mm)	Debljina/Thickness (mm)
FAO 300	11,370	8,520	5,580
FAO 400	11,695	8,725	5,385
FAO 500	11,980	8,820	5,914
FAO 600	11,820	9,285	5,570

Na osnovu izmjerenih podataka o gubitku mase svakih 5 minuta izračunate su eksponencijalne jednadžbe kod zahtijevanih vrijednosti temperatura za svaki istraživani hibrid do ravnotežne vlažnosti kukuruza (tablica 3).

Tablica 3 Eksponencijalne jednadžbe istraživanih zrna hibrida kukuruza
Table 3 Exponential equations of investigated maize grain hybrids

Hibrid Hybrid	Početna vlaga Initial moisture (%)	Eksponencijalna jednadžba Exponential equation	Koeficijent korelacije Correlation coefficient
FAO 300	32,04	$w=29,606956*e^{-0,014460\tau}$	0,993575
FAO 400	29,46	$w=28,781169*e^{-0,015772\tau}$	0,997203
FAO 500	33,82	$w=30,708216*e^{-0,010366\tau}$	0,986599
FAO 600	30,75	$w=29,054187*e^{-0,013269\tau}$	0,993646

Da bi se moglo usporediti krivulje sušenja istraživanih hibrida korišteno je matematičko modeliranje jednadžbi brzine otpuštanja vode iz zrna (Krička, 1993). Kod svih istraživanih eksponencijalnih jednadžbi utvrđen je koeficijent korelacije između 0,98 i 0,99 koji pokazuju da su istraživanja otpuštanja vode iz zrna vođena precizno te da su dobiveni rezultati međusobno usporedivi. Analizirajući općenito jednadžbe sušenja uočava se, da eksponencijalni koeficijent varijabli ima negativan predznak, što znači da krivulja pada tj. pokazuje tendenciju brzine sušenja. Što eksponent ima veću apsolutnu vrijednost, sušenje je brže. Temeljem navedenog najbrže je otpuštao vodu hibrid FAO grupe 400, dok je najsporije otpuštao vodu hibrid FAO grupe 500.

Nakon što je zrno hibrida bilo sušeno na temperaturi zraka od 130 °C, njegova dinamička čvrstoća ispitana je u centrifugalnom bubnju (tablica 4) što može simulirati uvjete kojima je zrno izloženo tijekom mehaničkog prikupljanja, transporta, skladištenja, itd.

Tablica 4 Mehaničko-dinamička oštećenja zrna istraživanih hibrida
Table 4 Mechanical-dynamic grain damage of investigated maize grain hybrids

Hibrid Hybrid	Vlaga nakon sušenja Moisture after drying (%)	Masa 1000 zrna 1000 grain weight (g)	Lom zrna Grain fracture (%)	Cijelo zrno Whole grain (%)
FAO 300	13,77	338,8	38,0	62,0
FAO 400	13,31	346,8	48,4	51,6
FAO 500	13,76	392,4	24,0	76,0
FAO 600	13,53	301,2	26,0	74,0

Kao što je već dokazano, dinamička snaga zrna izravno ovisi o njegovom sadržaju vlage (Pliestić, 1989). Kako bi se usporedili rezultati lomova između zrna različitih hibrida, bitno je dokazati da se istraživanje provodi na otprilike istoj vlažnosti zrna, u ovom slučaju oko 14%. Iz rezultata vidljivo je da brzina sušenja utječe na lom zrna te je najsporije osušen hibrid FAO grupe 500 ostvario najmanji postotak loma (24,0%), dok je najbrže osušeni hibrid FAO grupe 400 ostvario najveći postotak loma (48,4%) u odnosu na ostale istraživane hibride.

U tablici 5 prikazani su udjeli proteina, masti, pepela i vlakna u osušenom zrnu istraživanih hibrida kao pokazatelji hranidbene vrijednosti zrna kukuruza, dok su u tablici 6. prikazane iste vrijednosti nakon godinu dana skladištenja u pothlađenim uvjetima (5 °C).

Tablica 5 Hranidbena vrijednost osušenih zrna istraživanih hibrida
Table 5 Nutritional value of dried investigated grains

Hibrid Hybrid	Proteini/Proteins (%)		Masti/Fat (%)		Pepeo/Ash (%)		Vlakna/Fiber (%)	
	14%	S.T.	14%	S.T.	14%	S.T.	14%	S.T.
FAO 300	7,84	9,12	2,06	2,39	1,27	1,48	2,84	3,31
FAO 400	8,92	10,40	2,81	3,28	1,16	1,36	2,52	2,94
FAO 500	8,25	9,61	2,33	2,71	1,16	1,36	2,33	2,71
FAO 600	8,34	9,72	2,81	3,28	1,07	1,24	1,94	2,26

Tablica 6 Hranidbena vrijednost osušenih zrna istraživanih kultura nakon jednogodišnjeg skladištenja
Table 6 Nutritional value of dried investigated grains after one year storage

Hibrid Hybrid	Proteini/Proteins (%)		Masti/Fat (%)		Pepeo/Ash (%)		Vlakna/Fiber (%)	
	14%	S.T.	14%	S.T.	14%	S.T.	14%	S.T.
FAO 300	6,68	7,76	3,29	3,82	1,06	1,24	2,81	2,36
FAO 400	9,47	11,01	2,87	3,34	1,24	1,45	2,77	3,26
FAO 500	8,44	9,82	2,56	2,98	-	-	3,41	3,97
FAO 600	9,87	11,48	2,72	3,20	1,04	1,21	2,82	3,31

Rezultati u tablicama prikazuju da su hibridi različitih FAO grupa imali slične hranidbene vrijednosti nakon procesa konvekcijskog sušenja. Nakon godinu dana skladištenja u pothlađenim uvjetima uočene su određene razlike u nutritivnom sastavu zrna istraživanih hibrida, no kvaliteta zrna nije značajno promijenjena, što skladištenje u ovakvim uvjetima čini povoljnim i preporučljivim.

ZAKLJUČAK

Zrno 4 različite FAO grupe kukuruza 300, 400, 500 i 600 sušeno je u podjednakim uvjetima. Koeficijent korelacije pokazao je da je sušenje provedeno kvalitetno te su rezultati usporedivi. Preko eksponencijalnih jednadžbi može se utvrditi da je najbrže otpuštao vodu hibrid FAO grupe 400, dok je najsporije otpuštao vodu hibrid FAO grupe 500. Također je utvrđeno da brzina sušenja utječe na lom zrna te je najsporije osušen hibrid ostvario najmanji postotak loma, dok je najbrže osušeni hibrid ostvario najveći postotak loma. Hibridi su imali slične hranidbene vrijednosti te se skladištenjem one nisu značajno promijenile, što konvekcijsko sušenje i skladištenje u pothlađenom prostoru čini kvalitetnom metodom čuvanja zrna kukuruza.

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IMPACT OF THE MAIZE HYBRIDS FAO GROUP ON THE WATER RELEASE RATE BY DRYING AND GRAIN NUTRITIONAL VALUE

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ABSTRACT

The most important energy feed in the Republic of Croatia is maize grain, and as a consequence of a large number of hybrids, the largest variations in the chemical composition are present. Maize grain must be preserved from one harvest to another. At harvest time, it has higher moisture content than the equilibrium and, in order to be stored, must be conserved. One way of conservation is convection drying. Since different grain hybrids with different initial humidity, morphological structure and the size of the grain are dried simultaneously in the drying process, different grain behavior occurs in the drying process. The release of surplus water to the equilibrium humidity (14%) is different for each hybrid, therefore the aim of the paper is to determine the water release rate through exponential equations for 4 different FAO maize groups 300, 400, 500 and 600. Also, the grain fracture after drying, which represents the simulation of the grain fall in the silage cell, as well as nutritional value of investigated maize hybrids after the drying process and after a year of storage under the cooled conditions (5 °C) will be determined. The slowest trend of drying had the FAO group 500 hybrid, while the fastest had the FAO group 400 hybrid. The drying speed affected the grain fracture, and the slowest-dried FAO group 500 hybrid achieved the lowest percentage of fracture (24.0%), while the fastest-dried FAO group 400 hybrid achieved the highest percentage of fracture (48.4%). Hybrids had similar nutritional values, and they did not change significantly during the storage period, what makes convection drying and cooled storage a good method of maize grain storage.

Keywords: *maize grain, drying, grain fracture, nutritional values, storage*

47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

DRYING PROCESS MODELING WITH EFFECTS OF PHYSICAL PARAMETERS ON DEHYDRATED SEEDS

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SUMMARY

Dehydration of agricultural products is part of the research regarding the conservation and preservation of the quality of agricultural and food products.

The paper aims to determine the optimal drying regime by analyzing the kinetics of the corn seed drying process and the qualitative indices of the obtained samples.

The mathematical modeling of the seed drying process used experimental data measured using the drying system. If the grain is applied to a non-uniform air distribution with too high drying temperatures in some points, it cracks in one or more places and becomes very brittle.

In order to overcome the drying uniformity problem, a device was conceived, built and constitutes a proposal for a patent. It is equipped with tronconic plates based on the Coandă effect, which allows uniform distribution of warm air in the mass of product to be dried.

Because moisture influences the internal friction coefficient of grain, the porosity of the seed samples was determined using a 3D scanner. Validation of the mathematical model for the porous seed medium was achieved by measuring the seed temperature at several positions in the dryer. By applying a heat and mass transfer model in a porous seed layer, the temperature field was simulated in three consecutive layers with a total thickness of 150 mm.

The results obtained by simulation and experiment gave the optimum parameters to have a uniform temperature gradient without harming the corn seed.

Keywords: *simulation, seed drying, porosity, heat transfer*

INTRODUCTION

Heat transfer is a complex phenomenon whereby thermal energy is exchanged between two independent regions or between two fluids based on a temperature difference (thermal potential) between them. Due to the existence of a thermal potential, the transfer of energy from the higher temperature region or fluid to the one with lower temperature is performed spontaneously. Heat transfer deals with the study of dynamic processes where the thermal energy at certain parameters is also converted to thermal energy, but to other parameters. Thermal transfer laws underlie the design and exploitation of a large number of unit operations, work processes, apparatuses and installations, characteristic of process industries.

In the food industry, heat transmission is a phenomenon that underlies many specific operations such as: heating, cooling, evaporation, condensation, drying, distillation etc. (Țenu et al., 2014)

In the case of drying cereal grains intended for food consumption, the artificial drying operation is carried out in order to ensure good storage and preservation without depreciating their food value.

At the same time, for cereal seeds and other plants, it is intended that the artificial drying operation does not destroy their quality parameters.

Therefore, the process of artificial drying of the seeds is complex and requires a great deal of attention in determining the heat regime of the drying agent, depending on the initial seed moisture and the physical condition.

Seeds have thermosensitive components and may undergo some changes during the drying process: decreased protein content, germination deterioration, color changes, volume changes, non-specific flavors, reduced nutrients, etc.

Depending on how it is done, seed drying can influence the quality both positive and negative.

Due to the corn root layer, drying of water is slower. Sudden drying at high temperatures of high moisture seeds causes instantaneous dehydration of the bean shell, welding of the outer ends of the capillary vessels, closing of the pores on the surface and preventing the outflow of the water from the grain. In such cases, by the accumulation of vapors in the capillary vessels and the formation of an overpressure inside them, the seeds crack and break and some of them descend and break into cotyledons. This can be seen in the resulted reconstructed images after scanning the dried grain with a 3D scanner. In general, the drying process depends on certain basic factors, namely the heating temperature of the material, the moisture content of the material and the velocity of the drying agent.

In order to efficiently use the drying process of agricultural products, to properly guide it and calculate the drying facilities, studies and research are needed. Numerous researches have been carried out over the years to ensure optimal conditions for the conservation of cereal seed and technical plants without impairing their quality.

At present, worldwide, for the drying of agricultural plants seed are used vertical and horizontal dryers, with continuous and discontinuous function, and the principle is based on dehydration by convection, in which heat is transferred from the drying agent to the product through convection.

Numerical simulations of a plug-flow fluidized bed dryer were done both under steady-state conditions (Khanali et al., 2013) and under dynamic conditions (Khanali et al., 2014).

Khanali et al. (2018) developed a model for shelled corn drying in a plug flow fluidized bed dryer and discovered that, as a result of axial dispersion, the simulated solid moisture content profile showed a discontinuity at the solid inlet boundary of the bed and then decreased continuously across the dryer length. A non-equilibrium model of the grain fixed deep-bed drying for rough rice has also been developed (Naghavia et al., 2010).

Over time, several mathematical models have been made for heat and mass transfer in porous media such as agricultural seed layers. Many models were obtained at low temperatures and low humidity of grain.

Baker et al. (2006) created a model which was based on analytical equations previously derived to simulate well-mixed fluidized bed dryers, combined with axial dispersion theory.

A 3-D numerical model was established to study the temperature variation within a small grain steel silo under quasi-steady state (Zhang et al., 2016).

A sequential method was developed to model a continuous plug flow fluidized bed dryer. The method is based on dividing the dryer into sections in series with ideal mixing for both solid and gas phases in each section (Bizmark et al., 2010).

Janasa et al. (2010) describes the evolutions of maize moisture and salt-soluble protein content during fluidized-bed drying with a constant drying air temperature between 50 °C and 100 °C.

The aims of this paper are to present a comprehensive method of CFD simulation in the heat recovery dryer, where the mathematical model of heat transfer, the distribution of the temperature of the drying agent and the temperature in the seed layer are presented simultaneously in two or three dimensions and to determine the optimum parameters in order to have a uniform temperature gradient without harming the corn seed.

MATERIALS AND METHODS

The experimental researches took place in the Agricultural Mechanization Laboratory of the "Ion Ionescu de la Brad" University of Agricultural Sciences and Veterinary Medicine from Iasi.

The raw material used, namely maize seed of the hybrid DKC 4717, was harvested in all cases at four stages of maturity.

In order to analyze the influence of the constructive and functional parameters of the drying plant on the quality of the finished product, four velocities and five drying agent temperatures were used.

Experimentally, a three-layer concentric seed dryer (Fig. 1) was designed and developed to study the temperature and the moisture content distribution in order to improve the qualitative indices of corn seeds subject to preservation.

Mathematical modelling was used in design, in the operational and optimization work. The mathematical model of the convective drying process is based on the theory of fluid dynamics, mass balance and energy.

The experiments were conducted by varying and monitoring the operating parameters of velocity and temperature of the warm air.

The temperature and humidity of the product were determined with sensors located in each of the three layers.

Additionally, the moisture and temperature of the hot air prior to penetration into the corn seed layer and after, were monitored by means of some moisture and temperature sensors.

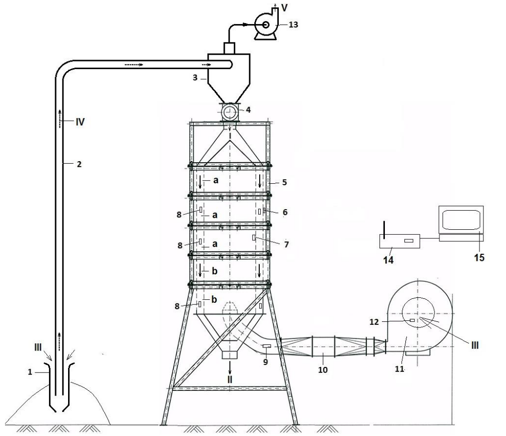


Figure 1 Vertical dryer with heat recovery (Cârlescu et al., 2018)
1 seed feed device; 2 pipe; 3 seed-air separator, 4 air lock, 5 vertical drier, 6 wireless sensor; 7 wireless sensor; 8 temperature sensor inside the dryer; 9 velocity sensor; 10 air heater battery, 11 fan; 12 wireless sensor; 13 pneumatic fan; 14 wireless device; 15 PC; I wet seeds; II dried seeds; III air; IV mixed air seeds; V air.

Determination of porosity in the seed layers was performed with the 3D SKYSCAN 1172 micro CT scanner and related software. The hot air velocity at the inlet and outlet of the dryer was monitored using the TROTEC TA 300 hot wire anemometer. Information obtained by the sensors is numerically transferred and graphically represented on a computer. The research method has been developed by mathematical modeling of mass and heat transfer phenomena in corn seed layers based on a series of data obtained by experiment on the vertical dryer model with heat recovery.

Numerical meshing techniques are the main means of approximation by meshing the continuous environments.

Discretization consists of the decomposition of a continuous analysis domain (2D and 3D geometry) into a finite number of discrete elements and the approximation of the whole by the assembly of the component elements.

By integrating the partial derivative equations on the finite control volume V ($V=\Delta x \cdot \Delta y \cdot \Delta z$), the first and second order integrals appear, which will take a discretized form respecting the values of the function in the neighboring volumes. The areas of separation between the adjacent control volumes are in this case discontinuous surfaces. The values of the function u on these surfaces are considered equal to the arithmetic mean of the values corresponding to the volumes placed on one side of each other.

Integrating first-order derivatives has a discreet overall form:

$$\int_{\Delta V}\left(\frac{\partial u}{\partial x}\right)dxdydz = dydz\int_{i-\frac{1}{2}}^{i+\frac{1}{2}}\left(\frac{\partial u}{\partial x}\right)dx = \left(u_{i+\frac{1}{2},j,k} - u_{i-\frac{1}{2},j.k}\right)\Delta y\Delta z \tag{1}$$

where: i, j, k as the index represents the natural number.

Second-order integration by a direction will be:

$$\int_{\Delta V}\left(\frac{\partial^2 u}{\partial x^2}\right)dxdydz = dydz\int_{i-\frac{1}{2}}^{i+\frac{1}{2}}\left(\frac{\partial^2 u}{\partial x^2}\right)dx = \left[\left(\frac{\partial u}{\partial x}\right)_{i+\frac{1}{2}.j.k} - \left(\frac{\partial u}{\partial x}\right)_{i-\frac{1}{2},j,k}\right]\Delta y\Delta z \tag{2}$$

Derivatives at the edge of the control volume can be expressed as a ratio between the difference in values of the corresponding function of two neighboring nodes and the distance between them:

$$\left(\frac{\partial u}{\partial x}\right)_{i+\frac{1}{2},j,k} = \frac{u_{i+1,j,k} + u_{i,j,k}}{\Delta x};\ \left(\frac{\partial u}{\partial x}\right)_{i-\frac{1}{2},j,k} = \frac{u_{i,j,k} + u_{i-1,j,k}}{\Delta x} \tag{3}$$

Entering the relation (3) in (2) results:

$$\int_{\Delta V}\left(\frac{\partial^2 u}{\partial x^2}\right)dxdydz = \frac{u_{i+1,j,k} - 2u_{i,j,k} + u_{i-1,j,k}}{\Delta x^2}\cdot\Delta V \tag{4}$$

Similar for the other two directions:

$$\int_{\Delta V}\left(\frac{\partial^2 u}{\partial y^2}\right)dxdydz = \frac{u_{i,j+1,k} - 2u_{i,j,k} + u_{i,j-1,k}}{\Delta y^2}\cdot\Delta V \tag{5}$$

$$\int_{\Delta V}\left(\frac{\partial^2 u}{\partial z^2}\right)dxdydz = \frac{u_{i,j,k+1} - 2u_{i,j,k} + u_{i,j,k-1}}{\Delta z^2}\cdot\Delta V \tag{6}$$

The expressions of the integrals of the mixed derivatives can be obtained using the integration of second-order mixed derivatives:

$$\int_{\Delta V}\left(\frac{\partial^2 u}{\partial x\partial y}\right)dxdydz = \frac{u_{i+1,j+1,k} - u_{i+1,j-1,k} + u_{i-1.j-1,k} - u_{i-1,j+1,k}}{4\Delta x\cdot\Delta y} \tag{7}$$

Finite volume discretization involves an analysis of the working range that is volumetric represented by the cylindrical unit. It has the form of a cylinder that has three slots where the cereal seeds are introduced for drying. The hot air enters this cylindrical box through the central region, being guided by a cylindrical tubing that connects to the dryer. The mesh geometry of the three-layer cylindrical unit is shown in fig. 2.

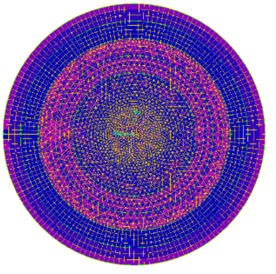


Figure 2 Cylindrical dryer meshing

In the CFD simulation process, the boundary conditions required to achieve the determination of the system of equations are imposed: at each node in the analysis domain, the calculation of the equation system is performed by the Gauss-Seidel iterative method. With the help of the presented method, using the imposed limit conditions, which are presented in Table 1 and Table 2, several solutions can be found. The convergence of solutions depends on the quality of the mesh, the contour conditions and the chosen mathematical model.

Table 1 Initial conditions imposed for corn seed processing

Layers	Drying time τ (min)	Initial product humidity in absolute values X (kg water vap. / kg dry product)	Product volumic mass ρ (kg/m^3)	Product specific heat c_p (J/kg K)	Product thermal conductivity k (W/m K)	Porosity Index ε (-)
I, II, III	65 min; 27 min	0,156	615	1679	0,158	0,345… 0,385

Table 2 Processing imposed conditions for the drying agent

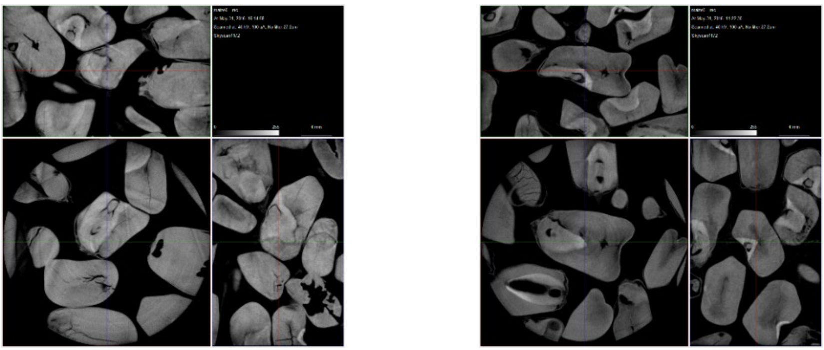
Parameters / Variants	Air velocity v (m/s)	Temperature T (K): Entering surface	Temperature T (K): walls $\frac{\partial v}{\partial n}=0$	Presure p (Pa): Exit surface	Air humidity X_a (kg vapors/kg dried air)	Air volumic mass ρ_a (kg/m^3)	η *10^{-5}	c_p (J/kg K)	K (W/m K)
I	2,0	T = 313 K = 40°C	T = 313 K = 40°C	p = 0	X_a=0,008	1,225	1,72	1011	0,0454
II	2,0	T = 343 K = 70°C	T= 343 K = 70°C	p = 0	X_a=0,020	1,325	1,72	1001	0,0244

where: η – dynamic viscosity; c_p – specific heat; k – conductivity.

RESULTS AND DISCUSSION

The porosity index is determined experimentally by scanning a determined volume (68.7 cm^3) of 78 maize seeds with a mass of 42.3 grams at a relative humidity of 25% and an absolute humidity of 0.156 (kg of water vapor / kg dry product) with a 3D SKYSCAN 1172 micro CT scanner at a resolution of 27.224 μm resulting in a porosity index of 34.5%.

Experimentally, at the end of the drying process, the moisture in the three layers of corn seeds decreases unevenly in the radial direction as follows: layer I - 11.5%, layer II - 11.7% and layer III - 14% and the porosity index varies on the three layers with seeds as follows: layer I - 38.5%, layer II - 38.0% and layer III - 37%. The porosity index was determined at the beginning of drying (corn seed humidity of 25%) and at the end of the drying process (maize seed humidity of 11.5%) (Fig. 3).



a b

Figure 3 Scanned corn seed at the resolution of 27,224 μm with 3D SKYSCAN 1172 micro CT scanner:
a – seeds with 25% initial humidity; b – seeds with 11.5% initial humidity.

The porosity index is introduced into the mathematical model with subunit values ranging from 0.345 to 0.385. In the CFD simulation with the FLUENT program, the porosity index of a layer of material is between 0 and 1, where at 0 the layer is completely closed, and at 1 layer it is completely open (Ansys Fluent, 2012). Corn seed humidity varies depending on the relative humidity of the air (Table 3).

Table 3 Seed balance moisture depending on air relative humidity

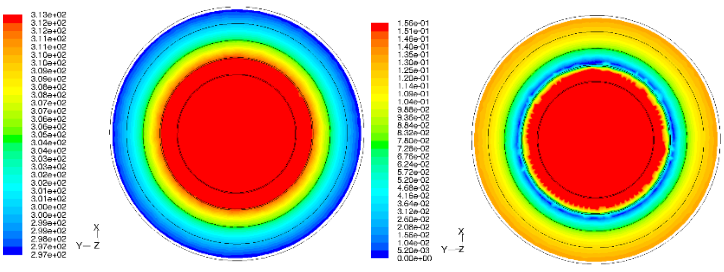
	Air relative humidity (%)							
Corn seed	20	30	40	50	60	70	80	90
	Corn seed humidity (%)							
	8,2	9,4	10,7	11,9	13,2	14,9	16,9	19,2

The maize seed moisture balance taken into account was 11.5% and the initial humidity was 25%. In this humidity range the absolute humidity is calculated according to Table 4.

Table 4 Relative and absolute humidity of corn seeds

Relative humidity (%)	25	23	21	19	17	15	13	11,8	11,6	11,5
Absolute humidity (kg water vapor / kg dry product)	0,156	0,129	0,104	0,081	0,058	0,036	0,015	0,003	0,001	0

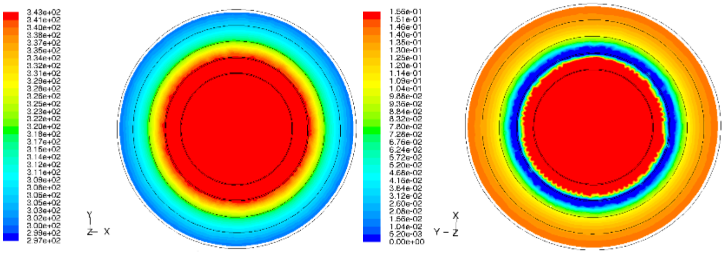
The temperatures for the two simulated variants were 313 K (40 °C) and 343 K (70 °C). In variant I, with a thermal agent at 313 K (40 ° C) on the cross section of the cylindrical dryer and three layers of corn seeds, the average temperature of the thermal agent decreases progressively from the layer I, which first contacts the agent at the second layer with 305 K (32 °C), reaching the third layer at an average temperature of 301 K (28 °C) until the end of the drying process. In order to observe the degree of uniformity of the temperature distribution in the three layers of corn seeds, a cross section was made through the cylindrical unit (Fig. 4a). On the inside of the red box is the temperature of the drying agent with the value of 313 K (40 °C). The results of the CFD simulation on the absolute humidity distribution of maize seed in the three layers of the cylindrical unit seed are shown in a cross section (Fig. 4b) with a lower mean value in the first layer of 0.001 (kg of water vapor / kg of dry product). Inside the unit, a red color of 0.156 (kg of water vapor / kg of dry product) is an initial seed moisture of maize seed, which in the present case has no physical significance because the drying agent is circulating inside.



a. b.

Figure 4 The cross section representations for the first simulation version
(v = 2 m/s; T = 313 K = 40°C)
a. temperature field (K); b. absolute humidity field (kg water vapors/kg dry product).

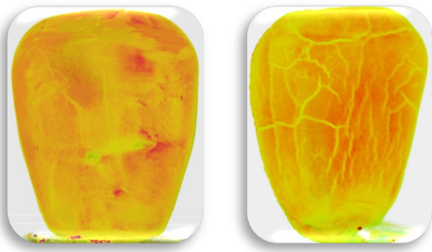
The cross section representations for the second simulation version for both the temperature field and the absolute humidity field are presented in fig. 5a and fig. 5b. In this case the higher value in seed layer II is 0.005 (kg water vapor / kg dry product) and the highest value in layer III is 0.11 (kg of water vapor / kg dry product).



a. b.

Figure 5 The cross section representations for the second simulation version
(v = 2 m/s; T = 343 K = 70ºC)
a. temperature field (K); b. absolute humidity field (kg water vapors/kg dry product).

The effects of an agressive drying process using high temperatures and low air velocities can be seen in fig. 6.



a. b.

Figure 6 Dehydrated corn seed longitudinal scanned sections
a. T = 40ºC; v = 2,5 m/s; b. T = 80ºC; v = 1 m/s.

After drying in each variant, corn seed were scanned using a 3D scanner in order to see to what extent the grains were affected. In this consideration, it has been found that the temperatures in the drying process can greatly influence the proportion and nature of the substances that are involved in the seed composition. For temperatures lower than 60 ºC regardless the fan velocity, nothing happens to the structure of the seed. When the grain mass is heated at temperatures above 60 °C, 70 °C, the chemical components of the seeds undergo transformations that reduce the qualities of the grains and fractures appear whose width increases with the increase of temperature.

Regarding the qualitative changes to the products that dry out in the post-maturation period, it was found that the low temperatures at the beginning of the seed drying process, which gradually increase as the humidity decreases, accelerate their post-maturation, improve the physical, biochemical and technological characteristics of the seeds.

Analyzing the results of the physical parameters obtained throughout the experiments, one can conclude that the best results concerning the drying time, the energy consumption, the protein content and the germination power of corn seeds have been recorded for the variants in which the drying process was done using low temperatures and high fan velocities.

CONCLUSIONS

In comparison, the corn seed humidity experimental values obtained at the end of the drying process were 11.5% in the first layer, 11.70% in the second layer, reaching 14% in the third layer. Larger differences in humidity between experiment and simulation are observed in the last seed layer, 8%. One possible explanation could be the excessive accumulation of moisture in the last layer, brought from the first two layers and which could not be removed during the drying time. From the point of view of the uniform drying of corn seeds the final humidity values in the seed layers were closer at the maximum velocity used of the drying agent and at low working temperatures. At temperatures higher than 50 ºC, for the germination power of the seeds the values obtained vary inversely proportional to the temperature, but at the same time, vary directly proportional to the thermal agent velocity.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

ENSILING ALFALFA LEAVES AS A HIGH PROTEIN FEED FOR MONOGASTRIC ANIMALS

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ABSTRACT

Legume leaves have a big potential as feed protein due to their high protein and therein high essential amino acid content. Especially in organic feeding of monogastric animals like pigs and poultry, essential amino acids are needed, and feeding of roughage could generate aditional animal welfare benefits. Hence, the aim of the study was to consider the interaction of the technique in relation to the protein content of the silage. During the ensiling process antinutritive saponins in the alfalfa leaves will be reduced, which is not possible with other conservation options like drying. Therefore a silage trial was conducted in 2018 in order to investigate the ensilability of alfalfa leaves using vacuum plastic bags. The plastic bag method was used for ensiling to guarantee a maximal detrainment of the silage material. The harvested material was ensiled without and with admitxures in different concentrations related to fresh mass. The admixtures were molasses (1.8 % and 3.8 %), dried pulp from sugar beet (7.5 % and 15 %) and cereal meal (7.5 % and 15 %). Crude protein content (XP) of starting material was 32.3 % of total dry matter (DM). Further analyses of ensilaged alfalfa leaves without admixtures showed a XP content of 28.5 % of total DM. If cereal meal was added with the concentration of 7.5 % and 15.0 %, the silage had a XP content of 24.9 % and 23.1 % of total DM, respectively. Addition of dried pulp from sugar beet with the concentration of 7.5 % and 15.0 %, revealed a XP content of 26.5 % and 23.2 % of total DM, respectively. Higher XP was achieved by addition of molasses. Its concentration of 1.9 % and 3.8 %, revealed a XP content of 29.7 % and 28.5 % of total DM, respectively. Regarding the lactic acid content (LAC), the *fermented alfalfa leaves without admixtures had a LAC of 8.7 % of total DM. With the addition of cereal meal (7.5 % resp. 15.0 %) resulted in LAC after 21 days of silaging of 8.3 % and 6.8 % of total DM, respectively. The LAC of alfalfa leaves with 7.5 % and 15.0 % dried pulp sugar beet was 5.5 % and 6.3 % of total DM, respectively. Alfalfa leaves ensiled in combination with molasses, showed LAC of 8.9 % of total DM (1.8 % molasses) and 11.4 % of total DM (3.8 % molasses). To conclude, silage of alfalfa leaves with its high protein content could be ensilied resulting in a good quality silage using appropriate admixtures and has therefore a potential as a major protein source in organic feed mixtures for monogastric animals because of its above average XP in the silage.*

Keywords: *silage admixtures, alfalfa leaves, vaccum plastic bags*

INTRODUCTION

Legume forage crops become more and more important as a protein source in agricultural production. So they could solve the challenge in organic pig and poultry production to reduce the lack of certain amino acids in so far available feed stuffs. High-quality legume leaf protein, rich in essential amino acids like lysin or methinonin, can be harvested by separating the leaf and stem biomass of alfalfa (*Medicago sativa*). Since alfalfa leaves, harvested at BBCH 60 or earlier, have a higher protein content (more than 30 % crude protein (XP)) than stems (Hoischen-Taubner et al., 2017). Therefore, Sommer and Sundrum (2015) also advised a separation of leaves and stems of legumes in order to achieve a high protein concentration. Also alfalfa which is cut at a very early stage (BBCH 50) has a XP content of more than 30 %. Additionally the concentration of methionin is high for both: 100 gram crude protein contain 1.8 gram methionin (DLG, 2014). Therefore, the amount of methionin in very young alfalfa plants or alfalfa leaves is comparable to soy and much higher than in peas (DLG, 2014). Legume forage crops like alfalfa or alfalfa-ray grass mixtures are common crops in organic farming because of their ability of nitrogen fixation (Pommer et al., 2009). Hence, the aim is to use this material as a protein feed for monogastric animals and to realize a roughage supply that is obligatory in organic poultry production (EU, 2008), at the same time. Especially in organic feeding of monogastric animals like pigs and poultry, essential amino acids are often limited within the diet, and feeding of roughage could generate aditional animal welfare benefits. Therefore, the aim of this study was to ensile alfalfa leaves with different admixtures in order to guarantee for an efficient fermentation during ensiling and a sufficient pH value reduction for a stable silage also during removal. Common admixtures (like molasses, dried pulp sugar beet, and mixed cereal meal) in two different concentrations were used to investigate the effect of ensiling in combination with alfalfa leaves. Additionally the effect of chopping the alfalfa leaves was considered.

MATERIALS AND METHODS

Harvest of alfalfa leaves

The alfalfa variety Plato was sown on an organic field near Freising, Germany, in autum 2016, where one topping was realised. The harvest of the silage raw material was at the first cut in the second year, on 3rd May 2018. The plant maturity was in primary growth (early bud and early flowering, BBCH 55). In the early afternoon after leaves dried up, the alfalfa leaves were harvested from the same field by a special prototype separating the leaves from the stems of the alfalfa plants. The special prototype had a stripper in the shape of a transverese roller with metal bars actuated by a tractor to separate the leaves from the plant stems. The leaves were stripped from stems by the metal bars and then thrown on a conveyer belt. The conveyer belt handed over the leaves to a second conveyer belt that transported them to an accelerator blowing the harvested leaves on a loader wagon. The stems were cut and harvested in a second step. The harvested leaves were transported to a dumpsite for weighing. There the starting material for ensiling was taken and dry matter (DM) was determined. The DM content of the alfalfa leaves was on average 19.2 % (n = 3 samples). To analyse the effect of chopping on the silaged variants, one part of the raw material was chopped with a theoretical chopping length of 4 mm by a chopper (Claas Jaguar 900 Speedstar) on the trial field. The DM content of the chopped alfalfa leaves was on average 20.2 % (n = 3 samples).

Ensiling the raw material and different variants

After harvesting the four material types, ensiling was realized in Freising within four hours after harvesting in reference to DLG e.V. guidelines (DLG, 2018). Three different admixtures were used for ensiling: molasses, dried pulp from sugar beet, and mixed cereal meal. The mixed cereal meal consisted of one third of each: winter wheat, winter barley and triticale. The results of the Weender analyses of the admixtures are shown in the following table 1.

Table 1 Overview of ingredients of all admixtures in gram referred to 1.000 grams of dry matter

	Molasses	Dried pulp from sugar beet	Mixed cereal meal
Dry matter	66.2 %	90.1 %	88.2 %
Crude protein (XP)	26	88	107
Crude fat (XL)	---	7	22
Crude fiber (XF)	---	219	45
Raw ash (XA)	62	97	26
Starch (XS)	---	---	662
Sugar (XZ)	---	4	19
Metabolic energy ruminants (ME)	13.06	10.47	12.96
Netto energy lactation (NEL)	8.52	6.39	8.20
Metabolic energy pig (ME)	---	---	14.44

The ensiling trial was modified according to the Rostock Model Silages (ROMOS) (Hoedtke and Zeyner, 2011). Therefore, the ensiling trail was conducted with polyethylene bags with a thickness of 90 µm, a length of 600 mm and a width of 400 mm. For vacuuming a vaccuming machine (Boss, Max-F46) was used. About 1 kg of fresh matter was filled into each plastic bag to have enough material for laboratory analyses. Five repetitions were prepared for each variant. Two bags were analysed after each week to determine pH. The futher three bags of each variant were mixed together in a pooled sample and analysed according to the Weender analyses. Due to gas development, some bags were punctured by a needle and immediately closed again by a special silage tape to aviod external gas entry. According to ROMOS, bags were wrapped with an adhesive tape around the sealed puncture. Thereby, care had to be taken that the shape was stabilized without the packing density being increased.

An overwiew of the different variant combinations is shown in the following table 2.

Table 2 Overview of the different variants with admixtures.

	Admixture (with its different concentrations related to fresh mass)						
Alfalafa leaves	no admixture	molasses		dried pulp from sugar beet		mixed cereal meal	
unchopped	-	1.8 %	3.8 %	7.5 %	15.0 %	7.5 %	15.0 %
chopped	-	1.8 %	3.8 %	7.5 %	15.0 %	7.5 %	15.0 %

The starting material of unchoppend and chopped alfalfa leaves had the following ingredients before ensiling.

Table 3 Overview of the ingredients of unchopped and chopped alfalfa leaves before ensiling related to 1.000 gram of dry matter.

	Alfalfa leaves unchopped	Alfalfa leaves chopped
Dry matter	17.9 %	18.6 %
Raw ash (XA)	115	121
Crude protein (XP)	323	311
Crude fiber (XF)	112	127
Crude fat (XL)	35	35
Sugar (XZ)	65	75
Metabolic energy ruminants (ME)	11.74	11.45
Netto energy lactation (NEL)	7.21	7.01
Metabolic energy pig (ME)	9.55	9.44

Storing and analysis

The ensilied bags were stored in a climatic chamber without light at the LfL located in Grub near Munich. The steady temperature was kept at 25 degree Celsius. After 21 days three bags of every variant were weighed and brought to the laboratory. Three repetitions were put together in a pooled sample for analysis and frosted at minus 20 degree Celsius until analysation. The material was analysed according to the follwing paramters "Weender Analyse" (dry mater, raw ash, crude protein, crude fiber), sugar, starch, alcohol, fermenation parameters (lactic acid content, acetic acid, propionic acid, and butyric acid) and ammonia. Therefore the analysis directives of VDLUFA methode manual were applied (VDLUFA, 1976). Losses, e.g. of volatile substances, were not considered further because so far no correction term for ensiled alfalfa leaves is available.

RESULTS AND DISCUSSION

While harvesting, the starting material alfalfa leaves and chopped alfalfa leaves had a DM content before ensiling of 19.2 % and 20.2 %, respectivley. After 21 days ensiling alfalfa leaves and chopped alfafla leaves had a DM content of 16.5 % and 18.5 %. Additionally the four important fermentation acids (lactic acid, acetic acid, propionic acid and butyric acid) in all variants were analysed. Theses acids support the decrease of the pH value in the silage, resulting in the conservation of the feed. The acid values and pH of the pooled sample are shown in the following figure 1. No propionic acid was detected in all variants.

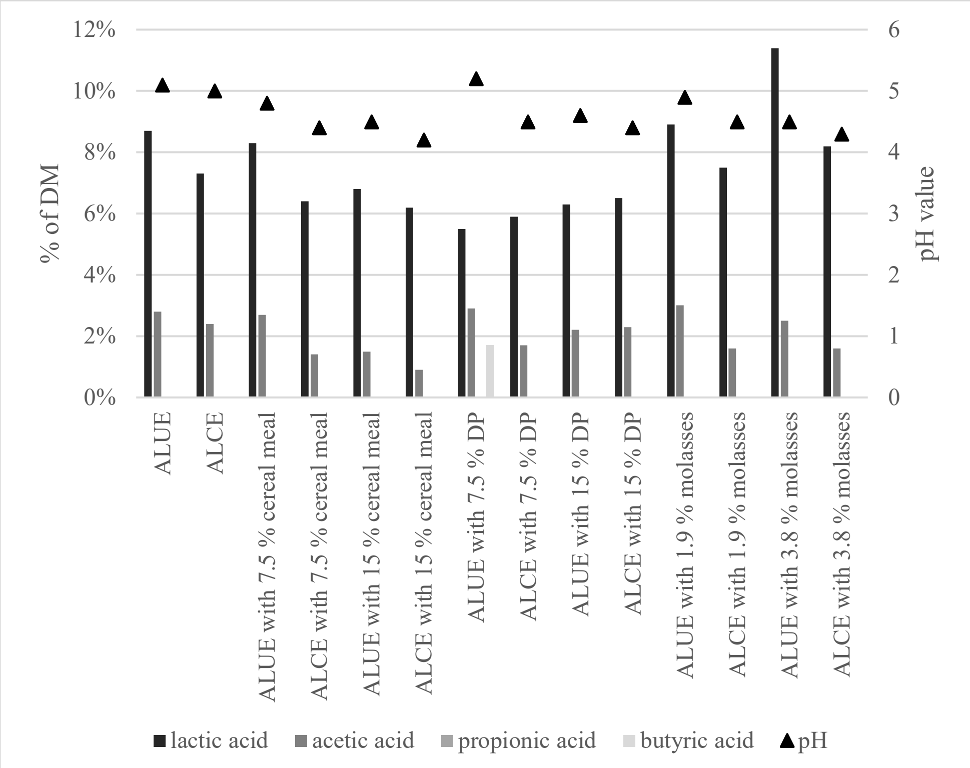

Figure 1 Lactic acid, acetic acid, propionic acid, butyric acid contents and pH value in all silage variants at day 21 after ensiling. ALCE = alfalfa leaves chopped and ensiled, ALUE = alfalfa leaves unchopped and ensiled, DP = dried pulp from sugar beet

The pH value varied among all variants from 4.2 to 5.2. Spiekers (2012) advises a pH value from 4.0 to 5.0 in gras silages. All variants except the alfalfa variants with dried pulp from sugar beet showed that chopping reduced the development of lactic acid. For dried pulp from sugar beet, the development of lactic acid for chopped and unchopped alfalfa leaves was nearly similar on a low level. One reason for the reduced development of lactic acid was the destruction of the cell walls which increased the loss of cell sap. Therefore, with less acid a lower pH value resulted for the chopped variants. All ensiled alfalfa variants ranged between

5.5 % and 11.4 % lactic acid as % of DM. According to Santos et al. (2016), who investigated effects of dry matter and length of storage on the composition and nutritive value of alfalfa silage demonstrated in their study that the maximal lactic acid contend was about 3.5 % of DM. So, alfalfa leaves tend to generate more lactic acid while ensiling in comparison to alfalfa because of a higher sugar content in the leaves compared to the whole plant. The content of acetic acid in alfalfa leaves varied from about 0.9 % to 3.0 % of DM. In the alfalfa trials of Santos et al. (2016), the acetic acid varied from about 0.4 % to 1.5 % of DM depending on DM and storage time. Only alfalfa leaves ensilaged with 7.5 % dried pulp from sugar beet showed 1.7 % of butyric acid which indicates a misfermentation (Spiekers, 2012).

After 21 days of ensiling, the XP contents of alfalfa leaves and chopped alfalfa leaves with its different variants were also analysed and are listed in table 4.

Table 4 Crude protein content per 1.000 grams of DM of the feed mixtures after 21 days of ensiling (without further corrections of volatile substances for DM calculation due to lack correction term for alfalfa leaves)

	Crude proteins [% XP per DM]	
	Starting material (calculated) * = analysed by laboratory	Ensiled material day 21 (analysed)
Alfalfa leaves	32.3 %*	28.5 %
Alfalfa leaves, chopped	31.1 %*	28.9 %
Alfalfa leaves with 7.5 % cereal meal	26.5 %	24.9 %
Alfalfa leaves, chopped with 7.5 % cereal meal	25.7 %	24.8 %
Alfalfa leaves with 15 % cereal meal	22.8 %	23.1 %
Alfalfa leaves, chopped with 15 % cereal meal	22.1 %	21.9 %
Alfalfa leaves with 7.5 % dried pulp from sugar beet	25.5 %	26.5 %
Alfalfa leaves, chopped with 7.5 % dried pulp from sugar beet	24.6 %	25.4 %
Alfalfa leaves with 15 % dried pulp from sugar beet	21.1 %	23.2 %
Alfalfa leaves, chopped with 15 % dried pulp from sugar beet	20.4 %	21.7 %
Alfalfa leaves with 1.9 % molasses	29.9 %	29.7 %
Alfalfa leaves chopped with 1.9 % molasses	28.8 %	28.3 %
Alfalfa leaves with 3.8 % molasses	27.8 %	28.5 %
Alfalfa leaves, chopped with 3.8 % molasses	26.8 %	28.2 %

The starting material alfalfa leaves and chopped alfalfa leaves had a XP content of 32.3 % and 31.1 %, respectively.These were higher XP contents compared to Hoischen-Taubner et al. (2017), who investigated a XP content of 28.3 % in alfalfa leaves which were not chopped. In seven variants, the crude protein content in the ensilaged variant was higher than the crude protein in the starting material ranged from plus 0.3 % to maximal plus 2.1 % of DM. But it has to be considered that the measurement error of the analytic method was 1 % (absolute) for XP values from 20.0 % - 25.0 % and 1 % (relative) for XP values from 25.0 % - 52.0 % (VDLUFA, 1976). Together with the sampling error, it is rather expected that the XP values are similar to the starting material or lower. According to Köhler et al. (2018) grass silages had a XP decrease of 0.8 % from 17.1 % of DM in starting material to 16.3 % of DM in the silage. Muck et al. (2015) investigated an increase of crude protein from 0.1 % to 0.7 % in a silo type conservation trail for alfalfa using a bunker silo (4.9 × 21.3 × 3.5 m), bag silo (2.4 m dia. × 52 m), and oxygen-limiting tower (4.3 m dia. × 15.2 m) caused by DM losses in the silos. The highest XP value with 29.7 % XP of DM belonged to alfalfa leaves with 1.9 % molasses. The XP contents of differents feeds can be 17.7 % of DM in silages, 18.3 % of DM in cobs, or 15.0 % of DM in hay (Meusburger, 2013). All variants of alfalfa leaves had a minimum XP content of 21.7 % XP of DM which is higher compared to the results of Meusburger (2013). To sum up, the results showed that harvesting and ensiling leaves produces a high protein feed.

Regularly there will be a decrease of the protein content during fermentation in a silo. All chopped variants except alfalfa leaves, chopped with 3.8 % molasses had a lower crude protein content than the variants which had not been chopped. So, chopping tends to reduce the crude protein content.

CONCLUSIONS

Various admixtures, like molasses, dried pulp from sugar beet, and mixed cereal meal, in two different concentrations were used in this silage trail to investigate their effect on ensiling in combination with alfalfa leaves. To sum up, the highest XP contents in alfalfa silages after 21 days were achieved by alfalfa leaves ensiled in combination with an adequate amount of molasses because of a small XP reduction during the fermentation process. The variants without admixtures showed in contrary a noticeable XP reduction. The addition of cereal meal as well as dried pulp from sugar beet caused lower XP contents in comparison to the variants without admixtures because of the amount of addition. Therefore, molasses with lower amounts of addition is considered to be the optimum in reduction of XP content and fermentation losses. The separation of leafs and stems in alfalfa leads to a high quality feed for monogastric animals because of a high XP content in the silage. Chopping of harvested leaf material tends to reduce XP content in the silage.

ACKNOWLEDGEMENTS

The project was supported by funds of the Federal Organic Farming Programme (BÖLN) based on a decision of the Parliament of the Federal Republic of Germany via the Federal Office for Agriculture and Food (BLE) under the innovation support program (grant 2815OE077).

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

POTROŠNJA ENERGIJE ZA SPREMANJE SIJENA

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SAŽETAK

Analiza potrošnje energije izvršena je kod dva načina spremanja sijena u polju – sušenjem na tlu, na jedanaest obiteljskih gospodarstava na različitim lokacijama u Sloveniji. Potrošnja energije u spremanju sijena sušenjem u polju na tlu, određena je iz utrošenog mineralnog dizelskog goriva, kod izvođenja različitih radnih operacija s traktorskim agregatom u jednom cjelokupnom procesu spremanja sijena (košnja, rastresanje i okretanje, prigrtanje, sakupljanje sijena sa samoutovarnom prikolicom ili sakupljanje sijena i baliranje s prešom za izradu valjkastih bala). Zbroj potrošnji energije za sve radne operacije daje nam podatke o konačnoj potrošnji energije za spremanje sijena sušenjem na tlu na dva različita načina (korištenje samoutovarnih prikolica ili baliranje sjena u valjkaste bale). Prosječna potrošnja cjelokupne energije (od košnje do baliranja sijena) na hektar površine (MJ·ha^{-1}) prilikom spremanja sijena s baliranjem sijena u valjkaste bale je viša za 27,6 % od prosječne potrošnje cjelokupne energije (MJ·ha^{-1}) kod spremanja sijena, kada se spremanje obavlja sa samoutovarnom prikolicom (energija utrošena od košnje do utovara sijena sa samoutovarnom prikolicom). Kod transporta sijena je prosječna satna potrošnja energije (MJ·h^{-1}) za transport valjkastih bala sijena prilikom spremanja sijena s baliranjem sijena u valjkaste bale, viša za 24,1 % od satne potrošnje energije za transport sijena sa samoutovarnom prikolicom. Prosječna satna potrošnja energije (MJ·h^{-1}) za manipulaciju s balama viša je za 6,5 % u usporedbi s radnim procesom pražnjenja samoutovarne prikolice i transporta sijena iz samoutovarne prikolice pomoću puhala u skladište za sijeno.

Ključne riječi: *spremanje sijena, sušenje sijena na tlu, strojevi za spremanje sijena, potrošnja energije*

UVOD

U slučaju da se travna krma konzervira kao sijeno, mora se sušiti do razine na kojoj ne postoji opasnost od kvarenja u skladištu. Svježa travnata krma koja je pogodno za košnju sadrži 80 do 85 % vode. U sijenu, koje se skladišti količina vode ne smije biti viša od 20 %. Sušenje na tlu traje tri do četiri dana, ovisno o godišnjem dobu - vremenu košnje, prinosu na hektar, botaničkom sastavu, intenzitetu mehaničkih zahvata u krmi i vremenskim uvjetima (Mrhar, 1993). Energetska analiza s ekonomskom analizom i analizom okoliša važan su alat za određivanje funkcioniranja poljoprivrednih sustava. Ekonomija, energija i okoliš su tri E (izvedena iz tri engleske riječi, skraćeno - Energy, Economics i Environment), koje se moraju uzeti u obzir u svim poljoprivrednim aktivnostima. Energetska analiza, kao važan objekt poljoprivredne proizvodnje, počela se proučavati sedamdesetih godina kao posljedica rasta cijena naftnih derivata (Ortiz Canavate i Hernanz, 1999). Uspostava metodologija za identifikaciju i procjenu različitih tokova energije uključenih u poljoprivrednu proizvodnju temelj je energetske analize. Cilj energetske analize je jasan: smanjiti unos energije ili potražiti druge obnovljive energije u poljoprivrednim procesima, uz uvođenje učinkovitijih metoda rada. Ovaj cilj je i kombiniran, ako je moguće, smanjenjem troškova proizvodnje i ekološki prihvatljivim proizvodnim metodama kao dijelom boljeg sustava upravljanja (Ortiz Canavate i Hernanz, 1999). Korištenje energije definira se kao neto energija koja se koristi za proizvodnju poljoprivrednih proizvoda dok se proizvod ne proda ili napusti farmu ili koristi kao hrana za uzgoj životinja (Dalgaard i sur., 2001). Korištenje energije može se podijeliti na izravnu i neizravnu energiju. Izravna energija ($E_{direktna}$) predstavlja unos energije u samu poljoprivrednu proizvodnju. Kada se navedeni unos energije može izravno pretvoriti u energetske jedinice (mineralni dizel, maziva, LPG ili energija zemnog plina za opskrbu energijom, električna energija za naknadnu obradu uroda, itd.). Indirektna energija ($E_{indirektna}$) je energija koja se koristi u proizvodnji inputa korištenih u proizvodnji poljoprivrednih proizvoda, a ti se inputi ne mogu izravno pretvoriti u energetske jedinice (strojevi, gnojiva, fitofarmaceutska sredstva, itd.). Ukupna energija za poljoprivrednu proizvodnju (Dalgaard i sur., 2001) može se predstaviti jednadžbom (1).

$$E_{usjeva} = E_{direktna} + E_{indirektna}$$

$$E_{usjeva} = (E_{dizel\ gorivo} + E_{ostala}) + E_{indirektna} \tag{1}$$

Kod spremanja sijena, za pogon traktora agregiranih strojevima za spremanje sijena koristi se mineralni dizel, što znači da je $EU_{direktna}$ (1) utrošena zbog izgaranja spomenutog goriva u motoru traktora, kod obavljanja različitih radnih operacija. Različiti autori navode da se prosječne vrijednosti potrošnje mineralnog dizela za različite poljoprivredne operacije uzimaju kao varijable koje se mjere za potrošnju goriva u $l \cdot ha^{-1}$ ili $kg \cdot ha^{-1}$ (Handler i Nadlinger, 2012). Mjerenje potrošnje goriva i pripadajućih emisija stakleničkih plinova u obavljanju raznih operacija za sakupljanje sijena sušenjem na tlu (krajnji proizvod spremanja sijena bile su male kvadarne bale) pokazao je najveću potrošnju goriva i pripadajuće emisije stakleničkih plinova (izračunato za suhu tvar) u radnim operacijama košnje i baliranja sijena. Manja potrošnja goriva ustanovljena je za radne operacije mehaničkog tretiranja krme, okretanja i prigrtanje sijena, a vrlo niska potrošnja goriva za transport i baliranje bala sijena (Morissette i Savoie 2014).

Cilj rada je odrediti potrošnju energije kod spremanja sijena u polju – na tlu na dva različita načina (korištenje samo utovarnih prikolica ili baliranje sjena u valjkaste bale).

METODIKA

Za određivanje potrošnje energije napravljen je energetski model, koji koriste podatke mjerenja potrošnje energije na obiteljskim gospodarstvima kod spremanja sijena. U energetskoj analizi unose se energija (izravna energija), koja se u potpunosti potroši tijekom razdoblja spremanja sijena. Inputi energije tijekom dužeg vremenskog razdoblja odnosno indirektne energije (za proizvodnju traktora, priključnih strojeva, opreme, itd. te energije za proizvodnju goriva) nisu uključeni u analizu. Za određivanje potrošnje energije odabrano je jedanaest obiteljskih gospodarstava na kojima spremaju sijeno sušenjem na tlu. Potrošnja energije definirana je kao energija fosilnog goriva (mineralni dizel), koja se koristi u provedbi raznih mehaniziranih radnih operacija. Ukupna utrošena energija za spremanje sijena u polju s tehnologijom sušenja sijena na tlu na površini od jednog hektara, određuje se dodavanjem pojedinačnih potrošnji energije za različite radne operacije (košnja, rastresanje i okretanje sijena, prigrtanje sijena, baliranje sijena, sakupljanje sijena sa samoutovarnom prikolicom ili prešama, itd.). Ukupni unos energije E_c (2) određuje se iz utrošenog mineralnog dizela koji se koristi u različitim metodama spremanja sijena na površini od jednog hektara. Potrošnja energije određuje se u $MJ \cdot ha^{-1}$ i $MJ \cdot t^{-1}$ ST. Za definiranje cjelokupne potrošnje energije, kod spremanja sijena, definirana je jednadžba (2) koja se sastoji od potrošnje energije za svaku radnu operaciju u procesu spremanju sijena.

$$E_c = E_k + E_o + E_z + E_{sp} + E_t \tag{2}$$

gdje je:
E_c = ukupna energija korištena u procesu spremanja sijena (MJ)
E_k = energija za košnju
E_o = energija za rastresanje i okretanje sijena
E_z = energija za prigrtanje sijena
E_{sp} = energija za sakupljanje sijena (prikolica ili balirka)
E_t = energija za prijevoz sijena (od parcele do obiteljskog gospodarstva-mjesta skladištenja)

Mjerenje potrošnje energije izvršeno je kod dva načina spremanja sijena u polju sa sušenjem na tlu na jedanaest obiteljskih gospodarstava na različitim lokacijama u Sloveniji sa traktorima i priključnim strojevima za spremanje sijena sa kojima raspolažu pojedina gospodarstava. Potrošnja energije u spremanju sijena sušenjem na tlu određena je iz utrošenog mineralnog dizelskog goriva, kod izvođenja različitih mehaniziranih radnih operacija u jednom cjelokupnom procesu spremanja sijena (košnja, rastresanje i okretanje, prigrtanje, sakupljanje sa samo utovarnom prikolicom ili sakupljanje sijena i baliranje s prešom za valjkaste bale, transport sijena sa samoutovarnom prikolicom ili s prikolicom za valjkaste bale). Ukupna potrošnja energije za spremanje sijena na površini od jednog hektara određuje se zbrajanjem potrošnje energije svakog pojedinog unosa energije.

Potrošnja energije u spremanju sijena u polju sa sušenjem na tlu određena je mjerenjem potrošnje goriva (volumenska metoda) pri obavljanju radnih operacija s različitim traktorskim priključnim strojevima za spremanje sijena. Potrošnja goriva izražena je u litrama po satu ($l \cdot h^{-1}$) za strojeve gdje se ne mogu dati informacije o potrošnji goriva u litrama po hektaru, npr. upotreba traktora za manipulaciju s valjkastim balama na dvorištu obiteljskog gospodarstva ili prijevoz valjkastih bala s prikolicom od lokacije spremanja sijena do obiteljskog gospodarstva. Potrošnje goriva izražene u litrama po hektaru ($l \cdot ha^{-1}$) uzete su za košnju, rastresanje i okretanje, prigrtanje sijena, sakupljanje i prešanje sijena s prešom za valjaste bale te sakupljanje sijena sa samoutovarnom prikolicom. Podaci o potrošnji goriva za različite radne operacije preračunati su u energiju potrošenu za svaku radnu operaciju izraženu u $MJ \cdot h^{-1}$ ili $MJ \cdot ha^{-1}$. Zbroj potrošnji energije za sve radne operacije daje nam informacije o konačnoj potrošnji energije za spremanje sijena u polju sa sušenjem na polju i skupljanjem sa samoutovarnim prikolicama ili s prešama za valjkaste bale. Potrošnja energije izražena je i u MJ energije/količina suhe tvari ($MJ \cdot t^{-1}$ ST) iz prinosa sijena na površini od jednog hektara (konačni sadržaj suhe tvari u sijenu iznosi 85%).

Potrošnja energije određena je pri obavljanju radnih operacija s različitim traktorima sa snagom motora od 60 do 90 kW i priključnim traktorskim strojevima (svi su dobivali pogon preko priključnog vratila traktora), koji su namijenjeni za košnju, rastresanje i okretanje, prigrtanje, sakupljanje i prešanje u valjkaste bale, itd.

REZULTATI I RASPRAVA

Modelski izračuni se temelje na prosječnoj potrošnji goriva za pojedine radne operacije. Rezultati mjerenja potrošnje energije za spremanje sijena s jedanaest obiteljskih gospodarstava prikazani su u tablicama 1, 2 i 3. U radu je predstavljena prosječna potrošnja energije s kojom najbolje možemo predstaviti potrošnju energije za različite radne operacije prilikom spremanja sijena na različitim lokacijama.

Izmjerena je količina mineralnog dizel goriva potrošenog za obavljanje navedenih radnih operacija. Osim toga mjerena je i potrošnja energije za prijevoz (prijevoz sijena ili valjkastih bala) od površina za spremanje sijena do obiteljskih gospodarstava gdje se skladišti sijeno ili valjkaste bale. Neke radne operacije izvode se samo jednom, na primjer košnja, a radne operacije kao što je rastresanje i okretanje te prigrtanje sijena nekoliko puta.

Tablica 1 Prosječna potrošnja energije za spremanje sijena na površini jednog hektara ($MJ \cdot ha^{-1}$), scenarij 1: sakupljanje i prijevoz sijena sa samoutovarnom prikolicom
Table 1 Average energy consumption for haymaking on one hectare surface ($MJ \cdot ha^{-1}$), scenario 1, collection and transport of hay with self-loading wagon

Radna operacija Working operation	Prosječna potrošnja energije Average energy consumption ($MJ \cdot ha^{-1}$)
Košnja (rotacijska – disk kosilica) Mowing (rotary disk mower)	182,28
Okretanje i rastresanje (rotacijski okretač – rastresač) Tedding and spreading (rotary tedder – spreader)	453,60
Prigrtanje sijena u zbojeve (rotacijske grablje) Windrowing of hay (rotary rakes)	567,00
Sakupljanje sijena sa samoutovarnom prikolicom Collection of hay with self-loading wagon	202,44
∑	1.130,22

Ukupna potrošnja energije uzima u obzir broj svih radnih operacija za spremanje sijena s površine od jednog hektara. Za mjerenje potrošnje energije, kod rastresanja, okretanja i prigrtanja sijena, uzeti su strojevi koji izvrše dva zadatka, npr. rastresanje i okretanje sjena te prigrtanje sijena (prigrtanje provenule mase trave, ostavljeno u zbojevima preko noći ili prigrtanje sijena u konačne zbojeve za sakupljanje sijena sa samoutovarnom prikolicom ili prešom za valjkaste bale). Za sakupljanje i prijevoz sijena osušenog na polju koristi se samoutovarna prikolica za utovar i prijevoz sijena prosječnog volumena od 22 m^3, scenarij 1.

U scenariju 2 koristi se preša za valjkaste bale s tlačnom komorom stalnog oblika (promjer valjkastih bala 1,35 m), koja omogućava smanjenje volumena sijena i povećanje njegove gustoće, čime se smanjuje broj transportnih aktivnosti i prostor potreban za skladištenje.

Tablica 2 Prosječna potrošnja energije za spremanje sijena na površini jednog hektara ($MJ \cdot ha^{-1}$), scenarij 2: sakupljanje i prešanje sijena s prešom za valjkaste bale
Table 2 Average energy consumption for storage of hay on one hectare surface ($MJ \cdot ha^{-1}$), scenario 2, collection and balling of hay with round baler

Radna operacija Working operation	Prosječna potrošnja energije Average energy consumption ($MJ \cdot ha^{-1}$)
Košnja (rotacijska – disk kosilica) Mowing (rotary disk mower)	182,28
Okretanje i rastresanje (rotacijski okretač – rastresač) Tedding and spreading (rotary tedder – spreader)	453,60
Prigrtanje sijena u zbojeve (rotacijske grablje) Windrowing of hay (rotary rakes)	567,00
Sakupljanje i prešanje sijena (preša za valjkaste bale) Collection and balling of hay with round baler	359,52
∑	1.562,50

Ukupna prosječna potrošnja energije prilikom spremanja sijena u polju sa sušenjem na tlu sa radnim operacijama od košnje do sakupljanja sijena sa samoutovarnom prikolicom za utovar i transport sijena, iznosi 179,4 $MJ \cdot t^{-1}$ ST, a kada se sijeno sakuplja te preša u valjkaste bale s prešom za valjkaste bale, potrošnja energije iznosi 248 $MJ \cdot t^{-1}$ ST. Prosječna potrošnja cjelokupne energije (od košnje do sakupljanja i prešanja sijena u valjkaste bale) na hektar površine ($MJ \cdot ha^{-1}$) prilikom spremanja sijena sa sakupljanjem i prešanjem sijena u valjkaste bale, viša je za 27, 6 % od prosječne potrošnje cjelokupne energije ($MJ \cdot ha^{-1}$) kod spremanja sijena, kada se spremanje obavlja sa samoutovarnom prikolicom (energija utrošena od košnje do utovara sijena sa samoutovarnom prikolicom). Sakupljanje sjena i njegovo prešanje u valjkaste bale te transport valjkastih bala u našem primjeru najveći su potrošači energije u usporedbi s drugim radnim operacijama u spremanju sijena. Kod drugih radnih operacija moramo uzeti u obzir i to da je prikazana kumulativna potrošnja energije jer se neke radne operacije ponavljaju nekoliko puta u procesu spremanja sijena u polju sa sušenjem na tlu, na primjer, tri puta rastresanje i okretanje sijena, tri puta prigrtanje zbojeva (dva puta za noćne zbojeve iz prigrnute provenute mase i jedanput za konačne zbojeve za sakupljanje sijena sa samoutovarnom prikolicom ili prešom za valjkaste bale).

U transportu sijena je prosječna satna potrošnja energije ($MJ \cdot h^{-1}$) za transport valjkastih bala sijena prilikom spremanja sijena sa sakupljanjem i prešanjem sijena u valjkaste bale, viša za 24,1 % od satne potrošnje energije za transport sijena sa samoutovarnom prikolicom.

Tablica 3 Prosječna satna potrošnja energije ($MJ \cdot h^{-1}$) za utovar, transport i manipulaciju s valjkastim balama te transport sijena sa samoutovarnom prikolicom za sijeno i transport sijena iz samoutovarne prikolice s puhalom za sijeno u skladište
Table 3 Average hourly energy consumption ($MJ \cdot h^{-1}$) for loading, transporting and manipulating with round bales and transporting hay with self-loaded wagon and hay transport from a self-loaded wagon with a hay blower to the hay storage

Radna operacija Working operation	Prosječna potrošnja energije Average energy consumption ($MJ \cdot h^{-1}$)
Utovar i transport valjkastih bala (traktor sa prednjim utovarivačem i prikolica za bale) Loading and transport of round bales (tractor with front loader and wagon for round bales)	400,68
Manipulacija sa valjkastim balama (traktor sa prednjim utovarivačem na skladišnom prostoru) Manipulation with round bales (tractor with front loader on storage area)	91,14
Transport sijena samoutovarnom prikolicom za sijeno Transport of hay with self-loaded wagon	304,08
Pražnjenje sijena iz samoutovarne prikolice i transport sijena u prostor za skladištenje sijena (samoutovarna prikolica i puhalo za sijeno) Unloading of hay from self-loaded wagon on storage area and transport of hay with blower to the hay storage	85,2 MJ

Nakon transporta valjkastih bala s prikolicom za valjkaste bale slijedi još manipulacija s valjkastim balama, istovarom bala s prikolice te njihovim spremanjem u prostor za skladištenje bala. Ta radna operacija se izvodi pomoću traktora agregatiranog s prednjim utovarivačem za valjkaste bale. U uporabi su i specijalne izvedbe traktora – teleskopski utovarivači, koji se mogu koristiti i za manipulaciju s balama, no nabava cijena im je visoka pa se rjeđe koriste na obiteljskim gospodarstvima.

U slučaju da se sijeno dovozi samoutovarnom prikolicom, izvrši se njeno pražnjenje i istovremeno punjenje s puhalom za sijeno (elektromotorni pogon) u skladišni prostor. Prosječna potrošnja energije za manipulaciju s balama viša je za 6,5 % u usporedbi s radnim procesom pražnjenja samoutovarne prikolice i transporta sijena iz samoutovarne prikolice pomoću puhala u skladište za sijeno.

ZAKLJUČAK

Izmjereni podaci o potrošnji energije tijekom spremanja sijena u polju sušenjem na tlu na dva načina omogućuju nam određivanje ukupne energije, koja je potrebna za spremanje sijena od košnje do transporta sijena na skladištenje. Na temelju izmjerenih podataka može se odrediti kako možemo uspješno smanjiti potrošnju energije i utjecati na ekonomičnost proizvodnje te posljedično i niži ugljični otisak procesa te konačnog produkta - sijena. Rezultati mjerenja pokazali su da je potrošnja energije kod spremanja sijena u polju sušenjem na tlu, gdje se vrši radna operacija sakupljanja i prešanja sijena u valjkaste bale i njihov transport prikolicom za bale, veća u odnosu na spremanje sijena sušenjem na tlu, gdje se za sakupljanje i transport sijena koristi samoutovarna prikolica za sijeno. Ukupna prosječna potrošnja energije prilikom spremanja sijena u polju sa sušenjem na tlu s radnim operacijama od košnje do sakupljanja sijena sa samoutovarnom prikolicom za utovar i transport sijena, iznosi 179,4 $MJ \cdot t^{-1}$ ST, a kada se sijeno sakuplja te preša u valjkaste bale s prešom za valjkaste bale, potrošnja energije iznosi 248 $MJ \cdot t^{-1}$ST. Prosječna potrošnja cjelokupne energije (od košnje do sakupljanja i prešanja sijena u valjkaste bale) na hektar površine ($MJ \cdot ha^{-1}$) prilikom spremanja sijena sa sakupljanjem i prešanjem sijena u valjkaste bale, viša je za 27,6 % od prosječne potrošnje cjelokupne energije ($MJ \cdot ha^{-1}$) kod spremanja sijena, kada se spremanje obavlja sa samoutovarnom prikolicom (energija utrošena od košnje do utovara sijena sa samoutovarnom prikolicom). Kod transporta sijena je prosječna satna potrošnja energije ($MJ \cdot h^{-1}$) za transport valjkastih bala prilikom spremanja sijena sa sakupljanjem i prešanjem u valjkaste bale, viša za 24,1 % od satne potrošnje energije za transport sijena sa samoutovarnom prikolicom. Prosječna potrošnja energije za manipulaciju s balama viša je za 6,5 % u usporedbi s radnim procesom pražnjenja samoutovarne prikolice i transporta sijena u skladišni prostor pomoću električnog puhala.

ZAHVALA

Rad je nastao u okviru Ciljnog istraživačkog projekta V4-1610 Tehnološka rješenja za proizvodnju kvalitetnog sijena, koji su sufinancirali slovenska istraživačka agencija i Ministarstvo poljoprivrede, šumarstva i prehrane.

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ENERGY CONSUMPTION FOR HAYMAKING

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ABSTRACT

Energy consumption analysis was carried out in two ways of haymaking with in field drying hay on eleven family farms at different locations in Slovenia. Energy consumption of haymaking is determined from used mineral diesel fuel when performing various working operations with the tractor aggregate in one complete haymaking process (mowing, spreading, tedding, side raking, hay collection with self-loading wagon or collecting hay and baling with round baler). Total energy consumption for all working operations provides us with data on final energy consumption for haymaking in two different ways (hay collection with self-loading wagon or collecting hay and hay baling with round baler). The average total energy consumption (from mowing to hay baling) per hectare area (MJ ha^{-1}) during hay making with hay baling in round bales is higher by 27.6 % than the average total energy consumption (MJ·ha^{-1}) in hay making, when hay is loaded with a self-loaded wagon (energy from mowing to loading hay with self-loaded wagon). In hay transport, average hourly energy consumption (MJ·h^{-1}) used to transport round bales is 24.1 % higher than hourly energy consumption for hay transport with self-loaded wagon. The average hourly energy consumption (MJ·h^{-1}) for manipulation with round bales is 6.5 % higher, compared with the working operation of unloading of self-loading wagon and the transport of hay from a self-loading wagon with the hay blower in the hay storage

Keywords: *hay making, hay drying in field, machines for hay making, energy consumption*

47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

POTENTIALS OF CROP RESIDUES AS ENERGY SOURCES AND FEEDSTOCK

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ABSTRACT

Crop residues are frequently targeted as energy sources and feedstock for diverse products.

It was performed six year lasting investigation aimed to consider potentials of mostly grown field crops, wheat, soybean and corn, crop residues in Province Vojvodina. Three potentials were distinguished: theoretical (whole aboveground residual biomass), technical (harvestable) and sustainable. It was distinguished weather conditions, common and dry, and analyzed impact on yield. The yields are expressed as absolute, and relative to grain yield (while the grain yield is almost always measured and is available in statistic documents).

During common seasons, technical potentials are, about 56 % for wheat, 45 % for soybean and 51/41 % for two considered corn stover collection procedures. During dry seasons technical potential is reduced between 30 and 50 %. It was defined on field remained aboveground residual biomass, and its relative (to grain) amount is between 43 and 60 %.

It was concluded that the defining of sustainable potentials is very complex. Nearby measures aimed to preserve soil fertility some overlooked issues are listed and commented.

Keywords: *crop residues, bioeconomy, potentials, sustainability.*

INTRODUCTION

Crop residues were, in the past, commonly used as feedstock for many products and as a fuel, primarily for heating. Re-application of crop residues started, in modern times, after oil crises, in the seventies of previous century. As global warming was identified, and defined as one of the most significant problems, their use is supported due to greenhouse gas emissions reduction effect. This is declared by many European documents, and the most significant is

Renewable Energy Directive (2009/28/EC). Recently, was, on European Union level, declared and supported bioeconomy (Anonymous, 2012b). This includes utilization of bio recourses as food, feed, fuel and feedstock for many products, to replace utilization of fossil ones, first of all oil. In this regard, crop residues, beside others, play important role. However, it is important to know about potentials of these materials.

The term potentials should be clearly defined. First is **theoretical potential**, whole aboveground biomass minus grain. This one has no importance for potential users, but can be used for calculation of on-field remained residual biomass. Second is **technical** (or harvestable) **potential**, and presents the mass that can be collected, and potentially used. Removal of crop residues has impact on soil fertility, its use causes additional costs, and has other reflections on environment and society. First after considering many complex impacts can be defined **sustainable potential**.

The best solution is to express potentials of crop residues relatively to grain yields. That is because the grain yield is almost always measured, and data on its production available in national or regional statistic documents.

One important, and frequently omitted impact on yield, i.e. potential, are seasonal weather conditions. Almost everywhere are farmers faced with droughts, followed by considerable reduction of main products, grain, but residual biomass as well. This fact should be considered by defining sustainable potential and supply security.

Some of issues related to sustainability of crop residues harvest and utilization were tackled, but one general approach does not exist. Typical positive example is analysis of wheat straw sustainable potential done in Germany (Zeller et al., 2012), but the authors were faced with many problems that need locally specific approaches. Another example presents consideration of impact on soil fertility (Sekulic et al., 2010), where was stated that crop residues removal should be evaluated based on existing humus percentage in soil. Blum et al. (2010) considered impact of residues removal on soil, whereby some measures to overcome it, like crop rotation, were considered. Powlson (2006) analyzed the same for utilization of big amounts of wheat straw as energy source for electricity power plant.

There are different statements on the percentage of the corn residues that can be removed without depleting soil fertility. Radhakrishna et al. (2012), suggested value of up to 33 %, Brechbill et al. (2011) 53.5 %, while Scechinger and Hettenhaus (1999) proposed range 40 to 50 %. The highest share of 58 % was mentioned by Wyman and Hinman (1990). In Scarlat et al. (2010) were presented potentials of crop residues in European Union and same considerations relate to impact on soil fertility.

Main objective of here presented investigation performed in Autonomous Province Vojvodina, aimed to define technical potentials of significant field crops. Further objective was to identify common and some overlooked impacts on sustainable potentials assessment.

MATERIALS AND METHODS

Measurements were performed for wheat, soybean and corn, in the period 2011 to 2016.

The samples of aboveground mass were taken from advanced farms that practiced common up-to-date technology, at three to five locations in Vojvodina, agricultural part of Serbia. At least four to eight mostly used varieties or hybrids of each species were treated. From the selected plots were taken five samples, for wheat and soybean from 1 m^2, and for corn from 1.4 m^2.

As a common seasons were considered those with average precipitations during vegetation periods, and dry with their reduction more than 20 %. There were three dry seasons for wheat and two for soybean and corn.

Wheat and soybean

Each sample was randomly taken from the field, avoiding taking at these from outskirts. Samples consisted of total above ground mass. The samples were elaborated in the laboratory as follows. Wheat was divided into: grain, chaff and stalks+leaves. Soybean was divided into: grain, stalks, branches+leaves and husks. Furthermore, stalks of both wheat and soybean straw were split into segments, Figure 1, to create dry mass distribution in stems height.

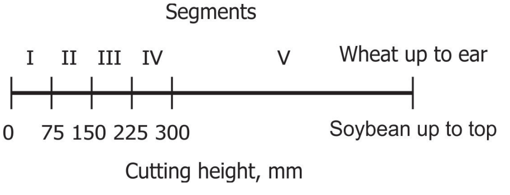


Figure 1 Wheat and soybean straw stalks segments

The amount of harvestable wheat straw, technical potential, includes harvested stalks, or mass, which is obtained by subtracting the amount that remains in the stubble and 30 % of the leaves are harvested (other remained on the field).

The amount of harvestable soybean straw includes stalk, without those which, as in the previous case, remains in the stubble and 30 % branches/leaves (it is assumed that 70 % of the leaves or branches/leaves are collectable). It is assumed that the overall baler losses (pickup device), for both crops, are about 10 %.

The mass of each plant part was measured using the balance with an accuracy of 0.1 g. For the determination of moisture content, grains were dried using the procedure defined by Anonymous (2008) and crop residue fractions according to the procedure defined by Anonymous (2012a).

Based on the measured values of moisture content for each fraction, yields expressed to dry matter were determined. For the stalks fraction diagrams of cumulative mass were made, starting from the ground. They are used to determine the remaining mass of the stubble on field, depending on the height of cutting bar.

Corn

Every single corn plant was divided into: grain, cob, husk, the lowest 0.2 m of stalk and other stalk with leaves and tassels, Figure 2. Lowest 0.2 m of stalks is treated as unusable (not harvested).

The amount of harvested stover was calculated based on following harvest procedures data:

Two-pass harvest. Grain harvest by combine with snapper–head and integrated shredder-cornrower described in Straeter (2011) and Shinners et al. (2012). The stover is picked up from windrow by a round or big rectangular baler. Cutting height is 0.2 m. Percentages of harvested fractions are 70, 90 and 90 %, for stalks+leaves, cobs and husks respectively, with additional baling losses of 20 %.

Multi-pass harvest. This is the conventional stover harvest procedure. As previous, but the combine harvester is equipped with an integrated stover shredder. It is followed by raking, forming windrow and baling. The cutting height is 0.2 m. Percentages of harvested fractions are 70 % for stalks+leaves and 40 % for cobs and husks combined, with additional baling losses of 20 % (Straeter, 2011).

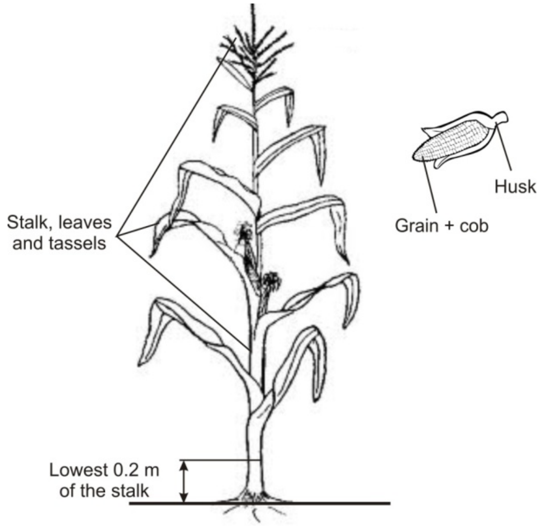


Figure 2 Fraction of corn plant, above ground

Sustainability issues

Common and overlooked impact on defining of sustainable potentials of crop residues removal are identified, based on own experiences and practice, and statements of other researchers.

RESULTS AND DISCUSSION

Wheat

Figure 3 shows the cumulative mass of wheat stalks depending on height, for years 2011 and 2012, as examples for representative for common and dry season. Based on this, the amount of stalks which remained on the field, i.e. stubble, depending on the cutting height, can be determined. Examples of cutting heights 10, 15 and 20 cm are indicated. On stubble remained mass of stalks was in 2011 about 16 and 26 %, and in 2012 about 22 and 33 %, for cutting heights 10 and 15 cm respectively.

The relevant data, average values for all samples, are given in Table 1.

The average grain yields were 6.85 and 5.11 Mg ha^{-1}, with a harvest index (HI) of 0.48 and 0.49, the total average yield of aboveground crop residues were 7.60 and 5.19 Mg ha^{-1}, respectively for selected representative seasons.

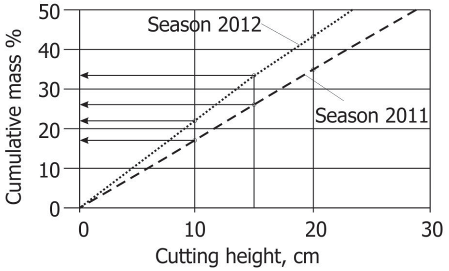


Figure 3 Cumulative mass of wheat stalks by height

Table 1 Obtained data for wheat (all data for dry matter, cutting bar height 15 cm), average for common and dry seasons

Parameter	Common	Dry
Grain yield, Mg ha^{-1}	6.9	5.1
Harvest index	0.48	0.49
Mass of aboveground residues, Mg ha^{-1}	7.6	5.2
Mass of harvestable straw, Mg ha^{-1}	3.8	2.1
Percentage of harvestable mass in comparison with mass of grain, %	55.5	40.0
Percentage of harvestable mass in aboveground residues, %	50.0	39.3
On field remained mass, Mg ha^{-1}	3.8	3.1
Percentage of on field remained mass in aboveground residues, %	50.0	60.7

Harvestable mass, technical potential, in dry seasons was, compared to common ones, reduced for 45 %, and on field remained mass 18 %, in average for five seasons measurements.

Soybean

The cumulative mass of soybean stalks, average for all samples, is given in Figure 4, and on stubble remained mass for cutting bar heights 7.5 and 10 cm, here presented examples for common and dry season, 2011 and 2012, respectively.

On stubble remained mass of stalks was in 2011 about 19 % and 24 %, and in 2012 about 25 % and 32 % for cutting heights 7.5 and 10 cm, respectively.

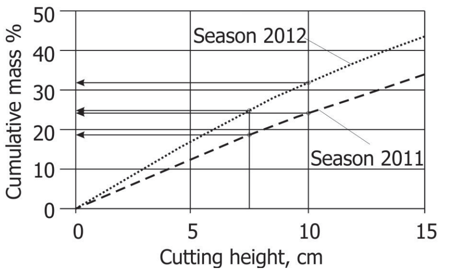


Figure 4 Cumulative mass of soybean stalks by height

The all relevant data, average values for all measurements, are given in Table 2.

Table 2 Obtained data for soybean (all data for dry matter and cutting bar height 7.5 cm), averages for seasons with common and dry weather

Parameter	Common	Dry
Grain yield, Mg ha^{-1}	4.7	2.7
Harvest index	0.47	0.41
Mass of aboveground residues, Mg ha^{-1}	5.3	3.8
Harvestable mass*, Mg ha^{-1}	2.1	1.3
Percentage of harvestable mass in comparison to mass of grain, %	44.7	48.1
Percentage of harvestable mass in aboveground harvest residues, %	39.6	34.2
On field remained mass, Mg ha^{-1}	3.2	2.5
Percentage of on field remained mass in aboveground residues, %	60.4	65.8

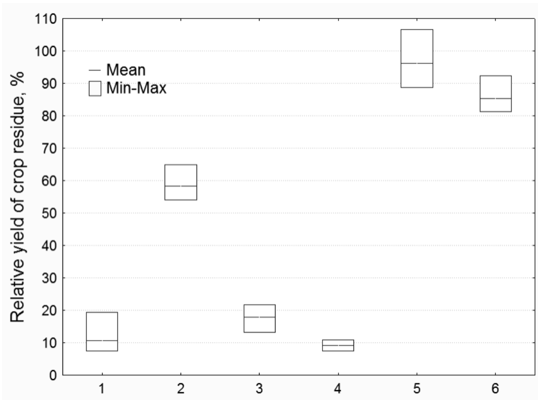
The inconvenient weather conditions, drought, cause the reduction of harvestable mass of 38 %, and on field remained 22 %, in average for five seasons measurements.

Corn

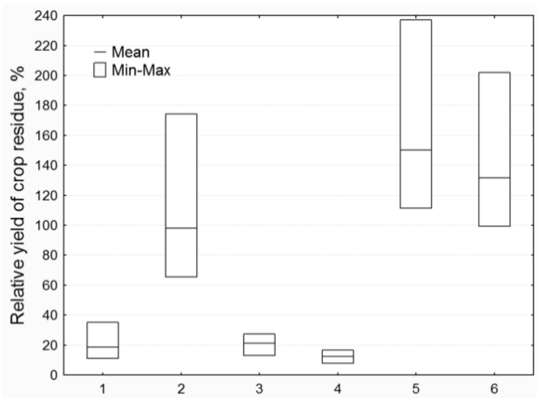
The obtained data on fraction yield are also calculated as relative, related to grain yield, and are presented in Figure 5 for selected representative seasons. Usable aboveground residues (6 in Figure 5) make about 85 % of grain in 2011, and about 132 % in 2012, common and dry seasons.

This significant change is the consequence of drought impact on grain yield. In the same time the yield of aboveground mass is considerably reduced.

The results are presented in Table 3. In all common seasons harvest index was slightly lower than 0.5, but for dry ones about 0.57. Average grain yield in common seasons was 10.3 Mg ha^{-1}, and 5.3 Mg ha^{-1} dry one. For both seasons, the percentage of harvestable mass related to total for the harvest procedures 1 and 2 was same, 53 and 43 % respectively, but harvestable mass considerably lower, 5.5/3.8 and 4.5/3.1 Mg ha^{-1}.



2011



2012

Figure 5 Range and average of relative yields of stover fractions, 1– lowest 0.2 m of stalks, 2– stalk+leaves, 3– cobs, 4– husks, 5– total aboveground residues, 6– sum of 2, 3 and 4, examples for common season 2011, and dry 2012

Table 3 Harvestable and remaining corn residues for defined harvest procedures (average values for dry matter), average for all common and dry seasons

Season	HI	Harvest procedure	Harvestable mass			Remained mass, Mg ha^{-1}
			RY, %	Mg ha^{-1}	PTM, %	
Common	0.49	1	51	5.5	53	4.6
		2	41	4.5	43	5.6
Dry	0.43	1	72	3.8	53	3.3
		2	59	3.1	43	4.0

RY– relative yield (to grain); PTM– percentage of total above ground mass

Harvestable residual mass, technical potential, was in dry seasons, compared to common ones, reduced for 31 %, and on field remained mass 30 %, in average.

Sustainable potential

Impact of crop residues removal on soil fertility has been investigated and reported frequently. However, it is still missing clear approach for its evaluation and quantification. Here are identified some not or slightly elaborated impacts.

– Impact of erosion, primarily wind erosion. This issue was partly elaborated related to assessment of land surface coverage, ASABE standard (Anonymous, 2012). Instruction for evaluation given by extension service in USA (Hickman and Schoenberger, 1989). Some evaluations have been performed for wheat and soybean (Golub et al., 2013) and corn (Golub et al., 2016). Of course, the result depends on applied soil tillage. This issue has environmental implications.

– For the users of big straw or stover amounts are used almost only big bales. Collection of crop residues with them is profitable only on bigger plots. Example, for round bales over 5 ha, and big rectangular over 10 ha. Examples given in Martinov (2015, 2016). This has impact on realistic potentials. This issue has economic implication.

– By collection of crop residues are removed also some nutrients, not only organic matter. This issue, with economic implication, has been frequently reported, but very often with wrong interpretation. Mostly was calculated with contents of elements, not compounds usable for crops. Typical is calculation of nitrogen lost, and less than 10 % of it is in mineral forms.

– For almost each case should be performed energy and greenhouse gas analyses of crop residues collection and utilization. It is present voluntarist approach. This issue has economic and environmental implication.

– Impact of crop residues collection and utilization has impact on society, especially rural areas. It is frequently mentioned, but not quantified by utilization of scientific approach. This issue has economic and social implication.

Technical potential of crop residues fluctuates, depending on weather conditions, and other impacts (e.g. diseases, insect infestations). This means some reserves of biomass should be planned and this has impact on overall costs of feedstock.

All mentioned makes defining of sustainable potential complex, but not impossible. Summarized results of the investigation are presented in Table 4.

Table 4 Summarized results of the investigation expressed as relative harvestable, technical, potentials and on field remained biomass

Crop		Harvestable relative to grain, %			Remained relative to grain, %		
		Common	Dry	Red. D to C	Common	Dry	Red. D to C
Wheat		55	40	45	50	60	18
Soybean		45	48	38	60	66	22
Corn	1	51	72	31	47	47	28
	2	41	59	31	43	43	29

Red. D to C – reduction of mass in dry season compared to common

CONCLUSIONS

In most of cases harvestable mass is about one half of grain yield, and on-field remained biomass approximately the same as collected. This should be taken into consideration by elaborating soil fertility preservation.

There are, nearby preservation of soil fertility, many, and some of them overlooked, issues having impact on defining sustainable potential of crop residues. Some quantification of them is possible, but detailed assessment should be performed for specific cases and sites.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

USE OF INVASIVE PLANT SPECIES TREE OF HEAVEN (*AILANTHUS ALTISSIMA* MILL.) BIOMASS IN ENERGY PRODUCTION

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ABSTRACT

Spreading of invasive plant species threatens habitats, ecosystems and indigenous species in areas where they would not come naturally. One of them is a plant species called Tree of heaven (Ailanthus altissima, Mill*), which is one of the most dangerous invasive woody plants in the world as well as in Croatia. Tree of heaven occupies space to the detriment of other plant species; it produces allelochemicals and shows the tendency of intense spreading and suppression of other domestic species. It reverses the landscape´s appearance and does invaluable damage to the ecosystem, by generating enormous quantities of potentially usable biomass. Biomass has a significant potential for further development. The use of biomass which remains after the removal of invasive species has many advantages, both regarding of increasing share of renewable energy production and environmental protection, as well as in reducing greenhouse gas emissions, which adversely affect human health and the environment.*

The research aimed to determine the possibility of using invasive plant species Tree of heaven remainings after its removal from nature as a raw material and determine its energy potential and the possibility of using it for energy purposes, by direct combustion and pyrolysis.

According to the analysis results it can be concluded that the Tree of heaven has a possibility of its utilization for energy purposes. It is justified to assume that this invasive species has potential as raw material for direct combustion, as well as in the process of pyrolysis, i.e., production of bio-oil and biochar.

Keywords: *biomass, energy, invasive species*

INTRODUCTION

The problem of alien invasive species has become more interesting in recent decades. The control of the introduction and spreading of invasive species, as well as the reduction of their influence on native species and the overall ecosystems, is today one of the most significant challenges of nature protection in Europe. The alien invasive species under The Convention on Biological Diversity, and the Bern Convention as well as in the opinion of numerous authors and institutions, are recognized as the second major threat to biodiversity, right after the direct destruction of natural habitats. In areas where they would never come naturally, alien invasive species endanger habitats, ecosystems and autochthonous species, resulting in numerous negative environmental and economic consequences (Novak and Kravarščan, 2014) by aggressive spreading. For the last decades, their spread has increased by trade, tourism, and travel (Novak and Kravarščan, 2014).

The Tree of heaven is an exotic and invasive deciduous tree that can grow in different environmental conditions, regardless of soil condition and location. This deciduous, extremely opportunistic, aggressive and adaptable species, due to it´s rapid growth, propagation by seeds and by root sprouts, and allelopathic chemical compounds (which suppress autochthonous vegetation) (Kovačić et al., 2008), today is considered to be one of the most invasive tree species in the world and also in Croatia (Novak and Novak, 2017). Tree of heaven was first introduced to Europe in 1740. from central Asia (China). During the 60s of the last century, it was planted in Croatia, as a target species that stabilize the soil and prevent landslides or as an ornamental species (Novak and Novak, 2017). It is known for its use in honey production, herbal medicine, furniture manufacturing, while in China it is used as a construction and tool wood and for the production of cellulose and silk. Most often it could be found at neglected fields, along the road, wild garbage dumps, agricultural areas, and near buildings, houses and other construction objects (Vukojević et al., 2012). According to Novak and Novak (2017), the Tree of heaven is widespread in all counties of Croatia. Its control is challenging and demanding, mainly because of its high regeneration ability, and it is best to use a combination of mechanical and chemical measures of suppression (Novak and Kravaršćan, 2014). Uncontrolled production of large quantities of biomass has aroused testing of its potential for energy production. This study aimed to determine the possibility of using biomass of Tree of heaven, which has remained after its mechanical removal from nature and to identify the differences between locations.

There are numerous possibilities for energy utilization of biomass. The most commonly used is a direct combustion process where biomass, without previous conversion into other forms, serves as a fuel (Trkmić and Janješ, 2012) for obtaining electrical and thermal energy. Apart from combustion, for further energy production or biomass conversion into various types of solid, liquid or gaseous fuels and products, other biochemical and thermochemical processes are used. Pyrolysis is a process which involves heating of organic materials (biomass) to temperatures from 300 to 1.400 °C in the absence of oxygen. At such high temperatures, organic materials thermally decompose releasing a vapor phase and a residual solid phase (biochar). On cooling the pyrolysis vapor, polar and high molecular-weight compounds condense out as a liquid (bio-oil) while low-molecular-weight volatile compounds remain in the gas phase (synthetic gas) (Laird et al., 2009). By this processes, instead of just burning biomass, valued products can be obtained. Energy characteristics and the possibility of using the Tree of heaven biomass, through the direct combustion and pyrolysis for energy purposes were examined, as well as the production of bio-oil as an energy source and biochar as a value-added product.

MATERIALS AND METHODS

The research was conducted at the Department of Agricultural Technology, Storage and Transport at University of Zagreb Faculty of Agriculture. Samples of the invasive plant species biomass were collected in five different locations in the area of Split-Dalmatia County (Klis, 43° 33'34.6 "N 16° 31'18.8" E, Lokvičići, 43° 27'56.3 "N 17° 05'25.4 "E, Gornji Muć, 43° 40'46.5" N 16° 29'38.9 "E, Gornji Muć, 43° 40'31.7" N 16° 29'41.9 "E, Žrnovnica, 43° 31'09.4" N 16 ° 32'54.9 "E) in April 2017. The analyzes were preceded by grounding of samples in the laboratory mill (IKA, Germany), followed by standard methods for determining the water content (HRN EN 18134-2:2015), ash (HRN EN ISO 18122:2015), coke (CEN / TS 15148: 2009), fixed carbon and volatile matter (CEN / TS 15148: 2009), and in the calorimeter IKA C200 (IKA, Germany) the higher heating values in the samples were determined (HRN EN 14918: 2010). Determination of cellulose, hemicellulose and lignin content of raw materials was conducted by the modified standard method ISO 5351-1: 2002. After the analysis of raw materials, i.e., the biomass of Tree of heaven, pyrolysis of samples was conducted in laboratory conditions at a temperature of about 400 °C. The proportion of obtained biochar and bio-oil was calculated, and the biochar was analyzed by the above-mentioned standard methods. Analysis of variance (ANOVA) was performed of results obtained by biomass and biochar analyzes, while the differences between the mean values were tested by t-test.

RESULTS AND DISCUSSION

Suitability of the raw material for the production of energy by direct combustion can be assessed by determination of its physicochemical, structural and energy properties. Therefore, Table 1 shows the mean value of the water content in the fresh sample, ash content, coke, volatile matter, fixed carbon as well as the higher and lower heating value of dry matter of the Tree of heaven biomass.

Table 1 The characteristics of the Tree of heaven biomass samples (dry matter)

	Location				
	L1	L2	L3	L4	L5
*Moisture (%)	$25{,}88^{BC}$	$40{,}67^{A}$	$28{,}89^{B}$	$19{,}30^{C}$	$34{,}81^{B}$
Ash (%)	$5{,}43^{B}$	$6{,}60^{A}$	$5{,}37^{B}$	$5{,}83^{B}$	$5{,}65^{B}$
Coke (%)	$15{,}59^{A}$	$14{,}35^{A}$	$15{,}99^{A}$	$13{,}97^{A}$	$16{,}47^{A}$
Volatile matter (%)	$81{,}11^{B}$	$82{,}36^{A}$	$79{,}38^{C}$	$81{,}39^{B}$	$78{,}88^{C}$
Fixed carbon (%)	$6{,}63^{C}$	$11{,}60^{B}$	$14{,}14^{A}$	$12{,}12^{B}$	$14{,}62^{A}$
**LHV (MJ kg $^{-1}$)	$14{,}68^{C}$	$15{,}71^{A}$	$15{,}01^{B}$	$14{,}48^{BC}$	$15{,}98^{A}$
***HHV (MJ kg $^{-1}$)	$15{,}96^{C}$	$17{,}03^{A}$	$16{,}35^{B}$	$16{,}15^{C}$	$17{,}29^{A}$

*Moisture content analysis is done on raw biomass; **LHV = lower heating value,
***HHV = higher heating value

The premise for the quality production of biochar is its higher contribution in pyrolysis process (Jurišić et al., 2017). Also, in this study, analyzes of biochar composition were made by standard methods for solid biofuels (Table 2). The water (moisture) in the fuel is found to be a non-combustible ingredient which has a negative impact on the biomass heating values. Part of the energy released during the combustion process is spent on evaporation of water (Francescato et al., 2008). Expected values for water content in biomass vary by about 10% for dried biomass, while for raw biomass they reach up to 50% (Yao et al., 2005). Water content is one of the most important parameters when it comes to fuels properties of biomass because it depends on it how will the biomass be transferred to energy (Ross et al., 2008). Biomass with the low and moderate water content of less than 50% is efficiently used in combustion processes, while alternatively it can be used for thermochemical conversion by gasification and pyrolysis (Permchart and Kouprianov, 2004). Freshly collected biomass typically has a water content of 40 to 65%, while residues of agricultural crops (maize, straw, etc.) that have been exposed to air-drying have about 15% or less (Ross et al., 2008). The water content in the analyzed samples ranged from the lowest value of 19.30% (location 4) up to 40.67% (location 2). A significant difference between the water content of the samples between different locations was determined, as shown in Table 1. The water content in the analyzed biomass samples from most locations is within the expected values. Deviations are only visible at location 2, with slightly elevated values compared to other results (wetland).

Ash is an incombustible mineral residue after the biomass was combusted. The variability of the ash content is affected by the different composition and availability of nutrients in the soil, climatic conditions, type of plant species, part of the plant itself, soil quality as well as fertilization (Vassilev et al., 2010). Vassilev et al. (2010) state that ash content, depending on the type and parts of biomass crops, usually ranges from 0.5% to 3% although they can range from 0.1% to 46%. Francescato et al. (2008) stated that the ash content in agricultural biomass ranges from 2 to 25%. It is desirable that ash content in the raw biomass is not high, given that the ash content and the content of combustible matter are inversely proportional, and by increasing of ash, the content of combustible matter reduces. The ash content in the analyzed samples is significantly different at some locations and differences were noted among the locations, as shown in Table 1. The minimum ash content was 5.37% at location 3, while the highest values were found at location 2 reaching the amount of 6.60%. The results can be compared with the study of grain straw (Grubor et al., 2015) where ash values are ranged from 2.54 to 9.04%. The average amount of ash in biomass of major energy crops in Croatia was 3.14% (Jurišić et al., 2017). Biochar is very heterogeneous and consists of stable and reactive components (Jurišić et al., 2016). Variations in the ash content in biochar depend on the same conditions as in case of biomass. The average value of ash content in biochar samples from all five locations is 22.14%, which is higher than the ash content of biomass. Table 2 shows statistically significant differences in the ash content of biochar between locations. Jurišić et al. (2017) indicate that the average content of ash in the biochar of important energy crops in Croatia was 5.60%, while in the biochar of grain straw; Grubor et al. (2015) indicate ash content values of 9.15 to 16.53%, which are closer to the results obtained in this research. Considering that larger content of ash, cause soot formation and corrosion in biomass combustion systems (Grubor et al., 2015); this biochar does not match the quality of other types of biochar when viewed from the aspect of ash content.

Higher content of coke is a desirable feature of biomass (Boboulos, 2010) and increases the quality of fuel. Coke remains because of the combustion process of flammable or volatile substances at very high temperatures (Voća et al., 2018). The average coke content obtained in analyzed samples of biomass ranges from a minimum of 13.97% at location 4 to 16.47% at location 5, and there are no statistically significant differences in the content of coke between the results. Grubor et al. (2015) obtained similar results for coke content from 16.20 to 34.76% in grain straw biomass. Jurišić et al. (2017) obtained the average content of coke in biomass of major energy crops in Croatia around 14.9%. From the aspect of coke content concerning other types of biomass, it can be concluded that it is a suitable material for energy production. According to the results shown in Table 2, it can be concluded that there are no significant differences between the locations in the coke content of biochar. Jurišić et al. (2017) stated the average content of coke in the biochar of important energy crops in Croatia at about 60.10%, while Grubor et al. (2015) did obtain values from 49.69 to 62.89% in grain straw biomass. Considering that the higher value of coke is preferable in biochar, it can be concluded that the Tree of heaven biomass is an excellent raw material for the pyrolysis process.

Table 2 The characteristics of the Tree of heaven biochar samples (dry matter)

	Location				
	L1	L2	L3	L4	L5
Ash (%)	$17{,}91^{D}$	$24{,}98^{A}$	$19{,}30^{C}$	$23{,}91^{B}$	$24{,}61^{AB}$
Coke (%)	$63{,}57^{A}$	$63{,}10^{A}$	$63{,}34^{A}$	$67{,}64^{A}$	$68{,}21^{A}$
Volatile matter (%)	$33{,}14^{A}$	$33{,}61^{A}$	$32{,}01^{B}$	$27{,}71^{C}$	$27{,}14^{C}$
Fixed carbon (%)	$54{,}60^{D}$	$60{,}34^{C}$	$61{,}49^{B}$	$65{,}79^{A}$	$66{,}37^{A}$
**LHV (MJ kg $^{-1}$)	$23{,}51^{B}$	$22{,}12^{D}$	$22{,}58^{C}$	$23{,}86^{A}$	$23{,}82^{A}$
***HHV. (MJ kg $^{-1}$)	$24{,}26^{A}$	$22{,}79^{B}$	$23{,}12^{B}$	$24{,}40^{A}$	$24{,}49^{A}$

Fixed carbon content (Cfix) represents a solid residue after combustion, i.e., after releasing volatile substances without ash (Garcia et al., 2012). Increase of fixed carbon content the increases heating value, thus improving the quality of biomass as fuel. According to Jarihul et al. (2012), the higher content of fixed carbon in biomass contributes to obtaining a higher amount of biochar regarding bio-oil and synthetic gas. Results of the fixed carbon content obtained from biomass range from 6.63% (location 1) to 14.62% (location 5). There were statistically significant differences between samples from different locations as shown in Table 1. The values of fixed carbon in grain straw biomass are in the range from about 5% (oat straw) to 13% (other straw) (Grubor et al., 2015). Jurišić et al. (2017) indicate that average values of fixed carbon biomass of major energy crops in Croatia are around 11.40%. Tree of heaven biomass has acceptable fixed carbon values, and obtained results were expected since values of the fixed carbon in the biomass of different cultures are similar. According to the results shown in Table 2, it can be concluded that there are significant differences between the locations in the content of fixed carbon in the Tree of heaven biochar. The content of fixed carbon in biochar samples ranges from 54.60 to 66.37%. In the case of grain straw biochar, fixed carbon values range from 33.15 to 50.25% (Grubor et al., 2015). Jurišić et al. (2017) obtained most similar results in the biochar, which also indicate that Tree of heaven is a suitable material for pyrolysis processes, with the 54.50% of fixed carbon in major energy crops biochar in Croatia.

During the combustion process, biomass decomposes on volatile gases and the solid residue. The term volatiles refer to the components such as light hydrocarbons, carbon monoxide, carbon dioxide, hydrogen, moisture, and tars released when the fuel is heated at a high temperature. Biomass generally has a very high content of volatile matter, with values that typically range around 75%, but can even increase up to 90%, which of course depends on the type of sample (Khan et al., 2009). In case of high concentrations of volatile matter, biomass is extremely flammable at lower temperatures, unlike fossil fuels. This is an undesirable feature due to the sudden release of energy at lower temperatures, causing that such fuels have lower energy value (Garcia et al., 2012, Quaak et al. al., 1999). Table 1 shows the significant differences between locations of volatile matter analysis of the analyzed biomass. Tree of heaven biomass analyzes shows the results for volatile matter from a minimum value of 78.88% (location 5) to a maximum value of 82.36% (location 2), and while the biochar values were ranged from 27.14 to 33.06%. According to Grubor et al. (2015), volatile matter in grain straw biomass were ranged from 34.62 to 79.66%, while in the case of biochar from 37.11 to 50.31%. Jurišić et al. (2017) stated average values of volatile matter of major energy crops biomass in Croatia were around 77.58%. Comparison of results shown that biomass, as well as biochar, have similar, even lower percent of volatiles compared to other biomass or biochars, which is positive for Tree of heaven as a material with energy potential.

The most important feature of each fuel is the heating value, also called calorific value. The heating value is a parameter that represents the amount of energy that can be obtained by combusting a certain amount of biomass (Garcia et al., 2012). It is an indicator of the chemical-related energy in the fuel, which turns into heat through the combustion process (Krička et al., 2010). The heating value of the biomass can be defined by its higher heating value (HHV), which is the energy content on a dry basis. The lower heating value (LHV) is calculated by subtracting the energy needed to evaporate the moisture content of the fuel (Khan et al., 2009). By analyzing the Tree of heaven biomass and biochar, average results of the HHV and LHV were obtained. Lowest HHV was ranged from the minimum value of 15.96 MJ kg^{-1}at location 1, to the maximum HHV at location 5 of 17.29 MJ kg^{-1}. The LHV was ranged from the minimum value of 14.68 MJ kg^{-1} at location 1 to the 15.98 MJ kg^{-1} at location 5. Table 1 shows the heating values of the analyzed biomass, while Table 2 shows data of the heating values for biochar, with statistically significant differences between the locations. In the grain straw biomass, Grubor et al. (2015) obtained an HHV from 16,41 to 18.24 MJ kg^{-1}, while Jurišić et al. (2017) recorded the average HHV of major energy crops biomass in Croatia of 17.69 MJ kg^{-1}. In case of biochar, obtained HHV of Tree of heaven were ranged from 22.79 to 24.49 MJ kg^{-1} and LHV from 22.12 to 23.86 MJ kg^{-1}. Grubor et al. (2015) recorded the HHV of biochar from 24.72 to 25.70 MJ kg^{-1}, while Jurišić et al. (2017) recorded an average HHV of biochar 30.67 MJ kg^{-1}. By comparing those values, it is evident that higher heating values of biomasses as well as of the biochar are similar to other results.

Biomass is a complex heterogeneous mixture consisting of key structural components such as cellulose, hemicellulose, and lignin. Voća et al., (2018) stated that most of the agricultural lignocellulose biomass consists of lignin (10-25%), hemicellulose (20-30%), and cellulose (40-50%). Lignin provides structures strength, and biomass with higher lignin content is more suitable for producing electricity and/or heat by direct combustion (Grubor et al., 2015). According to the results shown in Figure 1, it can be concluded that the highest content of cellulose was found in samples of location 5, highest content of lignin was found in samples of location 3, and highest content of hemicellulose was found in samples from location 1. According to Grubor et al. (2015), the content of cellulose in the biomass of grain straw was ranged from 30.64 to 45.66%, the lignin content was ranged from 22.28 to 29.27%, and the hemicellulose was ranged from 17.56 to 39.67%. By comparing the obtained values with the literature data and the expected values for biomass, it is apparent that the lignin content is higher than expected, and it can be concluded that the biomass is suitable for direct combustion.

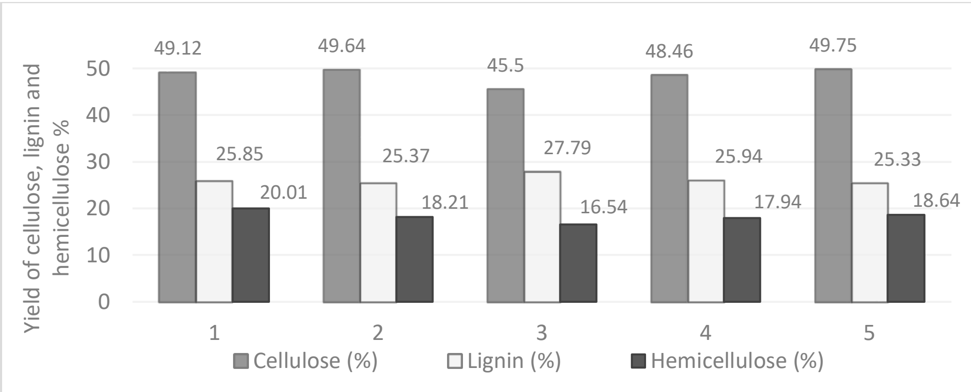

Figure 1 Cellulose, lignin and hemicellulose yield in Tree of heaven biomass

Table 3 Content of carbon, hydrogen, nitrogen, sulfur and oxygen in biomass and biochar (dry matter)

%	Biomass					Biochar				
	L1	L2	L3	L4	L5	L1	L2	L3	L4	L5
C	37,73^{D}	44,71^{B}	46,46^{A}	42,9^{C}	43,55^{BC}	66,02^{A}	61,19^{C}	66,85^{A}	64,26^{B}	66,31^{A}
H	5,85^{A}	6,03^{A}	6,14^{A}	5,99^{A}	6,01^{A}	3,45^{A}	3,07^{A}	2,49^{B}	2,48^{B}	3,06^{A}
N	2,97^{A}	2,91^{A}	2,56^{A}	1,63^{B}	2,38^{A}	3,99^{A}	2,98^{BC}	3,10^{B}	2,62^{C}	3,95^{A}
S	0,38^{A}	0,36^{A}	0,35^{A}	0,30^{A}	0,35^{A}	0,45^{A}	0,35^{A}	0,39^{A}	0,53^{A}	0,52^{A}
O	53,07^{A}	45,99^{CD}	44,5^{D}	49,18^{B}	47,72^{BC}	26,09^{D}	32,41^{A}	27,18^{C}	30,11^{B}	26,17^{D}

From the obtained values of the Tree of heaven biomass and biochar (Table 3), it can be noted that the highest, most desirable amount of carbon and hydrogen, as well as the lowest amount of sulfur and oxygen content, have locations 2 and 4, although the differences between locations are minimal. The analyzed biomass contains oxygen ranging from 47.20 to 47.71%, carbon in the range of 42.48 to 43.39%, hydrogen ranging from 6.14 to 6.29%, nitrogen ranging from 2.76 - 3.40% and sulfur 0.35-0.40%.

In Figure 2, the mean value of the obtained bio-oil and biochar after the pyrolysis is shown graphically. The pyrolysis process of organic matter is very complex, and this process generates three important products – biochar and volatile and non-volatile gases (bio-oil) (Jurišić et al., 2017). Depending on the conditions of the process (such as the particle size in the biomass material and the temperature of the process itself), carbon-rich biochar was obtained (yield: 10-35%), volatile gases (yield: 30-70%) and non-volatile gases manifested as bio-oil: 15-35%). Furthermore, the content of biochar after pyrolysis is proportional to the lignin and hemicellulose content in biomass (Jahirul et al., 2012). The highest amount of biochar (39.52%) was obtained by analyzing the samples of location 2 and the lowest amount of biomass (28.30%) by analyzing samples from site 4. It is also evident that the most significant amount of bio-oil (59.60%) was obtained by analyzing samples of location 4, and the smallest amount of bio-oil (40.39%) by analyzing samples of location 2. The biochar yields in grain straw range from about 55 to 75% (Grubor et al., 2015). Jurišić et al. (2017) indicate slightly lower amounts of biochar (23.93%) and bio-oil (33.13%) in major energy crops in Croatia. There is an excellent potential for biochar and bio-oil production compared to the comparative literature approximate values.

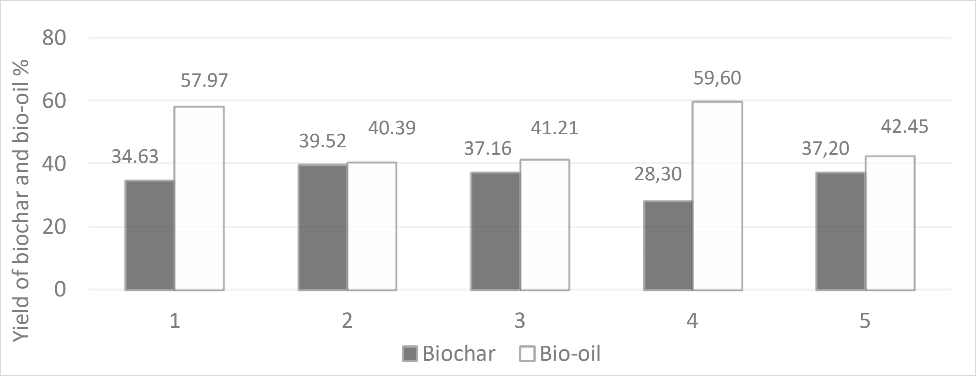

Figure 2 Pyrolysis products in Tree of heaven biomass samples yield

CONCLUSIONS

Based on this research of the invasive species Tree of heaven (*Ailanthus altissima*) biomass, its potential as a raw material for direct combustion, as well as in the process of pyrolysis, i.e., the production of bio-oil as an energy source and biochar as a value-added product was confirmed.

There is a significant difference in Tree of heaven biomass between sites in the content of water, ash, fixed carbon, volatile substances, and heating values. There is a significant difference in the biochar of the Tree of heaven between the sites for ash and heating values.

Tree of heaven biomass contains water ranging from 19.3 to 40.67%, indicating that the results fit into the literature values. Water content from site 2 makes an exception with its elevated value (which is acceptable, given that unlike others, location 2 it is a wetland area).

Analysis of the ash content in biomass (5.37 - 6.60%) and biochar (17.91 - 24.98%) showed higher ash content compared to the literature, which is not a desirable feature of biomass. Expected results of volatile substances stated in the literature, were lower than in biomass what indicates that Tree of heaven is not desirable raw material for direct combustion, but low values of volatile substances in biochar shows that biochar is a desirable raw material for pyrolysis processes. From the perspective of coke, fixed carbon and heating values in biomass and biochar, biomass represent a potential raw material for energy production.

ACKNOWLEDGEMENTS

This research was funded by the Croatian Science Foundation (HRZZ) within the project “Young Researchers' Career Development Project – Training of Doctoral Students”, co-financed by the European Union, under the OP “Efficient Human Resources 2014-2020” from the ESF funds.

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KORIŠTENJE BIOMASE INVAZIVNE BILJNE VRSTE PAJASEN U PROIZVODNJI ENERGIJE

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SUMMARY

Strane invazivne vrste agresivnim širenjem ugrožavaju staništa, ekosustave i autohtone vrste na područjima gdje prirodnim putem ne bi dospjele. Biljna vrsta pajasen (Ailanthus altissima), jedna je od najopasnijih invazivnih drvenastih biljaka kako u svijetu, tako i u Hrvatskoj. Preuzima prostor na štetu ostalog bilja, luči alelokemikalije te pokazuje tendenciju intenzivnog širenja i potiskivanja ostalih autohtonih vrsta. Nepovratno mijenja izgled krajolika te nanosi neprocjenjivu štetu na ekosustav stvarajući ogromne količine potencijalno iskoristive biomase. Biomasa ima značajan potencijal za daljnji razvoj. Primjena biomase, preostale nakon uklanjanja invazivnih vrsta ima nebrojne prednosti, kako u povećanju udjela proizvodnje obnovljive energije, tako i u pogledu smanjenja emisije stakleničkih plinova te štetnog utjecaja na zdravlje ljudi i okoliš. Cilj ovog rada bio je istražiti mogućnosti korištenja ostataka invazivne vrste pajasen, nakon njegovog uklanjanja iz prirode te procesom izgaranja i pirolizom biomase ispitati njegov energetski potencijal i mogućnost korištenja u energetske svrhe. Sukladno dobivenim rezultatima analiza, može se zaključiti da pajasen nudi mogućnost iskorištenja u energetske svrhe. Opravdana je pretpostavka da ova invazivna vrsta, ima potencijal kao sirovina za izravno izgaranje, kao i u procesu pirolize, odnosno proizvodnje bioulja i biougljena.

***Ključne riječi**: biomasa, energija, invazivne vrste, pajasen*

47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

INVESTIGATION AND COMPARISON OF INDICATORS OF FODDER BEAN WASTE AND WOOD PELLETS

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ABSTRACT

Biomass resources can be found in many countries of the world and can become a renewable local source of energy that will replace fossil fuels. The presented paper provides research results of widely used in Lithuania fodder beans growing, harvesting and waste utilization for energy purposes. Fodder bean waste and wood waste (sawdust) pellets were comparatively investigated, and physical-mechanical and thermal properties were determined when plant pellets were burned. Investigations were carried out in the fields and laboratories of the Institute of Agricultural Engineering and Safety, Aleksandras Stulginskis University (ASU) and in the Lithuanian Energy Institute (LEI). Moisture content of fodder bean waste pellets reached 8.67 ± 0.26 %, and pellet density was very high and reached 1311.40±64.67 kg m^{-3} DM (dry matter). The determined average calorific value was also sufficiently high and reached 17.0±0.3 MJ kg^{-1}. Also, emissions of harmful gases when these fodder bean waste and wood pellets were burned were investigated. All these results are in accordance with the requirements of standard EN 14961-1 normative properties.

Keywords: *fodder bean, waste, wood, solid biofuel, pellets, properties*

INTRODUCTION

Wood is generally the most common choice of fuels for coal-fired boilers. Use of biomass for energy production incorporates benefits, such as reduced CO_2 emissions, reduced SO_2 and NO_x formation through a reduction of bound nitrogen in fuel (Verma et al., 2012).

Use of natural state biomass (chips, sawdust and straw) is unattractive, and potential consumers generally become disheartened from using this kind of fuel permanently. Also, because of high moisture content, irregular shape and sizes, and low bulk density, natural state biomass is very difficult to handle, transport, store and utilize in its original form. When these biomass types or their mixes are made into the pellets or briquettes, they are easier to store, distribute and use for energy generation (Kaliyan and Vance Morey, 2009), (Mariusz et al., 2013). Densification of biomass materials into pellets or briquettes could reduce costs of transportation, handling, and storage (Mani et al., 2006). However, the competitive raw material market has increased the price of wood material.

In the recent years, various biomass materials have been used for production of pellets, *e.g.* waste paper, wheat straw mixtures, corn stover, tea waste, bamboo, and other agricultural waste (Longbo et al., 2016). Availability of agricultural waste for energy use strongly depends on variables like consumption pattern, economic development and fraction of biomass material in all waste production (Grammelis, 2011).

CO emissions from several agricultural fuels (not pellets) are to fourteen times higher than from wood pellets (Carvalho et al., 2013). Pelletization of agricultural waste and use of pellets can contribute to optimisation of combustion process and subsequently reduce emissions (Vicente et al., 2015).

Fodder bean is grown worldwide in cropping systems as grain and green-manure legume. Fodder bean contributes to sustainability of cropping systems via its ability to contribute nitrogen to the system via biological N_2 fixation, diversification of systems leading to decreased disease, weed and pest build-up and potentially increased biodiversity, reduced fossil energy consumption in plant production, and providing food and feed rich in protein. The limited resources of fossil energy, the emissions of CO_2 as a result of production, distribution and application of fertilizer N, and health and environmental implications of losses of large amounts of N from fertilized soils, as a consequence of in efficiencies in plant use of fertilizer has recently increased sowing of fodder bean seed, as the role of source N for future growing systems (Jensen et al., 2010).

Large amounts of fodder bean biomass residues are left on the fields concentrated in one place. According to the amounts of by-products of agricultural crops grown in Lithuania, it is noticeable that the main by-products of beans are waste after thrashing, which make up about half of the total production. These residues can be employed for alternative uses – for thermo-chemical conversion (Minajeva et al., 2018). This biofuel can be used in households for small household boilers with the capacity of 10-50 kW and centralized boiler houses. However, physical-chemical and thermal properties of biomass fuel, such as volumetric and energy density, heat value, chemical composition, moisture and ash content, are important for their use in residential devices (Olsson and Kjällstrand, 2006).

In this study, two kinds of raw materials (fodder bean waste and sawdust for comparison) were applied for pelletization. These pellets were investigated to compare energy consumption and pellet properties, including, pellet density, hardness, higher heating value and combustion characteristics and harmful emissions.

MATERIALS AND METHODS

Solid biomass can be characterized by various physical-mechanical and thermal properties: moisture content, density, compression strength, ash, heat content and harmful emissions caused by combustion of pellets. In the course of experimental research, samples of vegetable waste from thrashed fodder beans were chopped and prepared for pelleting. Granulating process consist of a few basic sub-processes: chopping of raw material, milling, drying, pelleting and cooling.

These pellets were produced without additional binding materials with stand a pressure of up to 22.5 $N \cdot mm^{-2}$. Laboratory tests are carried out to determine resistance of granules, while crushing strength is evaluated by force acting upon destruction of a pellet (Pastre, 2002), (Jasinskas and Scholz, 2008).

First of all, stem chopping a drum chopper of forage harvester was used (Jasinskas et al., 2014). Retsch SM 200 mill was used for the produced chaff milling. Milling quality was determined using standard methodology. After mill making, dry bean waste (10-12% moisture) is moved by conveyor to a pellet mill. For pellet production, the plant mill was granulated by a small capacity (80-120 kg h^{-1}) granulator with a horizontal granulator matrix; the diameter of pellets was 6 mm (Streikus et al., 2016). After extrusion, pellets temperature was 90-100°C, and it was immediately reduced down to 25°C.

Fodder bean waste pellet and wood pellet calorific value, ash content and harmful emissions were determined at the Lithuanian Energy Institute, Thermal equipment research and testing laboratory in accordance with the valid in Lithuania and EU countries standard methodology (Šiaudinis et al., 2015). Calorific value (KJ kg^{-1}) of investigated pellets was determined by a IKA C 5000 calorimeter (IKA, Germany) by the standard methodology (BS EN 14918:2009), ash content – according to LST EN 14775:2010 standard and was assimilated with each other.

RESULTS AND DISCUSSION

The obtained pellets tend to a cylindrical form with an average diameter of 5.99±0.08 mm and 24.32±1.96 mm length for pellet samples. It is very important to determine moisture content since numerous studies show that it affects properties such as thermal conductivity, specific heat capacity, density and deformation force characteristics. According to research by Dafnomilis et al. (2018), determined moisture of wood pellets was about 8-11 %. The results of the performed studies show that moisture of fodder bean waste pellets is equal to 8.67 ± 0.26 %, and all these results are in accordance with the requirements of normative properties of standard (EN 14961-1).

Determined density of produced granules in dry matter (DM) reaches as much as 1,311.40 ± 64.67 $kg \cdot m^{-3}$. Depending on the type of wood, wood pellets density can to reach 1,200–1,900 $kg \cdot m^{-3}$. Similarity between most of the physical properties of fodder bean waste and wood pellets means that the fundamental design of equipment and infrastructure between the two bulk materials would remain the same.

The maximum (critical) determined pressure force F of fodder bean waste pellet was 586.16 ± 137.7 N. This force is sufficiently high, and we can conclude that produced pellets are resistant to external forces.

Fodder bean waste pellet elemental composition, ash content and heat indexes are presented in Table 1.

Table 1. Fodder bean waste pellet elemental composition, ash content and calorific value

Parameter	Value
C (%)	46.22±1.10
H (%)	5.69±0.44
N (%)	1.27±0.31
S (%)	<0.01
O (%)	42.89±1.56
Cl (%)	0.32±0.08
Ash (%)	3.93±0.11
Net calorific value (MJ kg^{-1})	17.0±0.3

The authors of the paper "Wood pellet quality with respect to EN 14961-2 standard and certifications" have assessed quality of wood pellet. The determined net calorific value of wood pellets (130 examples) was 16.9-17.4 MJ kg^{-1} (Duca et al., 2014). The determined average calorific value of fodder bean waste pellet was sufficiently high and reached 17.0±0.3 MJ kg^{-1}.

Also, emissions of harmful gases (CO_2, CO, NO, SO_2, NH_3, HCl, O_2, C_xH_y) when these fodder been (FB) waste and wood pellets were burned were investigated. The results are presented in the Fig. 1–8 below.

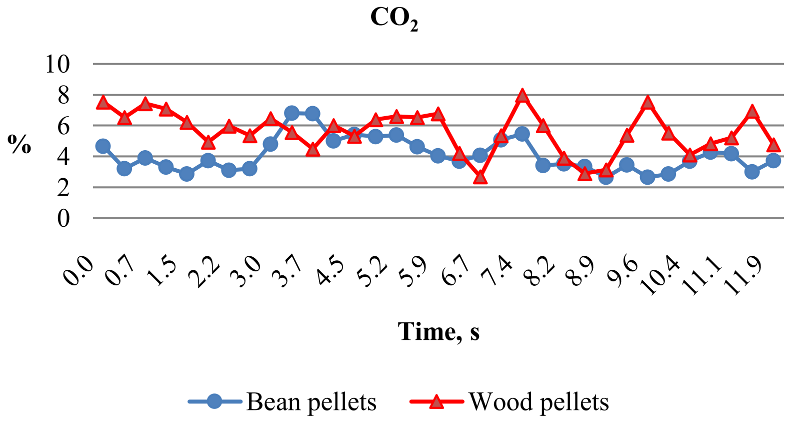

Figure 1 CO_2 emissions during combustion of pellets under standard laboratory conditions

The average CO_2 emissions of FB pellet are 4.1 % and wood pellet – 5.6 %. According to studies by Venturini et al. (2018), CO_2 emission of wood pellet varied from 3.6 % to 8.0 %.

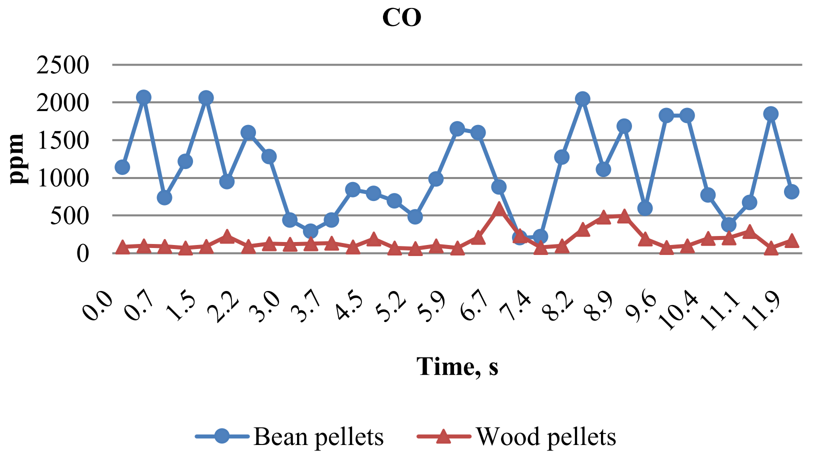

Figure 2 CO emissions during combustion of pellets under standard laboratory conditions

The average of CO emissions of FB pellet is 1072.5 ppm and wood pellet – 172 ppm. The concentration of CO depends on the quality of pellets.

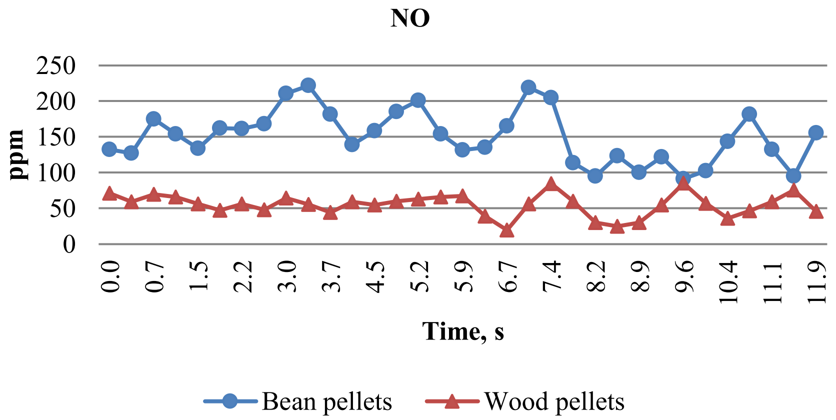

Figure 3 NO emissions during combustion of pellets under standard laboratory conditions

The average of NO emissions of FB pellet is 151 ppm and wood pellet – 55 ppm. By the different standards, NO emissions of the wood pellets are 32-102 ppm.

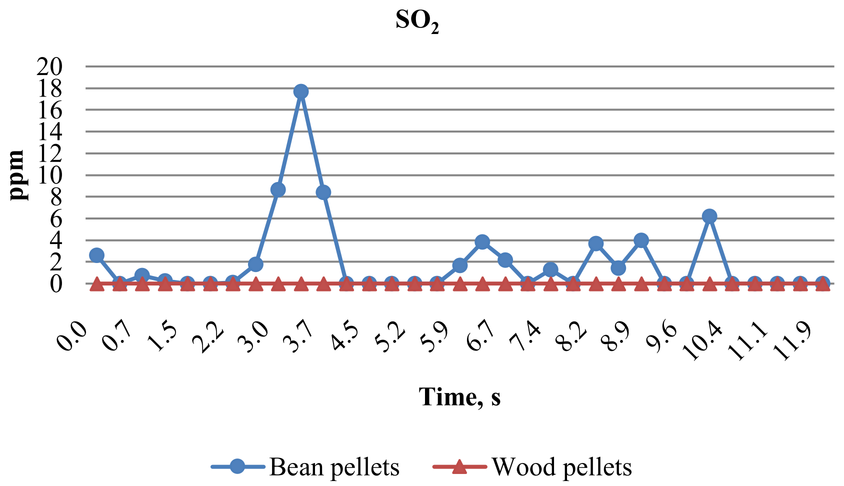

Figure 4 SO_2 emissions during combustion of pellets under standard laboratory conditions

The average of SO_2 emissions of FB pellet is 2 ppm and wood pellet – 0 ppm.

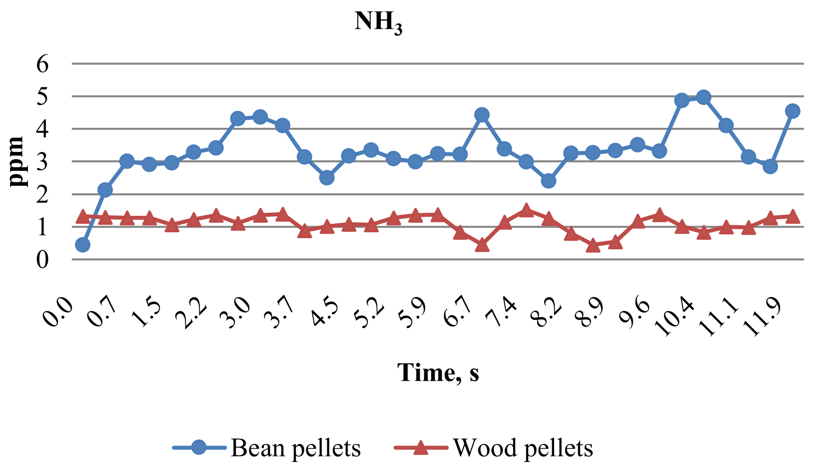

Figure 5 NH_3 emissions during combustion of pellets under standard laboratory conditions

The average of NH_3 emissions of FB pellet is 3.3 ppm and wood pellet – 1.1 ppm.

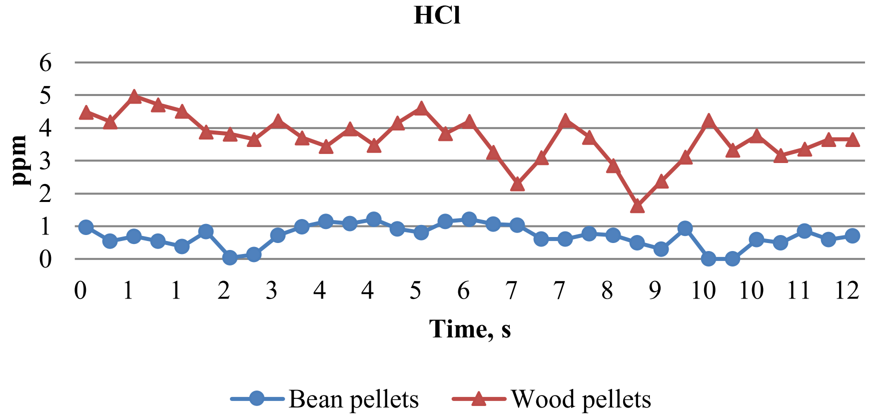

Figure 6 HCl emissions during combustion of pellets under standard laboratory conditions

The average of HCl emissions of FB pellet is 0.7 ppm and wood pellet – 3.7 ppm.

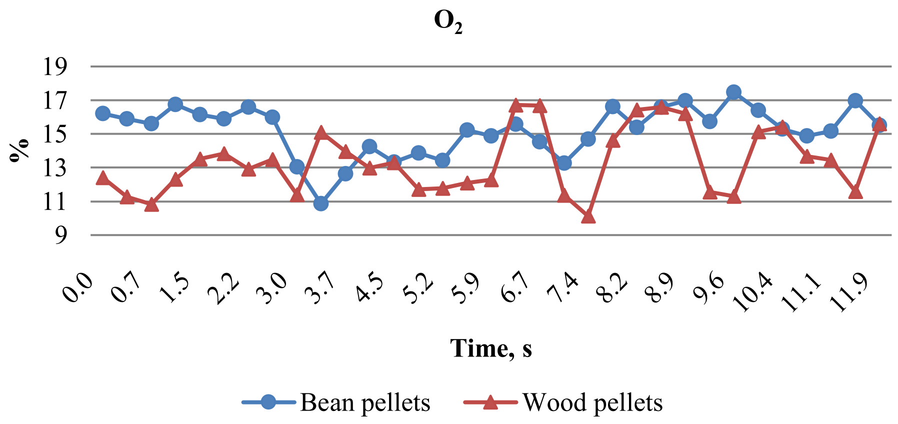

Figure 7 O_2 emissions during combustion of pellets under standard laboratory conditions

The average of O_2 emissions of FB pellet is 15.2 % and wood pellet – 13.4 %.

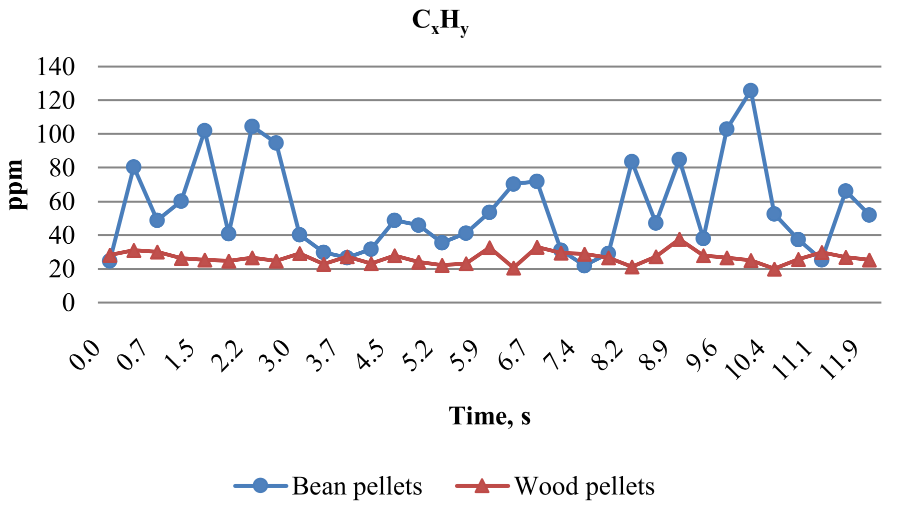

Figure 8 C_xH_y emissions during combustion of pellets under standard laboratory conditions

The average of C_xH_y emissions of FB pellet is 56.1 ppm and wood pellet – 26.7 ppm.

All the determined harmful gases emissions when burning the fodder bean waste pellets were in the allowed values. So, this biofuel can be used together with wood and other plant pellets for heat production in the boilers of low and average capacity.

CONCLUSIONS

Differences between the results of the present study and the data of other researchers can be associated with pellet quality, raw material and burning devices.

Determined density of the produced granules of fodder bean waste in dry matter (DM) was sufficiently high and reached 1,311.40 ± 64.67 kg·m^{-3}. The wood pellet density, depending on the type of wood, varied from 1,200 till 1,900 kg·m^{-3}.

Investigated thermal properties of the produced biofuel show that average calorific value of fodder bean waste pellets was sufficiently high and reached 17.0±0.3 MJ kg^{-1}, and, for comparison, the determined net calorific value of wood pellets was very similar and reached 16.9-17.4 MJ kg^{-1}.

After evaluation of harmful gases emission when burning of fodder bean waste pellets, it was determined that NO formation in the pellet boiler is mainly due to the oxidation of a portion of biomass nitrogen. For this reason, NO emissions when burning the fodder bean pellets is higher than burning of wood pellets.

Determined average value of CO emissions when burning the fodder bean pellets was sufficiently high and reached 1072.5 ppm; when burning wood pellets harmful, emissions were 6 times less and reached 172 ppm.

After investigation of fodder bean waste pellets properties and harmful gases emissions, it can be stated that they meet the requirements for high-quality biofuel.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

PIROLIZA OSTATAKA NAKON PROIZVODNJE PIVA S CILJEM DOBIVANJA ENERGIJE I PROIZVODA DODANE VRIJEDNOSTI

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SAŽETAK

Proces proizvodnje piva je energetski zahtjevan postupak, a sukladno smjernicama Europske unije, nusproizvodi procesa proizvodnje moraju se zadovoljavajuće zbrinuti. Pivski trop predstavlja glavni nusproizvod u proizvodnji piva. Postoji veliki potencijal u iskorištenju pivskog tropa s ciljem proizvodnje energije. Trenutno je najčešći oblik zbrinjavanja anaerobna fermentacija i proizvodnja bioplina, međutim, zbog velikih količina nusproizvoda koji nastaju tijekom proizvodnje piva, potrebno je istražiti i druge oblike dobivanja energije iz ove sirovine.

Cilj ovog rada bio je istražiti mogućnost iskorištenja nusproizvoda proizvodnje piva procesom pirolize, a s ciljem proizvodnje energije i proizvoda dodane vrijednosti.

Analiza kemijskog sastava triju različitih uzoraka pivskog tropa (Staropramen, Ožujskog te Tomislav piva) pokazala je određene različitosti u sastavu vode, pepela, koksa, hlapljivih tvari, fiksiranog ugljika te u sastavu organskih kemijskih spojeva (dušika, vodika, ugljika, kisika i sumpora). Osim toga, nakon provedenog procesa pirolize, analizirana su i svojstva dobivenog biougljena.

Nakon provedenih analiza utvrđeno je da je pivski trop, kao najzastupljeniji nusproizvod pivske industrije, vrlo dobra sirovina za proizvodnju energije procesom pirolize.

***Ključne riječi**: pivski trop, piroliza, biougljen, proizvodnja energije*

UVOD

Poljoprivrednu biomasu i ostatke iz prerađivačke industrije je moguće pretvoriti u razne oblike energije koristeći različite tehnologije pretvorbe (Krička i sur., 2016.). Najčešće korištena je termokemijska pretvorba biomase i to neposrednim spaljivanjem, uplinjavanjem, ukapljivanjem ili pirolizom (Akhtar i Amin, 2012). Iskorištenje poljoprivrednih ostataka i ostataka iz prerađivačke industrije za proizvodnju energije i proizvoda dodane vrijednosti termokemijskim postupcima moglo bi djelomično zamijeniti konvencionalna goriva (Jurišić i sur., 2016).

Piroliza je termokemijski postupak koji se provodi u odsutnosti kisika i koji rezultira s tri različita proizvoda: biouljem, biougljenom i sintetski plinom (Krička i sur., 2017.) Pirolitička proizvodnja energenata još uvijek je u ranoj fazi razvoja te treba prevladati brojne tehnološke i ekonomske barijere kako bi ušla u kompeticiju s tradicionalnim fosilnim oblicima energenata (Jahirul i sur., 2012). Relativna količina svakog produkta ovisi o uvjetima procesa, svojstvima biomase i vrsti postupka pirolize (Krička i sur., 2017).

Biougljen je visokovrijedna sirovina koja ima potencijal u smislu poboljšivača tla, ali i energenta za su-spaljivanje u elektranama (Anderson i sur., 2013). Budući da ugljik potječe od atmosferskog ugljičnog dioksida, primjena biougljena na tlu može doprinijeti smanjenju koncentracije CO_2. Osim uklanjanja ugljika, biougljen u tlu smanjuje emisije drugih glavnih stakleničkih plinova, kao što su N_2O i CH_4 (van Zweiten i sur., 2009). Glavninu sastava biougljena čine ugljik uz kisik te različiti anorganski spojevi (Jahirul i sur., 2012). Biougljen je moguće upotrijebiti na različite načine, a prema Lairdu i sur. (2009), biougljen može biti zamjenski izvor energije u postojećim elektranama na praškasti ugljen.

Proces proizvodnje piva je energetski zahtjevan postupak, a sukladno smjernicama EU, nusproizvodi procesa proizvodnje moraju se zadovoljavajuće zbrinuti. Nusproizvodi koji nastaju prilikom proizvodnje piva su voda, pivski trop, kvasac, ugljikov dioksid i korjenčići ječmenog slada (Šakić, 2008).

Nusproizvodi pivske industrije zbog ekonomskih i ekoloških pogodnosti nastoje se reciklirati te ponovno upotrijebiti kao sirovina ili energent. Postoji veliki potencijal u iskorištenju nusproizvoda iz proizvodnje piva s ciljem proizvodnje energije. Trenutno je najčešći oblik zbrinjavanja anaerobna fermentacija i proizvodnja bioplina. Međutim, zbog velikih količina nusproizvoda koji nastaju tijekom same proizvodnje, potrebno je istražiti i druge oblike dobivanja energije iz ove sirovine.

Kao tri najznačajnija nusproizvoda proizvodnje piva mogu se izdvojiti otpadna voda, pivski kvasac te pivski trop. Pivski trop može se koristiti kao stočna hrana, dodatak proizvodima namijenjenim za ljudsku prehranu, sirovina u biotehnologiji, sirovina za proizvodnju građevinskog materijala, proizvodnju ugljena, papira, energije kao i adsorbens (Silva i sur., 2004). Po svojem sastavu, pivski trop je lignocelulozni materijal s oko 20 % celuloze, 30 % neceluloznih polisaharida (većina arabinoksilan) i 30 % lignina u suhoj tvari (Jozinović i sur., 2014). Pivski trop se dobije na kraju procesa hidrolize, a predstavlja mješavinu razgrađenih i nerazgrađenih sastojaka slada u vodi (Pejin i sur., 2013). Kemijski sastav pivskog tropa može jako varirati, ovisno o sorti ječma, uvjetima sladovanja i komljenja, kao i vrsti i kvaliteti nesladovanih sirovina koje se koriste u proizvodnji piva (Pejin i sur., 2013).

Pivski trop se u Hrvatskoj prvenstveno koristi kao stočna hrana, a u razvijenijim državama sve se više upotrebljava kao sirovina za proizvodnju bioplina, bioetanola te biougljena.

Temeljem svega navedenog, cilj ovog istraživanja bio je utvrditi mogućnost iskorištenja nusproizvoda proizvodnje piva – pivskog tropa, procesom termičke anaerobne razgradnje pri visokim temperaturama - pirolizom, a s ciljem proizvodnje energije i proizvoda dodane vrijednosti.

MATERIJALI I METODE

U istraživanju su korišteni ostaci proizvodnje piva iz tri različita uzorka i to: uzorak pivskog tropa dobivenog nakon proizvodnje piva Staropramen, uzorak pivskog tropa dobivenog nakon proizvodnje piva Ožujsko, uzorak pivskog tropa dobivenog nakon proizvodnje piva Tomislav. Pivski trop preuzet je netom nakon završetka proizvodnje piva, u svježem stanju iz proizvodnog procesa Zagrebačke pivovare. Nakon preuzimanja, utvrđen je početni sadržaj vode u uzorcima te su uzorci osušeni prirodnim putem za potrebe daljnjih analiza sastava ulazne sirovine.

Analizi ulazne sirovine prethodilo je usitnjavanje uzoraka u laboratorijskom mlinu, nakon čega su standardnim metodama utvrđeni sadržaji vode (HRN EN 18134-2:2015), pepela (HRN EN 18122:2015), koksa (HRN EN 18123:2015), fiksiranog ugljika (računski) i hlapive tvari (HRN EN 18123:2015). Određivanje ukupnog ugljika, vodika, dušika i sumpora, provedeno je metodom suhog spaljivanja na Vario, Macro CHNS analizatoru (Elementar Analysensysteme GmbH, Njemačka) prema protokolima za ugljik, vodik, i dušik (HRN EN 16948:2015) te sumpor (HRN EN 15289:2011). Sadržaj kisika utvrđen je računski. Određivanje udjela celuloze, hemiceluloze i lignina provedeno je modificiranom standardnom metodom ISO 5351-1:2002. Gornja ogrjevna vrijednost određena je korištenjem IKA C200 adijabatskog kalorimetra (HRN EN 14918:2010), dok je donja ogrjevna vrijednost dobivena računski.

Nakon analiza ulaznih sirovina, pripremljeni uzorci su prosijani u situ tresilici (EN 15149-2:2010) te su uzorci veličine čestica 630 μm izdvojeni za proces pirolize. Proces pirolize uzoraka proveden je na količini od 20 g uzorka, pri temperaturi od 300 °C – 500 °C, pri čemu su utvrđeni udjeli proizvedenog biougljena i bioulja (računski). Sastav biougljena potom je analiziran gore navedenim standardnim metodama za čvrstu biomasu, kako bi se utvrdila njegova kvaliteta za korištenje u procesima suspaljivanja.

REZULTATI I RASPRAVA

U ovom radu istražene su nove mogućnosti dobivanja energije iz pivskog tropa nakon proizvodnje triju najznačajnijih piva Zagrebačke pivovare (Staropramen, Ožujsko i Tomislav). Procesu pirolize prethodila je analiza odabranih sirovina s ciljem uvida u mogućnost njihova neposrednog spaljivanja za dobivanje energije. U Tablici 1 prikazan je sadržaj vode te goriva svojstva triju ulaznih sirovina.

Voda se u gorivu nalazi kao nesagorivi sastojak i ima izravan učinak na ogrjevnu vrijednost biomase zbog količine topline koja se troši na njeno isparavanje (Francescato i sur., 2008). Sadržaj vode u svježem pivskom tropu iznosio je prosječno 74,52 % za uzorak od

Staropramen piva, 71,84 % za uzorak od Ožujskog piva te 72,61 % za uzorak od Tomislav piva (Tablica 1).

Tablica 1 Sadržaj vode i goriva svojstva ulazne sirovine
Table 1 Moisture content and fuel properties of raw material

Uzorak Sample	Voda, % Moisture, %	Pepeo*, % Ash*, %	Koks, % Coke, %	Cfix, % Cfix, %	Hlapiva tvar, % Volatile matter, %
Staropramen	74,52	5,71	19,80	14,08	76,30
Ožujsko	71,84	5,39	19,41	14,02	77,37
Tomislav	72,61	3,82	18,13	14,31	77,90

Legenda: * - izraženo na suhu tvar; Legend: * dry matter based

Sadržaj pepela ima katalitički utjecaj na termičku razgradnju, odnosno više koncentracije pepela rezultiraju većim koncentracijama ugljena i plinova (McKendry, 2002). Goriva s nižim udjelom pepela bolja su za termičko iskorištenje jer manje količine pepela olakšavaju njegovo uklanjanje, transport i skladištenje, kao i iskorištenje i odlaganje (Krička, 2017). Prosječni sadržaj pepela u analiziranim uzorcima pivskog tropa iznosio je 5,71 % za uzorak od Staropramen piva, 5,39 % za uzorak od Ožujskog piva te 3,82% za uzorak od Tomislav piva (Tablica 1). Staropramen i Ožujsko pivo su svijetla piva, dok je Tomislav tamno pivo koje se dobiva od karameliziranog ječmenog slada, ima veći sadržaj alkohola od svijetlih piva te zbog toga ima veća odstupanja u sadržaju pepela. Sperandio i sur. (2017) u svojem istraživanju navode sadržaj pepela u analiziranom pivskom tropu od 5,3 % uz standardnu devijaciju od 2,4 % pa se može zaključiti da je pivski trop poželjna sirovina za neposredno izgaranje. Koks je sekundarni ugljen koji nastaje pri višim temperaturama (Mohan i sur., 2006) te predstavlja poželjno svojstvo sirovine (Boboulos, 2010). Prosječni sadržaj koksa u analiziranim uzorcima iznosio je 19,80 % za uzorak od Staropramen piva, 19,41 % za uzorak od Ožujskog piva te 18,13 % za uzorak pivskog tropa dobivenog od Tomislav piva. Krička i sur. (2017) istraživali su sadržaj koksa na različitim tipovima biomase te dobili vrijednosti sadržaja koksa od 16,03 % za rezidbene ostatke od voćarskih kultura, 19,09 % za ratarske ostatke, 22,23 % za kominu maslina i grožđa te 30 % za stabljiku kukuruza. S obzirom na visoki sadržaj koksa u svim uzorcima analiziranog pivskog tropa, može se zaključiti kako pivski trop predstavlja dobru sirovinu za proizvodnju energije. Sadržaj fiksiranog ugljika, uz pepeo, predstavlja kruti ostatak nakon gorenja odnosno ispuštanja hlapljivih tvari (Jurišić i sur., 2016). Vrijednost sadržaja fiksiranog ugljika dobivena je računski iz prethodno provedenih analiza. Prosječni sadržaj fiksiranog ugljika za uzorak pivskog tropa dobivenog od Staropramen piva iznosio je 14,08 %, za uzorak od Ožujskog piva 14,02 % te za uzorak od Tomislav piva 14,31 % (Tablica 1). Fiksirani ugljik tijekom gorenja prelazi u ugljen te gori kao kruto gorivo u sustavu izgaranja biomase (Garcia i sur., 2012). Povećanjem vrijednosti sadržaja fiksiranog ugljika povećava se i ogrjevna vrijednost, a time i kvaliteta pivskog tropa kao sirovine za energetsku iskoristivost. Tijekom procesa izgaranja, pivski trop se razgrađuje na hlapive tvari te kruti ostatak. Za biomasu je tipično da ima visok sadržaj hlapivih tvari, do 80 %, a goriva koja imaju visoki sadržaj hlapivih tvari imaju manju energetsku vrijednost. Hlapive tvari se sastoje od zapaljivih ugljikovodika, ugljikovog monoksida ili vodika, nezapaljivog ugljikovog i sumpornog dioksida te dušikovih oksida (Khan i sur., 2009). Analizom pivskog tropa, utvrđen je sadržaj hlapivih tvari u uzorku Staropramen piva od 76,30 %, u uzorku Ožujskog piva od 77,37 % te u uzorku Tomislav piva od 77,90 % (Tablica 1).

U Tablici 2 prikazane su ogrjevne vrijednosti istraživane biomase.

Tablica 2 Ogrjevna vrijednost ulazne sirovine
Table 2 Calorific value of raw material

Uzorak Sample	Gornja ogrjevna vrijednost, MJ kg^{-1} HHV, MJ kg^{-1}	Donja ogrjevna vrijednost, MJ kg^{-1} LHV, MJ kg^{-1}
Staropramen	19,31	17,90
Ožujsko	19,77	18,31
Tomislav	19,44	17,99

Ogrjevna vrijednost je mjera za određivanje sadržaja energije u gorivu. Ogrjevne vrijednosti najvažniji su parametar u ovakvim istraživanjima jer predstavljaju količinu energije koja se može dobiti izgaranjem određene količine biomase (Garcia i sur., 2012). U Tablici 2 prikazane su gornje i donje ogrjevne vrijednosti uzoraka pivskog tropa dobivenog nakon proizvodnje Staropramen, Ožujsko i Tomislav piva te je vidljivo da su dobiveni približno jednaki rezultati za sva tri analizirana uzorka. Varijacije u ogrjevnoj vrijednosti biomase uglavnom proizlaze iz razlike u staničnoj kompoziciji te koncentraciji vlage i pepela (Lewandowski i sur., 2003). Jurišić i sur. (2014) navode u svojem istraživanju provedenom na biomasi trave *Miscanthus x giganteus* donju ogrjevnu vrijednost koja se kretala u rasponu od 16,14 MJ kg^{-1} do 17,20 MJ kg^{-1}. S obzirom na usporedbu dobivenih vrijednosti, može se utvrditi da je pivski trop s ovog aspekta vrlo kvalitetna sirovina za dobivanje energije.

U Tablici 3 prikazan je lignocelulozni sastav ulazne sirovine.

Tablica 3 Lignocelulozni sastav ulazne sirovine
Table 3 Lignocellulosic structure of raw material

Uzorak Sample	Celuloza*, % Cellulose*, %	Lignin, % Lignin, %	Hemiceluloza, % Hemicellulose, %
Staropramen	29,77	30,26	22,26
Ožujsko	30,35	30,36	19,84
Tomislav	26,51	37,65	18,46

Legenda: * - izraženo na suhu tvar; Legend: * dry matter based

Pivski trop je lignocelulozni materijal bogat vlaknima, koja čine 70 % njegova sastava (Pejin i sur., 2013). Glavne komponente vlakana pivskog tropa su hemiceluloza, lignin i celuloza (Santos i sur., 2003). U Tablici 3 prikazan je sadržaj celuloze, lignina i hemiceluloze u istraživanim uzorcima pivskog tropa. Za uzorak Staropramen piva dobiveni su rezultati od 29,77 % celuloze, 30,26 % lignina i 22,26 % hemiceluloze, za uzorak od Ožujskog piva utvrđeno je prisustvo 30,35 % celuloze, 30,36 % lignina i 19,84 % hemiceluloze, a u uzorku od Tomislav piva 26,51 % celuloze, 37,56 % lignina te 18,46 % hemiceluloze. Mussatto i Roberto (2005) u svome istraživanju kemijskog sastava pivskog tropa dobili su vrijednosti od

16,8 % celuloze, 27,8 % lignina, 28,4 % hemiceluloze, dok su Bogar i sur. (2002) dobili vrijednosti od 15 % celuloze, 22 % lignina te 23 % hemiceluloze. S obzirom na navedene lieraturne podatke, može se zaključiti da lignocelulozni sastav pivskog tropa jako oscilira, a ovisi o vrsti i kvaliteti sirovina za proizvodnju piva te uvjetima sladovanja i komljenja.

U Tablici 4 prikazan je elementarni sastav istraživanih sirovina.

Tablica 4 Elementarni sastav ulazne sirovine
Table 4 Elemental analysis of raw material

Uzorak Sample	N* (%)	C (%)	S (%)	H (%)	O (%)
Staropramen	3,48	46,84	0,54	6,43	42,70
Ožujsko	4,04	49,20	0,32	6,69	39,75
Tomislav	4,12	50,71	0,28	6,67	38,22

Legenda: * - izraženo na suhu tvar; Legend: * dry matter based

Visoki sadržaj ugljika poželjno je svojstvo u biomasi, jer goriva s većim sadržajem ugljika imaju bolje ogrjevne vrijednosti. Ugljik se u biomasi nalazi u složenim spojevima koji prilikom izgaranja oksidira uz oslobađanje energije (Brown, 2011). U ovom istraživanju dobiveni su rezultati od 46,84 % ugljika za uzorak od Staropramena, 49,20 % ugljika za uzorak od Ožujskog piva te 50,71 % ugljika za uzorak od Tomislav piva (Tablica 4). Sperandio i sur. (2017) u svojem istraživanju na pivskom tropu dobili su vrijednosti od 45,7 % ugljika. S obzirom na dobivene rezultate prema sadržaju ukupnog ugljika, uzorak pivskog tropa od Tomislav piva bio bi najpoželjniji uzorak pivskog tropa za dobivanje energije. Vodik, kao element, povećava ogrjevnu vrijednost goriva te stvara plamen i najzaslužniji je za razvijanje plinova (Jurišić i sur., 2014). Vodik predstavlja drugi najvažniji gorivi element u gorivu i od posebne je važnosti da se analiza vodika odvija u suhom uzorku jer se u suprotnom prilikom analize detektira i vodik vezan u vodi koja se po prirodi nalazi u uzorcima (Brown, 2011). U ovom istraživanju dobiveni su rezultati od 6,43 % vodika u uzorku od Staropramena, 6,69 % vodika u uzorku od Ožujskog piva te 6,67 % vodika u uzorku od Tomislav piva (Tablica 5). Sperandio i sur. (2017) analizirajući pivski trop dobiven u malim pivovarama, dobili su rezultate od 9,0 % vodika u uzorku. Visok sadržaj sumpora i dušika nepoželjno je svojstvo biomase, jer njegov sadržaj utječe na emisije nepoželjnih plinova (NOx i SO_2) pri izgaranju biomasa (Gracia i sur., 2012). Dušik predstavlja negorivi dio goriva, odnosno predstavlja balast jer i sam ne gori i zauzima mjesto u gorivu nekim drugim korisnim elementima, odnosno tvarima (Voća, 2015). U ovom istraživanju dobiveni su rezultati od 3,48 % dušika u uzorku od Staropramen piva, 4,04 % dušika u uzorku od Ožujskog piva te 4,12 % u uzorku od Tomislav piva. U istraživanju koje su proveli Sperandio i sur. (2017) udio dušika u uzorku pivskog tropa iznosi je 4,2% uz standardnu devijaciju od 0,2 %. Sadržaj sumpora u ovom istraživanju iznosio je 0,54 % u uzorku Staropramen piva, 0,32 % u uzorku od Ožujskog piva te 0,28 % u uzorku od Tomislav piva (Tablica 4). Sadržaj kisika ima snažan utjecaj na ogrjevnu vrijednost koja se linearno smanjuje s povećanjem koncentracije kisika (Hodgson i sur., 2010). Iako je kisik goriva tvar, njegova prisutnost u gorivu je nepoželjna jer on može uzeti udio u izgaranju zamjenjujući dio kisika iz zraka, neophodnog za izgaranje (Vasillev i sur., 2010). U ovom istraživanju, računski su dobiveni rezultati od 42,70 % kisika u uzorku od Staropramen piva, 39,75 % kisika u uzorku od Ožujskog piva te 38,22 % u uzorku od Tomislav piva (Tablica 4).

Nakon analize pivskog tropa može se zaključiti da su sva tri uzorka pogodna za daljnje energetsko iskorištenje neposrednim izgaranjem.

U Tablici 5 prikazan je udio biougljena nakon procesa pirolize, kao i njegova ogrjevna vrijednost ovisno o tipu uzorka.

Tablica 5 Udio i ogrjevna vrijednost biougljena nakon pirolize biomase
Table 5 Share and calorific value of biochar after the biomass pyrolysis

Uzorak Sample	Udio nakon pirolize, % Share after pyrolysis, %	Gornja ogrjevna vrijednost, MJ kg^{-1} HHV, MJ kg^{-1}	Donja ogrjevna vrijednost, MJ kg^{-1} LHV, MJ kg^{-1}
Staropramen	50,15	27,06	25,85
Ožujsko	46,65	28,98	27,95
Tomislav	39,65	29,01	28,12

Procesom pirolize, prethodno analizirani pivski trop razdvojen je na tri produkta (bioulje, biougljen te rezidualne plinove). U radu je istražena frakcija biougljena, kao potencijalna sirovina u procesu neposrednog izgaranja. Dobiveni udjeli biougljena prikazani su u Tablici 5, gdje je vidljivo da je najveći udio biougljena dobiveno nakon pirolize pivskog tropa od Staropramen piva.

Iz Tablice 5 vidljivo je da je prosječna donja ogrjevna vrijednost iznosila 25,85 MJ kg^{-1} za uzorak od Staropramen piva, 27,95 MJ kg^{-1} za uzorak od Ožujskog piva te 27,12 MJ kg^{-1} za uzorak od Tomislav piva. Razlike između ogrjevnih vrijednosti biougljena dobivenog pirolizom pivskog tropa mogu se objasniti razlikama u sastavu izvornih sirovina. Ogrjevna vrijednost fosilnog ugljena veća je od ogrjevne vrijednosti biougljena, i uglavnom iznosi oko 28-40 MJ kg^{-1} (Jurišić i sur., 2016). Jurišić i sur. (2016) navode gornju ogrjevnu vrijednost kod analiziranog biougljena dobivenog od koštice trešnje od 25,68 MJ kg^{-1} te 25,21 MJ kg^{-1} kod analiziranog biougljena dobivenog od koštice višnje. S obzirom na navedene rezultate istraživanja, može se zaključiti da biougljen dobiven pirolizom pivskog tropa, kao agroindustrijskog ostatka, predstavlja kvalitetniji izvor energije od biougljena dobivenog od koštica trešnje i višnje.

U Tablici 6 prikazana su goriva svojstva dobivenog biougljena.

Tablica 6 Goriva svojstva biougljena nakon pirolize biomase
Table 6 Fuel properties of biochar after the biomass pyrolysis

Uzorak Sample	Pepeo*, % Ash, %	Koks, % Coke, %	Cfix, % Cfix, %	Hlapiva tvar, % Volatile matter, %
Staropramen	10,21	52,12	41,91	47,88
Ožujsko	9,33	61,99	52,66	38,01
Tomislav	9,11	63,93	54,82	36,07

Legenda: * - izraženo na suhu tvar; Legend: * dry matter based

Prosječni udio pepela u biougljenu pivskog tropa iznosio je 10,21 % za uzorak od Staropramena, 9,33 % za uzorak od Ožujskog piva, te 9,11 % za uzorak od Tomislav piva (Tablica 6). Jurišić i sur. (2016) navode kako je sadržaj pepela u biougljenu dobivenom nakon pirolize koštica trešnje iznosio 2,79 % te 3,67% nakon pirolize koštica višnje. S obzirom na navedene rezultate, a budući da je visok sadržaj pepela nepoželjna komponenta u biougljenu, može se utvrditi da, s aspekta udjela pepela, biougljen dobiven pirolizom pivskog tropa nema zadovoljavajuće kriterije za visoku energetsku iskoristivost.

Prosječni sadržaj koksa u biougljenu pivskog tropa iznosio je 52,12 % za uzorak od Staropramen piva, 61,99 % za uzorak od Ožujskog piva te 63,93 % za uzorak od Tomislav piva (Tablica 6). Visoki udio koksa u biougljenu predstavlja dobru osobinu kod izgaranja te se može utvrditi da pivski trop ima zadovoljavajući sadržaj koksa u biougljenu.

Sadržaj fiksiranog ugljika u biougljenu pivskog tropa prosječno je iznosio 41,91 % za uzorak od Staropramen piva, 52,66 % za uzorak od Ožujskog piva te 54,82 % za uzorak od Tomislav piva (Tablica 6). S obzirom da je za energetsku iskoristivost biougljena poželjna niska vrijednost fiksiranog ugljika, može se zaključiti da, s aspekta sadržaja fiksiranog ugljika, biougljen dobiven od pivskog tropa Staropramen piva predstavlja najkvalitetniji biougljen od svih istraživanih sirovina. Sadržaj hlapivih tvari u biougljenu pivskog tropa iznosio je prosječno 47,88 % za uzorak od Staropramen piva, 38,01 % za uzorak od Ožujskog piva, te 36,07 % za uzorak od Tomislav piva (Tablica 6). U prethodno navedenom radu, Jurišić i sur. (2016) navode slične vrijednosti hlapivih tvari od 47,09 % u biougljenu dobivenom pirolizom koštice trešnje i 39,87 % u biougljenu dobivenom pirolizom koštice višnje.

ZAKLJUČAK

Na temelju provedenih analiza pivskog tropa, dobivenog nakon proizvodnje tri različite vrste piva, njegovog pirolitičkog izgaranja te analize dobivenog biougljena može se zaključiti da je analiza kemijskog sastava triju različitih uzoraka pivskog tropa (od Staropramen, Ožujskog te Tomislav piva) pokazala određene različitosti u sastavu vode, pepela, koksa, hlapivih tvari, fiksiranog ugljika te u elementarnom sastavu (dušika, vodika, ugljika, kisika i sumpora). Ogrjevne vrijednosti sva tri uzorka bile su gotovo identične, a najveću donju ogrjevnu vrijednost imao je uzorak pivskog tropa od Ožujskog piva (18,31 MJ kg^{-1}). Nakon provedene pirolize uzoraka, utvrđeno je da je najveći udio biougljena dobiven nakon pirolize ostataka proizvodnje Staropramen piva (50,15 %). Osim toga se pokazalo da je biougljen od pivskog tropa dobivenog od tamnog Tomislav piva imao bolje ogrjevne vrijednosti od biougljena dobivenog od pivskog tropa svijetlih piva (Staropramen i Ožujsko).

Ovim istraživanjem je utvrđeno da je, uzevši u obzir najvažnije parametre, pivski trop od Ožujskog piva najbolja sirovina za proces neposrednog izgaranja, a pivski trop od Tomislav piva najbolja sirovina za dobivanje visokovrijednog biougljena kao energenta procesom pirolize te se nakon svih provedenih analiza može utvrditi da je pivski trop, kao najzastupljeniji nusproizvod pivske industrije, vrlo dobra sirovina za proizvodnju energije procesom pirolize.

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PYROLYSIS OF BSG WITH THE AIM OF GAINING ENERGY AND ADDED-VALUE PRODUCTS

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ABSTRACT

Beer production process is a very demanding process and its byproducts need to be efficiently disposed, according to the EU directives. The Brewers' spent grain (BSG) represents the main byproduct in beer production. There is a vast potential of using BSG for energy production. Nowadays, the most common method of disposal is anaerobic digestion and biogas production. However, exploring other energy generating processes for this raw material is necessary, considering the great amount of byproducts generated during the beer production process.

The aim of this study was to explore the possibility of generating energy and added-value products by converting BSG via process of thermal decomposition at high temperatures –pyrolysis. The chemical composition analysis of three different samples of BSG (from beers Staropramen, Ožujsko and Tomislav) has shown a certain diversity in the composition of moisture, ash, coke, volatile matter, fixed carbon, and in the elemental composition (nitrogen, hydrogen, carbon, oxygen and sulphur). Moreover, after the pyrolysis, biochar properties were also analyzed. After all analyses have been conducted, it can be concluded that BSG, as the most common byproduct in beer production process, is a very good raw material for energy production through pyrolysis.

Keywords: *Brewers' spent grain (BSG), pyrolysis, biochar, energy production*

47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

RELATIONSHIPS ANALYSIS BETWEEN THE GRINDING PARAMETERS OF *MISCANTHUS GIGANTEUS* STALKS USING A HAMMER MILL

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SUMMARY

In order to better demonstrate the link between main parameters of the grinding process, in this paper we present the values of these parameters, experimentally determined by grinding miscanthus stalks using a hammer mill, equipped successive with four different sives, respectively four types of hammers (one, two and three step edge and a triangle edge). Each time the grinding energy was determined for five rotor frequency of the hammer mill. Also, there were statistically analyzed the sets energy – feeding flow, energy – rotor rotation frequency, energy – sieve orifice diameter, in order to establish the statistic correlation according to each analyzed group using Excel MS Office. If we consider the connection between sieve orifice diameter and energy, for one step hammer according to statistical analysis the relation is weak and for step two hammer according to statistical analysis the relation is moderate. Another correlation that resulted in being weak after experimental results statistical interpretation for the relation between consumed energy and rotor frequency. Also, the values the energy consumption for hammer with one step and a sieve with orifices of ϕ25 mm were between 53.55 kJ·kg^{-1} and 92.21 kJ·kg^{-1} while the feeding rate had values between 0.129 kg·s^{-1} and 0.214 kg·s^{-1}.

Keywords: *miscanthus grinding, energy consumption, rotor frequency, feeding rate, statistical analysis*

INTRODUCTION

Due to renewable energies importance given in the last years or so, the study of biomass is revealing aspects and parameters that should be taken into consideration when analyzing the material preparation process starting with the material behavior and continuing with the equipment used for all processes involved.

Knowledge of size reduction of biomass would help in the future in making the decision of which equipment type is better for material grinding and also contributing to reducing biomass loses but most importantly reducing operating costs. When analyzing size reduction, researched mainly analyzed the energy consumption obtained through subjecting biomass to shredding, cutting or grinding.

If we take into consideration the influence on a hammer mill production rate of the constructive and functional parameters we can name: the shape and the dimension of the hammer, rotors dimensions, the form and dimension of the sieve orifices, rotor speed, feeding flow, etc.

An important parameter for hammer mill experimental data analysis is the specific grinding energy. Kayode and Koya (2013) showed that there is a linear correlation between grinding energy and machine-material parameters, shaft speed, the feed rate and material bio-stiffness (in experimentation process were Palm kernel and coconut shells). Experimental verification showed that the used models adequately predicted comminution energy and was in accordance with Rittinger's classical theory.

The energy consumption variation was analyzed by researchers (Macmanus et al., 2016) using a laboratory hammer mill equipped with a 4.75 mm sieve and using as raw material for grinding palm kernel shell and groundnut shell. The study's conclusions revealed that the material type and hammer mill screen aperture significantly influenced the energy requirement for grinding the two materials (Macmanus et al., 2016).

In paper (Shastri et al.2014) the goal was to determine the optimal levels of size reduction through a combination of modelling and experimental studies using for testing miscanthus and switchgrass. The experimental results had shown that specific energy consumption decreased according to a power law with increasing particle size. The study concluded that the optimal miscanthus particle size range was 4–6 mm is order not to increase costs.

The study of energy consumption while using for grinding process a hammer mill was also the purpose of researchers in paper (Ghorbani et al., 2013) which correlated the energy consumption to sieve orifices dimensions and mechanical properties of the biomass (alfalfa). The results were analyzed by applying regression analysis thus concluding that the energy consumption increases once with the decrease of sieve orifices dimensions.

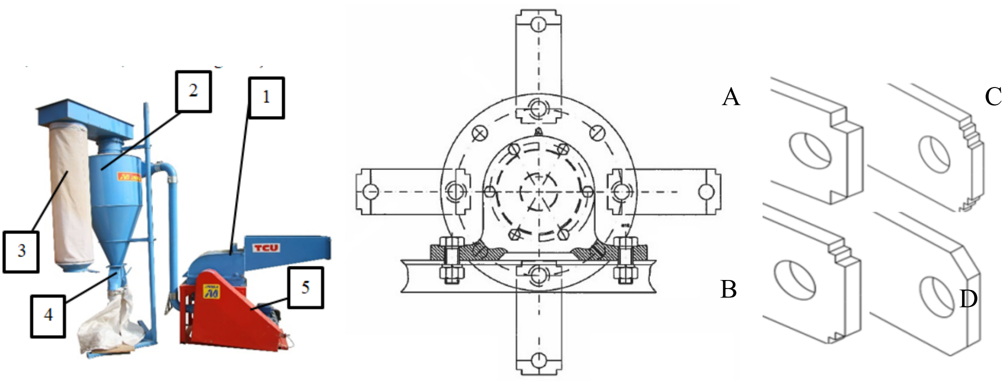
The correlation between rotor frequency and grinding energy consumption, while using hammer mills, was also confirmed by researches in paper (Colton, 1974; Ghorbani et al., 2011).

In order to better confirm this dependency, the authors (Bitra et al., 2009; Ghorbani et al., 2010; Ghorbani et al., 2013; Shastri et al., 2014; Dorcas et al., 2014; Cafferty et al., 2014,) analyzed the energy consumption on the work flow considering the sieve orifices dimensions, biomass humidity content or rotor frequency. They reached similar conclusions this being that there is an inverse dependency of energy consumption with sieve orifices dimensions, each time the sieve orifices became smaller the energy consumption increased thus outlining a rise in production capacity along with a rise in sieve orifices dimensions. Some other conclusion had shown a rise of energy consumption with a rise of material humidity (Cafferty et al. 2014) and a rise of the rotor rotation speed (rise of frequency) (Bitra et al. 2009).

The purpose of this paper is to present in an original manner the correlation between the fundamental parameters of *Miscanthus giganteus* stalk grinding process by using one of the most known relations in mathematical statistics.

MATERIALS AND METHODS

In order to obtain data regarding the energy consumption of a hammer mill, experimental research was conducted by using a MC-22 hammer mill and as feedstock *Miscanthus giganteus* stalks. The hammer mill had a 0.33-0.50 kg·s^{-1}productivity on grinding corn stalks, respectively 0.22-0.42 kg·s^{-1} on grinding packaged hay, using a sieve with Ø4 mm orifice size. MC-22 hammer mill is equipped with a 22kW electrical engine, it has a 220 mm hammer rotor diameter and a rotor length of 500 mm. All 24 hammers are set up in a parallel distribution and have a length of 135 mm.



a. b. c.

Figure1 a. Hammer mill MC 22 (hammer mill; 2. exhauster; 3. cyclone with support and dust collector bag; 4. grinding material evacuation vent; 5. electrical engine; 6. grinded material.), **b.** hammer mill rotor, **c.** four types of hammer (A – one step hammer; B – two steps hammer; C- three steps hammer; D – triangle hammer)

The biomass used for testing, *Miscanthus* stems, was harvested with a special harvester that fragmented the stalks at an average size of 125 mm. Also, the medium moisture content for miscanthus biomass was about 10.3%. The grinding process took place after about 3 months, when the average humidity for miscanthus biomass was between 8.89 – 11.99%.

Grinding energy consumption was calculated by taking into consideration all the rotor frequencies applied (50 Hz, 47.5 Hz, 45 Hz, 42.5 Hz, 40 Hz), four diameters mill sieve orifices for four types of hammers (one, two and three step edge hammer, triangle edge hammer) and the material feeding flow values.

The hammer mill feeding flow (loading the hammer mill) was different from one experiment to another, even when the hammer mill was equipped with the same type of sieve. The grinding energy consumed throughout the entire experiment was calculated based electric current voltage and intensity (triphase) determined during hammer mill operation process by using specific equipment, inclusively with a data acquisition system for each phase of the voltage networks.

Thus, for the main grinding quality parameters a statistical analysis represents the solution for a better description of the connection between them in order to better identify which is the optimal working process of the hammer mill. This analysis was chosen mostly because of the hammer mills undifferentiated working process character.

The statistically analyze was applied for correlation between the energy and the feeding flow, the energy consumption and the rotor frequency, the energy consumption and the sieve orifice diameter.

The statistically determined parameters were correlation (corr) between each pair, R^2 coefficient, linear regression line b, covariance (cov) and Kurtosis coefficient (Kurt). All parameters were obtained by using Excel MS Office and using the relations:

$$corr(x,y) = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2 (y_i - \bar{y})^2}} \tag{1}$$

$$\mathrm{R}^2 = \frac{\sum_i (y - \bar{y})^2 - \sum_i (y - \hat{y})^2}{\sum_i (y - \bar{y})^2} \tag{2}$$

$$b = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sum_i (x_i - \bar{x})^2} \tag{3}$$

$$\mathrm{cov}_p(x,y) = \frac{1}{n} \sum_i (x_i - \bar{x})(y_i - \bar{y}) \tag{4}$$

$$\mathrm{cov}_s(x,y) = \frac{1}{n-1} \sum_i (x_i - \bar{x})(y_i - \bar{y}) \tag{5}$$

$$kurt(x) = \left\{ \frac{n\,(n+1)}{(n-1)(n-2)(n-3)} \sum \left(\frac{x_i - \bar{x}}{s} \right)^4 \right\} - \frac{3\,(n-1)^2}{(n-2)(n-3)} \tag{6}$$

where:

$i = 1 \ldots n$ – number of experiments;

x_i, y_i – sets of values obtained in experiments;

$\bar{x}$, $\bar{y}$ – value average x_i respectively y_i;

s – standard deviation;

b – linear regression slope.

The statistical correlation analysis of the experiment pair parameters (as they have been defined in the paper summary), which is the papers main objective, is based on the data presented in table 1.

RESULTS AND DISCUSSION

The results obtained are presented in table 1. Data presented in table 2 shows a negative correlation (-0.349) between energy consumption E [kJ·kg^{-1}] and sieve orifices diameter d_s [mm], thus proving that there is a relation between these parameters, an inversely proportional relation.

Table 1 Hammer mill parameters and grinding energy variation

Biomass of *miscanthus giganteus*									
		Hammer with one-step corners		Hammer with two-step corners		Hammer with three-step corners		Hammer with triangle corners	
Sieve holes diameter mm	Rotor frequency Hz	Feeding rate kg·s^{-1}	Energy kJ·kg^{-1}	Feeding rate kg·s^{-1}	Energy kJ·kg^{-1}	Feeding rate kg·s^{-1}	Energy kJ·kg^{-1}	Feeding rate kg·s^{-1}	Energy kJ·kg^{-1}
25	50	0.144	92.213	0.250	114.28	0,294	59,636	0,263	51,772
25	47.5	0.185	71.113	0.250	102.13	0,357	41,129	0,167	73,047
25	45	0.214	54.561	0.208	76.845	0,313	30,528	0,161	65,963
25	42.5	0.150	53.558	0.147	80.857	0,278	35,063	0,167	86,871
25	40	0.129	58.156	0.200	48.449	0,294	37,694	0,179	72,909
16	50	0.225	42.934	0.172	94.961	0,250	64,312	0,313	44,745
16	47.5	0.227	40.811	0.192	72.357	0,152	93,624	0,238	52,377
16	45	0.135	48.437	0.167	88.193	0,208	59,486	0,294	38,161
16	42.5	0.121	42.956	0.143	67.108	0,217	56,017	0,208	68,958
16	40	0.129	55.320	0.167	96.524	0,167	67,810	0,125	70,510
10	50	0.217	59.631	0.185	169.17	0,161	102,83	0,192	71,965
10	47.5	0.192	51.797	0.143	126.36	0,147	99,599	0,152	91,567
10	45	0.167	47.738	0.192	78.992	0,143	96,243	0,139	114,21
10	42.5	0.167	64.424	0.167	105.10	0,156	69,587	0,111	100,31
10	40	0.116	65.717	0.116	176.30	0,125	97,646	0,109	88,458
7	50	0.139	102.09	0.119	169.17	0,122	96,636	0,135	119,28
7	47.5	0.156	125.13	0.143	126.36	0,125	102,68	0,132	107,19
7	45	0.128	108.60	0.139	78.993	0,139	90,463	0,135	99,043
7	42.5	0.135	76.676	0.116	105.10	0,104	88,936	0,114	111,00

This conclusion is with no doubt in accordance to literature that studied this correlation on hammer mills (Scholtz et al., 2002; Yu et al., 2006; Dilts, 2007; Bitra et al., 2009; Bitra et al., 2009; Bitra et al., 2009; Miao et al., 2011; Ghorbani et al., 2011; Ghorbani et al., 2013; Caffery et al., 2014; Paun et al., 2014; Shastrim et al., 2014; Drocas et al., 2014; Dabbour et. al., 2015; Liu et al., 2016,). A similar phenomenon, a negative correlation, occurs for the pair parameters energy consumption E [kJ·kg^{-1}] – feeding rate q [kg·s^{-1}] of the material subjected to grinding, the relation being also, inversely proportional (or the one step hammer mill the correlation is -0.329, for two step hammer the correlation is -0.635, for three step hammer the correlation in -0.845, respectively for the oblique edge hammer the correlation in -0.838).

In this case the conclusion is less exact than before because is in agreement with some papers (Montgomery, 2001), but in disagreement with others, (Liu et al., 2016). Thus, it is necessary to take into consideration each authors definition for the specific energy consumption.

Table 2 Statistical characteristics regarding the correlation between energy consumption and same parameters of the hammer mill used for grinding miscanthus

Biomass of *miscanthus giganteus*					
Parameter pair	Correlation (rel.1)	Determination coefficient, R^2 (rel.2)	Regression linear slope (rel.3)	Covariance P (rel.4)	Kurtosis (rel.6)
Hammer with one-step corners (A)					
Energy – Sieve holes diameter	-0.349	0.122	-1.164	-54.999	-0.603
Energy – Rotor frequency	0.232	0.054	1.504	18.798	4.122
Energy – Feeding rate	-0.329	0.109	-199.03	-0.286	0.177
Hammer with two-step corners (B)					
Energy – Sieve holes diameter	-0.627	0.393	-2.969	-140.279	-0.571
Energy – Rotor frequency	0.153	0.024	1.691	21.134	0.591
Energy – Feeding rate	-0.635	0.404	-398.64	-0.659	-0.900
Hammer with three-step corners (C)					
Energy – Sieve holes diameter	-0.847	0.717	-2.950	-139.382	-1.270
Energy – Rotor frequency	0.285	0.081	1.934	24.161	-0.618
Energy – Feeding rate	-0.845	0.713	-266.34	-1.536	-1.485
Hammer with triangle step corners (D)					
Energy – Sieve holes diameter	-0.629	0.396	-2.602	-122.937	-0.516
Energy – Rotor frequency	-0.305	0.093	-2.454	-30.6795	1.445
Energy – Feeding rate	-0.838	0.702	-385.43	-1.4706	-0.958

Regarding the correlation between rotors frequency υ *[Hz]* and energy consumption E *[kJ·kg^{-1}]*, results have shown a positive correlation for hammer mills equipped with hammers with a step edge (one, two or three) and a negative correlation when the hammers have an oblique edge.

Statistically in 75% cases the direct proportional dependence can be tested.

Rotor frequency it is underlined in paper (Moiceanu et al., 2015), mainly regarding the grinded material dimensions. According to paper (Colton, 1974) for one step edge hammer the relationship between the energy consumption and sieve orifices diameter is weak, for two step edge hammer and oblique edge hammer the correlation in moderate while for a three-step edge hammer the correlation in strong. Regarding the correlation between the energy consumption E [kJ·kg^{-1}] and rotors frequency ν [Hz], it can be said that for one and two step edge hammer there is no relation while for three and oblique edge hammer the relation is weak.

Considering the correlation between the energy consumption and material flow according to (Colton, 1974) it can be said that there is a weak connection between parameters in that case of one step edge hammer, a moderate connection for two step edge hammer and strong correlation for three and oblique edge hammers. If the determination coefficient is analyzed it can be seen that its values show the influence of the feeding rate on the energy consumption for three step and oblique edge hammers explained through 70% of the situations.

The statistical parameters negative values (correlation, covariance, regression linear slope and kurtosis) show an inversely proportional dependence between the analyzed couple, while the positive values show a direct proportional dependence of the grinding parameters, for the pairs proposed for analysis. Closer the value of the statistical parameters (indicated through relations 1 – 6) is to zero, smaller the dependence between the two analyzed parameters, while as further from the zero are the values, the dependence in more pronounced (either direct, either inversely).

For example, the linear regression curve between energy and the three variables shows, in certain limits, that the data are in direct dependency (positive curve) or in reverse dependency (negative curve). Since 1989 (Thyn, 1989) and until now (Shi et. al., 2003; Nakach et al., 2004; Toneva and Peukert, 2007; Shashidhar et al., 2013; Kwon et. al., 2014; Yancey et al., 2013; Moiceanu et al., 2015) scientists have been developing a model for hammer mills that also include a statistical component.

CONCLUSIONS

Knowing that scientists are still in plain process of understanding and optimizing the grinding process it must be said that hammer mills need to be further analyzed and improved. Our experiments targeted miscanthus biomass grinding by using hammer mill MC22 with a 22 kW engine and four types of hammers, at different revolution speeds.

In this paper the data presented show the correlation between pairs of parameters from which it can be concluded:

- the positive values of covariation show a direct link of energy with the hammer rotor frequency (one step hammer 18.798, two step hammer 21.134, three step hammer 24.161), but its negative values show a reverse link of energy with the size of the sieve orifices (values between -54.99 to -140.279), respectively with the feeding rate (values between -0.286 and -1.536);
- the correlation between the energy consumption and sieve orifices diameter is mainly a reversed dependency (mostly negative values under -0.847), thus it can be said that this hypothesis can be applied in 87.5% of the cases;
- the correlation coefficient R^2 show the connection between paired parameters, thus the highest values recorded was for energy consumption – sieve holes diameter 0.717, and the lowest values was registered for energy consumption – rotor frequency 0.024;

- a positive linear regression slope demonstrates a positive correlation between the energy consumption and the rotor frequency while for the other paired parameters the regression linear slope is negative which expresses a negative correlation.

Our results can contribute to biomass grinding users and designer's knowledge of the correlations between energy and tuning and command parameters, for grinding energetically plants. Future experiments should be done in order to evaluate and propose better hammers for hammer mills, with edges that positively influence the grinding process (a smaller figure in energy consumption for a better grinding degree).

ACKNOWLEDGEMENT

The work has been funded by National Grants GNaC 2018 ARUT, Internal Research Grant, through the Financial Agreement 06/15.10.2018.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

INFLUENCE OF MOTION TYPE ON GRANULOMETRIC DISTRIBUTION OF GRIST OBTAINED FROM SOME VARIETIES OF WHEAT AND CORN

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ABSTRACT

Granulometric analysis of granular materials is carried out in the milling plants laboratories with devices that have overlapping sieves. The constructive variety of the devices makes the results of granulometric analyses not always be the same, if different classification devices are used, whether the sample time is the same. This thing is happening, especially, due to the parameters of the oscillation movement, respectively the vibration amplitude and frequency.

This study highlights the type of movement as a parameter that influences granulometric distribution of the grist obtained from the Romanian wheat varieties Glosa and Rapsodia, respectively Romanian corn of the varieties Favorit and Olt. The wheat and corn samples were harvested in the South-East of Romania in 2017. At the time of the experiment they were grinded with a laboratory mill, and then subjected to granulometric analysis with two classifiers with overlapping sieves which imparts different movements to the set of sieves used in analyses (one prints a vibratory motion, and the other a circular translation motion).

The experimental results were tested by regression analysis with multiple distribution laws known in the granulometric analysis technique and they showed that the type of movement of sieve block that performs the sifting operation, influence the efficiency of this operation, for the same sample time.

The study may be useful in particular to users of granulometric analysis equipment, respectively to the labourers which work in specialized laboratories of panification and milling plants

Keywords: *grist sieving, vibratory movement, circular translation motion, granulometric distribution, distribution laws*

INTRODUCTION

In industrial milling plants, grinding and sifting operations are complementary (being made in the same technological passage) and repetitive, both in breakage phase, as well as in the detachment and milling phases. The grinding operation of cereals is most often done in mills with fluted or smooth rollers, while the sifting operation is most often done in a flat sieve compartment. The efficiency of both operations is influenced by a multitude of physical or technological factors such as (Constantin et al., 2014, KeShun Liu, 2009, Campbell et al., 2012, Karimi et al. 2009, Dal-Pastro et al., 2016): the hardness and size of the seeds, the characteristics of the grinding machines, the kinematic regime of the screening machines, the size and the shape of the particles, the relative movement of the particles on the separation surfaces, the characteristics of the screening surface, the amount of material feeding the screen surface, etc. These factors, if are not properly analysed, can influence negatively the effectiveness of the above mentioned operations.

Moreover, all these factors must be taken into account in the laboratory analyses of the processing plant, because the results of these analyses should impose the working regime of the equipment from process streams. Thus, in recent years, the screening operation, in particular, was in the attention of researchers in the country and abroad.

It is very good to know that the main analysis from which the dimensional characteristics of the screening surfaces can be accurately determined is particle size analysis. Thus, it can be said that this analysis is not only done in the food industry, as well as in the pharmaceutical industry (Hickey and Giovagnoli, 2018), cement industry (Siler et al., 2016) and in all industries involving granular and powdery materials. Therefore, it can be said that the particle size analysis is an important analysis. The way it is done influences the final results and therefore the conclusions drawn from the analysis of the results. The paper presents comparatively the results of several particle size analyses performed with two sieves classifiers with different operating regime.

MATERIAL AND METHODS

The samples analysed were two varieties of Romanian wheat (Glosa and Rapsodia) and two varieties of Romanian corn (Olt and Favorit) harvested in 2017 year.

The GLOSA wheat variety was obtained by a complex hybrid combination. The average height of the plant is 85-95 cm, being similar or slightly superior to that of the Flamura 85 and Fundulea 4 wheat varieties.

Wheatear is white, arista, of cylindrical shape and has a medium density. The seeds are of medium size, of elongated shape, have reddish colour and, under normal conditions of culture, have a mass of 1000 grains of 42-43 g and a hectolitric mass of 76-79 kg/hl (according to Fundulea INCDA). The Glosa variety is a precocious variety and has good resistance to fall, is resistant to wintering, drought and heat, and has a good resistance to sprouting. The Glosa variety has medium resistance to brown rust and is resistant to mildew and present yellow rust breeds. Production growth was mainly due to its ability to form more frequent wheat fields. Glosa variety quality is characterized by strong gluten, with a sedimentation index similar to Dropia varieties.

The Rhapsody variety has the bush in oblique position to a tilt angle with a horizontal close to 0^o, in the twinning phase. The flag leaf has the semi-applied position after the blossoming phase. The leaves are medium in length and width and are covered with a waxy layer not to intense, in the second part of the grain filling period. The average plant height is between 95 and 105 cm, being the same height as the Dropia and Flamura 85 control varieties. The wheatear is white, semi-dense, arista, of pyramid shape. The seeds are of medium size, of elongated form, red in color and have a mass of 1.000 grains of 42-45 g and a hectoliter mass of 77-79 kg/hl under normal conditions of culture (according to Fundulea INCDA). The Rapsodia variety is an early variety, having a vegetation period similar to the Dropia and Flamura 85 witnesses, with good resistance to fall, wintering, drought and heat. The Rapsodia variety is an early variety, having a vegetation period similar to the Dropia and Flamura 85 witnesses, with good resistance to fall, wintering, drought and heat. It is resistant to rust brown and medium resistant to current yellow rust and mildew races. It has a medium level of fusariosis resistance and a medium level of resistance to sprouting.

The Favorit corn variety is a medium-sized to high variety: 226-257 cm, middle corn cob insert: 66-87cm and total leaf / plant: 13. The corn cob is cylindrical, the average length of 18-19 cm, 18-20 rows of seeds/ corn cob; the seed is of dentate type, yellow-yellow light colour. It has good resistance to falling and breaking, at low temperatures during the first part of the vegetation period and to the occurrence and medium resistance to drought (according to Fundulea INCDA).

The Olt corn variety is a semi-late maize hybrid, very popular in Romania, especially in the south-east and west of the country, from the 4AGRO range, with the FAO 430 group (matured in 135-138 days), presenting a vigorous plant with big corn cob and dentate. The total height is about 245 cm, it does not sprout and forms a single ear. The corn cob has about 16 rows of yellow seeds. Grain production is about 13,000 kg/ha in non-irrigated and about 15,000 kg/ha in irrigated. Resistant to drought, heat, fusariosis of the cob and stalk, helmitosporiosis, fall and breakage of the strains at maturity (according to INCDA Fundulea).

Samples were grinded using a laboratory mill model Sadkiewicz. After grinding, the samples were homogenized and divided into 100 gram samples. They were sifted on a set of 5 overlapped sieves with different apertures (Table 1) mounted on two classifiers: ANALYSETTE 3 SPARTAN, trained in a vibratory motion at a 2 mm amplitude for 3 minutes and VIPO, trained in a motion of circular translation at a speed of 120 rpm for 3 minutes. Pankratov in 2016 and Constantin in 2014, presents in detail the working methodology for particle size analysis, also used in this paper. It is noted that the same sample analysed was used the same set of sieves, mounted on the two classifiers.

Based on the results obtained in the particle size analyses performed with the sieves classifier, have been tested by non-linear regression analysis in Microcal Origin vers. 7.0, correlation of experimental data with Rosin-Rammler, Schuhman, Gauss, and log-normal distribution laws for the cumulative percentage of material separated through the openings of the sieve's classifier.

The four types of particle size distribution laws applied in the regression analysis are based on the mathematical statistical method of small particles for grinded biological materials, (Pruteanu et al., 2018).

Schuhman distribution law is defined by the relation:

$$T(x) = 100 \cdot \left(\frac{x}{\alpha}\right)^{\beta} \tag{1}$$

where *T(x)* – is the percent mass of fraction with particles smaller than x (passed through the sieve of x size); *x* – is the size of the sieve holes through which particles have passed; α – particle size module of the product (the size of the sieve holes through which all the sample particles, theoretically, pass 100%); β – the distribution module.

Rosin – Rammler distribution law is defined by the relation:

$$T(x) = 100 \cdot (1 - e^{-\alpha \cdot x^{\beta}}) \tag{2}$$

where *T(x)* and *x* have the meaning of relation (1), and α and β are the own coefficients of the grinded material. The relation (2) as well as the relation (1), represents the cumulative distribution law of the percentage fraction of the fraction separated by the x sized holes of the sieves, depending on x.

Gauss distribution law (normal) is defined by the relation:

$$T(x) = y_0 + A \cdot e^{\frac{(x-x_c)^2}{2 \cdot w^2}} \tag{3}$$

where *T(x)* and *x* have the meaning of relation (1), xc, y_0, A and w are the own coefficients of material.

Log-normal distribution is defined by the relation:

$$T(x) = \frac{\alpha}{x} \cdot e^{-\beta \cdot (\ln x - \gamma)^{\beta}} \tag{4}$$

where *T(x)* and *x* have the meaning of relation (1) and, α, β and γ are the own coefficients of the grinded material.

According to the specialty literature, the fineness of grist is appreciated by the mean diameter d_m of the grinded particles. This was determinate by the particle size analysis of the mass of the grinded material, calculated as the weighted average of the mean sizes of the material fractions obtained by sieving with classification devices:

$$d_m = \frac{\sum p_i \cdot d_i}{\sum p_i}, \text{ [mm]} \tag{5}$$

where: p_i is the percentage of material on the *i* classifier sieve ($i = 0, 1, 2, \ldots, 5$); $\Sigma p_i = 100$ – the percentage of material on the sieves; d_i – the mean particle size of each intermediate fraction, considered as the arithmetic mean of the size of the hole sieve corresponding to the fraction $d_i = (l_i + l_{i+1})/2$. For the upper sieve of the classifier it is theoretically assumed that there would still be a sieve with the sides of the holes of ($\sqrt{2} \cdot l_5$).

RESULTS AND DISCUSSION

The dimensions of the sieves used for the experiments and the weight of the material fractions on each sieve for the separated material are presented for the wheat samples in Table 1 and for the corn samples in Table 2.

The correlation with the experimental data for the previously proposed distribution functions is given by the correlation coefficient R^2, presented in Table 3 together with the equation coefficients, which depend on the grinding conditions, that is to say they depend on the grist fineness and the differential speed of the milling rolls.

Table 1 Values of the weight p_i (%) of the grist refused by the classifier sieves, of the percentage weights T (%) of the fraction with smaller particles than the classifier sieves, x (mm) side of the sieve holes used for the particle size analysis and the average diameter values for the wheat samples analysed

x [mm]	RAPSODIA Wheat => VIPO		RAPSODIA Wheat => Analysette		GLOSA Wheat => VIPO		GLOSA Wheat => Analysette	
	p [%]	T [%]	p [%]	T [%]	p [%]	T [%]	p [%]	T [%]
0.00	15.0	0.0	32.0	0.0	4.5	0.0	27.0	0.0
0.25	18.0	15.0	19.3	32.0	19.4	4.5	18.0	27.0
0.35	18.7	33.0	19.3	51.3	32.2	23.9	27.8	45.0
0.50	14.5	51.7	8.9	70.6	16.9	56.1	7.0	72.8
0.63	21.1	66.2	12.1	79.5	17.0	73.0	10.7	79.8
1.00	12.7	87.3	8.4	91.6	10.0	90.0	9.5	90.5
	Mean diameter = 0.56 mm		Mean diameter = 0.43 mm		Mean diameter = 0.56 mm		Mean diameter = 0.45 mm	

Highlighting the differences between size distribution of grinded particles was done using the same sieve on the sieve shaker for all the materials used in the experiment, the same for the two types of sieve shakers. It should be noted, still, that on the upper sieve of sieve shaker different percentages of material were obtained, which means that not all the materials have been grinded the same way, especially because of their different physical and mechanical characteristics.

Table 2 Values of the weight p_i (%) of the grist refused by the classifier sieves, of the percentage weights T (%) of the fraction with smaller particles than the classifier sieves, x (mm) side of the sieve holes used for the particle size analysis and the average diameter values for the corn samples analysed

x [mm]	FAVORIT Corn => VIPO		x [mm]	FAVORIT Corn => ANALYSETTE		x [mm]	OLT Corn => VIPO		x [mm]	OLT Corn => ANALYSETTE	
	p [%]	T [%]		p [%]	T [%]		p [%]	T [%]		p [%]	T [%]
0.00	18.3	0.0	0.00	33.7	0.0	0.00	11.3	0.0	0.00	19.7	0.0
1.00	20.9	18.3	1.00	20.7	33.7	0.80	14.0	11.3	0.80	6.7	19.7
1.40	26.7	39.2	1.40	14.9	54.4	1.00	31.5	25.3	1.00	33.4	26.4
2.00	14.2	65.9	2.00	10.6	69.3	1.60	34.0	56.8	1.60	24.5	59.8
2.50	12.3	80.1	2.50	11.6	79.9	2.50	6.0	90.8	2.50	8.8	84.3
4.00	7.6	92.4	4.00	8.5	91.5	3.15	3.2	96.8	3.15	6.9	93.1
Mean diameter [mm]		1.88	Mean diameter [mm]		1.70	Mean diameter [mm]		1.57	Mean diameter [mm]		1.59

Table 3 Values of α and β coefficients from relations 1, 2 and 4 and y_0, x_c, w and A from relation 3, as well as values R^2 coefficient of the four relations

Cumulative distribution law	Coefficients	Rapsodia Wheat - Vipo	Rapsodia Wheat - Analysette	Glosa Wheat - Vipo	Glosa Wheat - Analysette	Favorit Corn - Vipo	Favorit Corn - Analysette	Olt Corn - Vipo	Olt Corn - Analysette
Rosin-Rammler	α	0.181	0.102	0.101	0.092	1.827	1.093	1.418	1.213
	β	-1.739	-1.758	-2.510	-1.948	-2.181	-1.694	-2.437	-2.034
	R^2	0.995	0.999	0.999	0.995	0.997	0.998	0.987	0.991
Schuhman	α	1.098	1.048	1.022	1.034	3.995	4.241	3.019	3.187
	β	0.953	0.61395	1.098	0.674	0.821	0.584	1.128	0.969
	R^2	0.966	0.963	0.899	0.935	0.925	0.967	0.957	0.969
Log-normal	α	$1.7\cdot10^{-15}$	$5.7\cdot10^{-14}$	$3.4\cdot10^{-19}$	$1.2\cdot10^{-15}$	$6.3\cdot10^{-15}$	$1.6\cdot10^{-11}$	$1.4\cdot10^{-15}$	$4.6\cdot10^{-11}$
	β	-0.025	-0.019	-0.024	-0.018	-0.022	-0.021	-0.025	-0.034
	γ	-38.898	-42.872	-44.359	-45.867	-40.537	-36.925	-42.314	-28.059
	R^2	0.963	0.960	0.895	0.931	0.921	0.964	0.954	0.967
Gauss	y_0	-11.598	-71.852	-5.388	-27.640	-11.458	-114.11	-8.742	-15.917
	x_c	0.930	0.894	0.854	0.851	3.406	3.629	2.886	2.978
	w	0.440	0.690	0.311	0.487	1.560	3.319	1.228	1.489
	A	99.964	165.133	106.040	123.308	111.337	206.725	107.05	108.641
	R^2	0.995	0.996	0.986	0.991	0.994	0.995	0.993	0.993

In the graphs from Figure 1 it can be seen that the allure and the character of the regression curves are in correlation with the experimental results obtained. They are either concave or convex or with a central inflection point, depending on the amount of material collected on each sieve of classifier. Also, it can be seen that the particle size distribution curves have different allure, depending on the type of sieve classifier used in particle size analysis (the type of movement the sieve classifier had it).

Analysing the data from Tables 1 and 2 it can be seen that the grist wheat was better sifted on the vibratory movement classifier (ANALYSETTE 3 SPARTAN), while the grist corn sifted better on the circular translational classifier (VIPO). Also, if the wheat samples of the two varieties (Rapsodia and Glosa) were used the same sieves, chosen according to the particle size analysis methodology, for the corn samples were used different sieves (4 mm, 2.5 mm, 2 mm, 1,4 mm and 1 mm for Favorit and 3,15 mm, 2,5 mm, 1,6 mm, 1 mm and 0,8 mm for Olt variety). It can be concluded that the wheat variety Olt was grinded in smaller particles than Favorit wheat under the same grinding conditions.

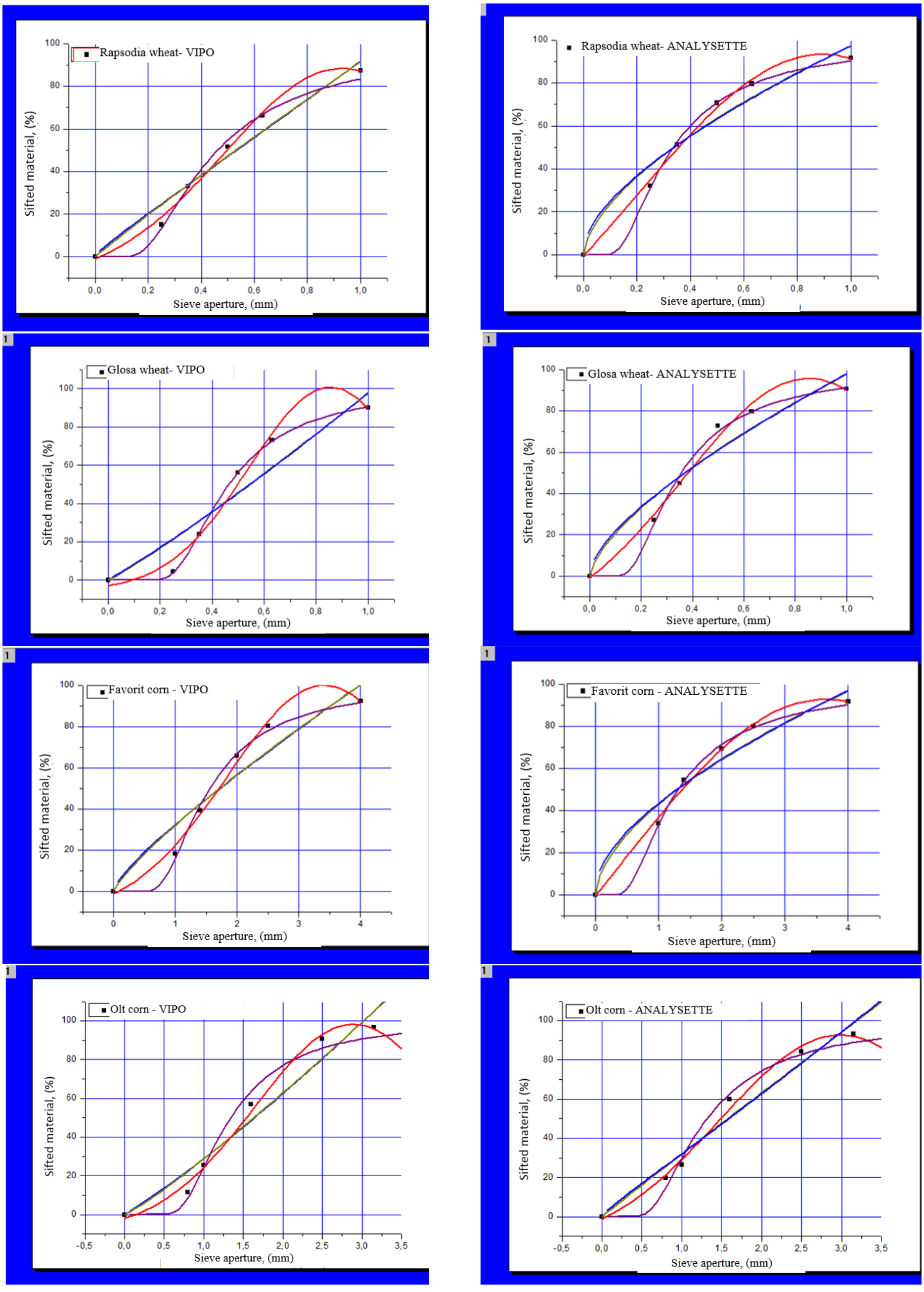

Figure 1 Cumulative distribution curves given by the relations (1 - 4) and the experimental points for the wheat and corn fraction analysed.

Gauss Log-normal Schuhman Rosin-Rammler

Different resistance to grinding of the seeds used in the experiment did they have a different particle size distribution, and at the particle size analysis this may be noticeable by the different amounts of material on the sieve shaker sieves. It can be observed, that the largest amount of material remained on the middle of the sieve columns. Cumulative distribution of the material on the sieve shows an increasing weight for all four equations used in the regression analysis, but the best correlation with experimental data is presented by Rosin-Rammler distribution function, followed by the Gauss distribution function, as can be seen from the analysis of the graphs and the values of the correlation coefficient R^2, which presents values between 0.987-0.999 for the first function, respectively between 0.986-0.996 for the second function. Interestingly, the two sieve shakers used in particle size analysis, with different movement characteristics, also have different sieving characteristics, better sifting being carried out on the sieve shaker with vibratory movement (ANALYSETTE).

Another hint that screening was performed more fully on the vibratory motion sieve shaker, is even the average particle diameter. Although it was sought through experimentation methodology that the samples have a similar degree of uniformity, it can be seen (from Tables 1 and 2) that the average diameters are different. In the case of wheat, for grist fractions sifted with VIPO sieve shaker, the mean diameters are 0.56 mm for both samples (Rhapsody and Glosa), and those sifted with ANALYSETTE sieve shaker, average diameters are 0.43 mm for Rhapsody and 0.45 mm for Glosa. This leads us to the conclusion that the sifting was performed more completely in the case of the sieve shaker with vibratory movement, since the amount of refusal from the higher sieves has decreased, growing on the lower ones (with the lower aperture).

The hypothesis can also be applied to Favorit corn samples. After sifting with sieve shaker that has circular translation motion, the average diameter was 1.88 mm, while for the sieve shaker with vibratory motion, the average diameter was 1.70 mm. But the exception of this hypothesis is the grist fractions obtained from Olt corn variety, which seems to better sifting on the sieve shaker with circular translation motion (the average diameter being 1.57 mm) than one with vibratory movement (the average diameter being 1.59 mm).

CONCLUSIONS

The granulometric distribution laws, used in the paper, show a very good correlation with the experimental data regarding the particle sizes of the fractions of the Romanian wheat and corn varieties. Knowing the average size and distribution by size, as well as the other physical characteristics of the particles of the milling fractions, are also requirements for choosing the sifting surfaces of the specific machinery from the milling or even bakery technological flows.

As a recommendation for laboratory workers in bakery or industrial milling laboratories: at sample of screening analysis it is necessary to use classifiers with sieves of the same type of movement and the same kinematic regime as the machines that make sifting and sorting on the technological flow. Otherwise, the results of the granulometric analysis may be inconclusive.

The data presented may be important in general for all specialists and workers in the field of cereal milling, and in particular for laboratory workers in milling and bakery units.

ACKNOWLEDGEMENTS

The work has been funded by the Institutional Development Fund of the Ministry of National Education through the Financial Agreement CNFIS-FDI 2017-0086.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

NUTS VARIETIES INFLUENCE ON WALNUT BREAKING AND PEELING PROCESS

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SUMMARY

One important problem in Romania is how to optimize the valorization the nuts, in conditions of large number of small orchards (less than 3 ha), scattered, difficult to find a uniform system of collection. A solution could be a small breaking and peeling machine, cheap and reliable. The paper, a consequence of requesting some owners of walnut orchards, presents the results of experiments with a new active organ (cracking rollers with a synchronous edge), focused on nuts' shear and breakage. It studied the influences of the variety of walnuts (with different sizes of fruits derived from the same variety), on the breaking and peeling process. The experimental research tested 5 Romanian varieties, using 30 different walnuts variety, in the same temperature and humidity conditions. Each nut's dimensions were measured on three rectangular axis and statistical parameter were determined (average, geometric mean, Standard Deviation etc.). After breaking process, the number of broken parts was accounted and statistical analyzed using Microsoft Excel 2016. It was considered that relation between the number of nut pieces after breaking process and initial dimensions' average (arithmetic, geometric and square), could qualify the process. The values of arithmetic (A), geometric (GA), and square (SQA) average of nuts dimensions are very closely (e.g. for one variety, A=30.68 and SQA=30.64). One conclusion was that larger walnuts are easier to break, and the number of pieces in which they break, are lower compared to smaller walnuts. The results will be integrated into a larger study completed with influences of conditions temperature, humidity, as well as walnut variety.

Keywords: *walnuts, cracking walnut, shell removal, dimensions*

INTRODUCTION

Since Roman times, the nut tree (*J.regia* L.) has been grown in gardens and orchards in Moldova and Romania. Today walnut cultivation is a traditional branch for Romanian agriculture, benefiting from a moderate climate, with deep solid opportunities and fertile lands to maximize the world's most valuable varieties of selection (Șerban, 2016). At global level, walnut has a special role in the wood industry and in fruit production, both inside the country and its integration into the world economy (FAOSTAT, 2011; Cristopoulous and Tsantili, 2011; Ojolo et al, 2015; Jenac et al, 2013 etc.).

In fact, since the last 20 years, each year comes became a new record. The walnut industry determines an urgent need to improve the efficiency of post-harvest processing, in particular drying, cracking and peeling operations. A lot of researches and engineers tried to develop new technical systems and applications for optimize and collaborate the farms dimensions, consumer's necessities and investments' possibilities (Sharifian et al, 2008; Sharifian and Derafshi, 2008; Marey et al, 2017; Ojolo et al, 2015; Mingzheng et al, 2014; Nahal et al, 2013; Atungulu et al, 2013; Ghafari et al., 2011).

One important topic of study regarding concept, designing and testing a new equipment for walnut cracking and peeling according with farmers' needs, must mandatory includes the analyze of the walnuts' behavior during cracking and peeling process. There are references regarding influences of raw materials properties as moisture, chemical properties, variety etc., different other studies that results can be transferred to application for cracking of walnuts (Shahbazi, 2013; Shahbazi, 2014; Vivian, 2017; Altuntas and Erkol, 2011; Altuntas and Ozkan, 2008; Bernik et al, 2010; Cerit et al, 2017; Chegini and Makarichian, 2014; Khir et al, 2014; Khir et al, 2013; Koyuncu et al, 2004; Koyuncu et al, 2003; Makarichian and Chegini, 2014; Tucu et al, 2006). Almost such studies consider as more important the quality of resulted broken parts.

In this study was examined the relation between the size of the walnuts and the breakage process using the special rollers with a synchronous edge. The main objective was to see if there is an influence of the size and variety of the walnut on the burst mode, evaluated by the number of resulting parts and the visual examination.

MATERIALS AND METHODS

Five different varieties of Romanian walnuts had been selected for the experiment (Sibisel 252 (sample 1), Germisara (sample 2), Claudia (sample 3), Ciprian (sample 4) and Valrex (sample 5)). From each variety, 30 different walnuts (randomly selected), were taken for burst tests (testing panel can be seen in figure 1). For insuring the experiments' control, each nuts was registered by numbering. Algorithm of the methodology is presented in figure 2.

Figure 1 Testing panel

For insuring the same pressure and more precision at measuring the dimensions, a micrometer was used, each walnut being measured in three rectangular directions: the length (L), the maximum diameter (D) measured in the largest section, and the diameter on rectangular direction, (d) (see figure 3). Also, walnuts were weighed individually for each variety, with 0.05 g precision (see figure 4).

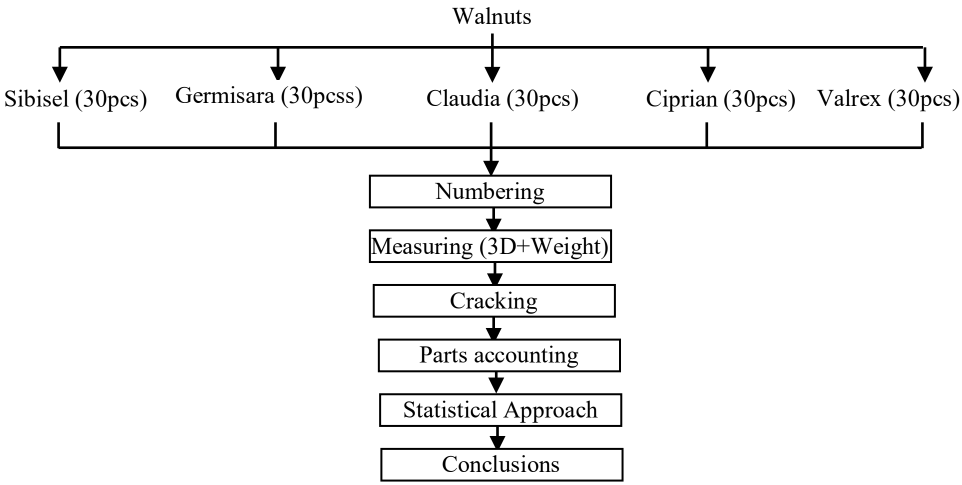

Figure 2 Methodology of the study

Figure 3 Measurement of the walnuts' dimensions

After accounting, the values obtained were registered into a table, where the average, geometric average, square average, mean value, and standard deviation were calculated.

In the next item of the experiment, the walnuts were broken by the equipment designed for cracking, and the numbers of broken parts were accounted.

Three equivalent dimensions were calculated:

Average, A:

$$A = \frac{L+D+d}{3} \quad (1)$$

Geometric average, GA:

$$GA = \sqrt{\frac{L*D+D*d+d*L}{3}} \quad (2)$$

Square average, SQA:

$$SQA = \sqrt[3]{L*D*d} \quad (3)$$

The equipment designed for cracking of the walnuts is presented in Figure 4, and the significance of parts are: 1-Funnel; 2-Bearings; 3-Rollers; 4-Box collecting breakouts (the pieces).

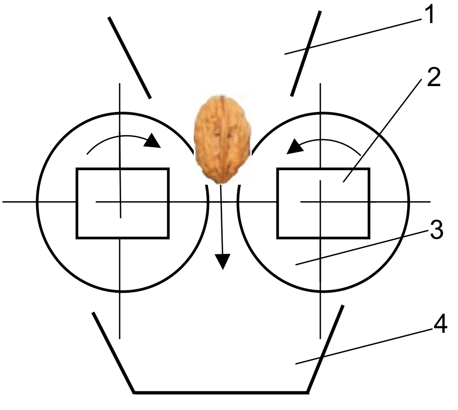

Figure 4 Functional schema of the equipment designed for cracking of the walnuts

A statistical analyze, made by Microsoft Excel 2016, consisting in calculation of standard deviation (Stdev), average (Avg) and variance (Var), for each group (L, D and d), of each 30 measurement was made.

After statistical analyze, were represented graphically the dependences between dimensions and number of parts and weight and number of parts, for each variety. Also, the optimum curves and R^2 were calculated for each variety and dependence.

In the last phase, based on dependences, conclusions were drawn.

RESULTS

Table 1 presents the final results regarding measurement of walnuts and broken parts, and statistical processing from all samples, according with presented significations.

Table 1 Walnuts and broken parts characteristics

	Sample 1			Sample 2			Sample 3		
	Avg	Stdev	Var	Avg	Stdev	Var	Avg	Stdev	Var
L, [mm]	32.80	0.91	0.86	40.36	2.21	5.06	35.58	1.00	1.04
d, [mm]	28.95	0.97	0.98	29.61	0.71	0.52	29.87	0.98	1.00
D, [mm]	30.30	1.09	1.22	29.76	0.63	0.41	31.77	1.00	1.04
Weight, [g]	10.28	1.07	1.19	9.86	0.86	0.77	11.81	0.87	0.78
A, [mm]	30.68	0.99	1.02	33.25	1.18	2.00	32.41	1.00	1.03
AG, [mm]	30,66	0.57	0.59	33.05	0.62	0.74	32.36	0.58	0.59
SQA, [mm]	30.64	0.99	1.01	32.89	1.00	1.03	32.32	1.00	1.03
Pieces	11	3	11	14	4	13	15	4	15

	Sample 4			Sample 5		
	Avg	Stdev	Var	Avg	Stdev	Var
L, [mm]	41.98	1.59	2.61	32.16	2.26	5.30
d, [mm]	33.28	1.63	2.74	29.11	1.84	3.49
D, [mm]	32.02	1.46	2.21	29.96	1.98	4.05
Weight, [g]	11.19	1.16	1.39	10.25	2.23	5.15
A, [mm]	35.76	1.56	2.52	30.41	2.03	4.28
AG, [mm]	35.62	0.90	1.45	30.40	1.17	2.45
SQA, [mm]	35.50	1.56	2.51	30.38	2.02	4.22
Pieces	14	3	9	10	2	5

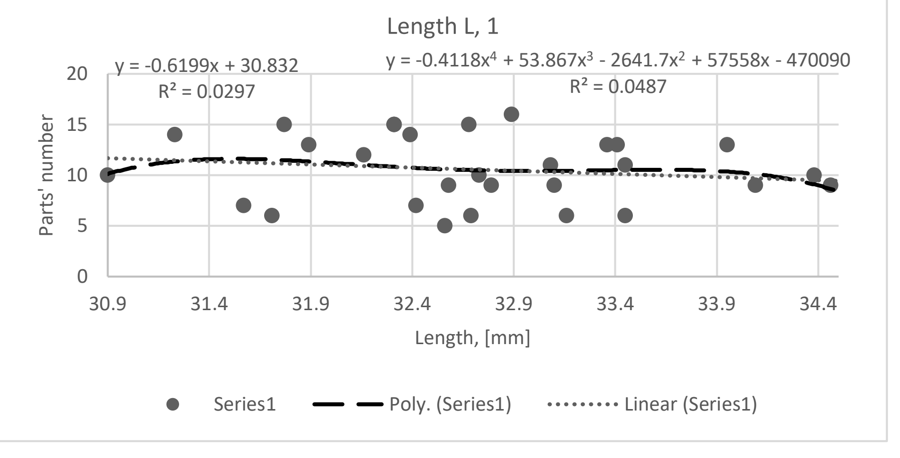

Figure 5 The influence of nuts length on the number of pieces for sample 1

The influences of length L, diameter D and d and nuts weight on the number of resulted broken o pieces are presented in figures 5-8.

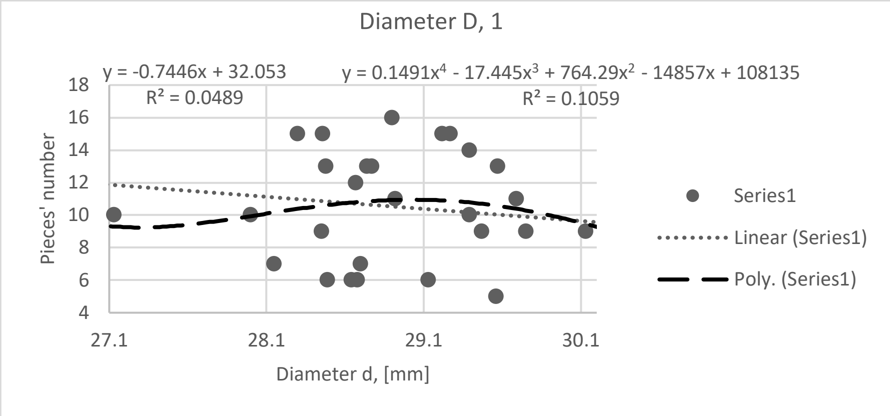

Figure 6 The influence of nuts diameter D on the number of pieces for sample 1

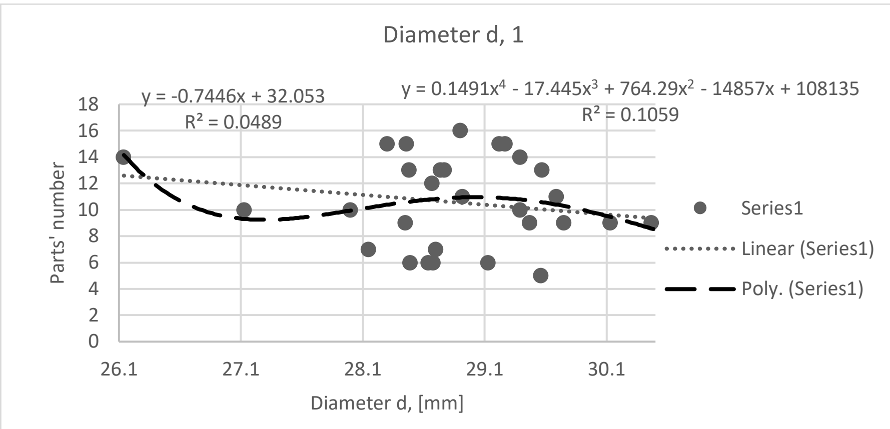

Figure 7 The influence of nuts diameter d on the number of pieces for sample 1

The optimum function for each dependence was established by regression. Calculus suggest a six-degree polynomial function, but is not professional. For study was used a 4th degree polynomial functions, whose detailed relationships can be seen on the picture. Also, the corresponding values of R^2 are on the image. Also, were represented the linear trends and corresponding values of R^2.

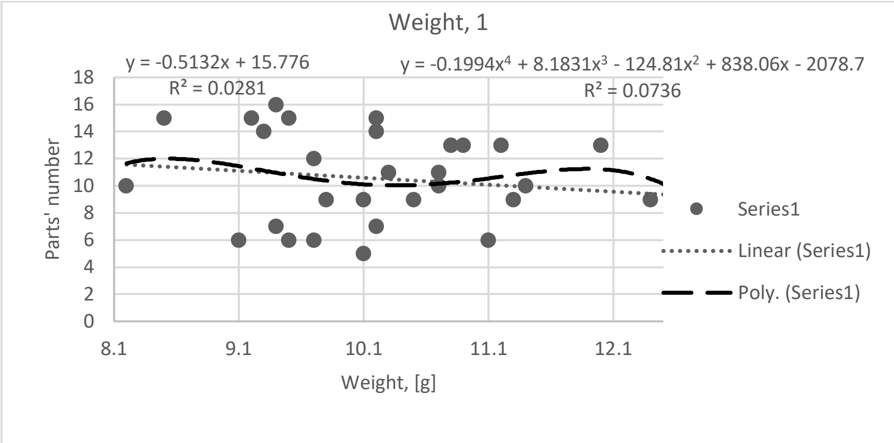

Figure 8 The influence of nuts weight on the number of pieces for sample 1

Such analysis was made for each variety, and the principals results were synthesized in table 2. The trend curves were split in five sections: Down (Dw), Slow Down (SD), Constant (H), Slow Growth (SG), Growth (G).

Table 2 Principals results after regression analysis by a polynomial function

	Sample 1		Sample 2		Sample 3		Sample 4		Sample 5	
	Trend	R^2	Trend	R^2	Trend	R^2	Trend	R^2	Trend	R^2
L, [mm]	SD	0,09	G	0,23	H	0,24	D	0,26	D	0,43
D, [mm]	SD	0,17	H	0,33	SG	0,17	D	0,06	D	0,34
d, [mm]	D	0,11	D	0,16	SG	0,17	D	0,11	D	0,24
Weight, [g]	D	0,068	W	0,13	H	0,2	SD	0,58	D	0,33

The results shown an acceptable reproducibility for sample 5 (variety Valrex), and the lowest reproducibility for varieties 1 and 3 (Sibisel and Claudia), that means high variability for the last two varieties. During the study was not identified similarly researches. Also, it will be necessary to correlate the distance between rollers and the dimensions of the walnuts.

CONCLUSIONS

The conception of a nuts' breaking machine must consider many important parameters in designing process: geometrical (rollers diameters and profile, distance between rollers etc.), mechanical (rupture force, rupture strain, required power etc.), functional (rotation speed, productivity, adjusting possibilities etc.) and economical (costs of investments, maintenance, repair and replacement etc.).

According to results, one conclusion was that larger walnuts are easier to break, and the number of pieces in which they break, are lower compared to smaller walnuts, but with poor probability.

The results of present research show the importance of breaking process for quality, because bursting directly affects core damage and the influences of nuts' variability (differences of dimensions and weight).

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

MECHANIZING THE GARLIC BULBS DETACHING INTO CLOVES

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SUMMARY

The necessity to mechanize the work for detaching garlic bulbs is justified through the reduction of labour force, as well as by the fact that the operation can be performed in a shorter time. Consequently, a study on the manner how the active bodies ensure bulbs detachment into cloves in normal conditions has been realized. The kinematics of the movement of the two rollers is chosen so that the rollers operate with rotation directions opposite to each other. The paper presents theoretical considerations of 2 hypotheses of clove crush by means of two rollers. For establishing the adequate type of active bodies for detaching the garlic bulb into cloves, a series of experiments have been conducted on both varieties, the spring respectively the autumn one. Opposite directions were chosen because, this way, the cloves detached from the bulb by the extremities of rubber rings will be eliminated in the exterior. In order to prevent harming or crushing the cloves during the detachment process, the diameter of rollers (namely the exterior diameter of rubber rings) is expected to be as small as possible, and the peripheral speeds need to be adequately chosen, elements that will be established during the tests performed on the experimental model.

Keywords: *bulbs, cloves, active bodies, garlic, optimization*

INTRODUCTION

Garlic is an annual vegetable crop that behaves like an annual plant. Garlic bulb is formed of multiple cloves situated tightly on the garlic stem. Garlic bulb is round or flattened in shape having longitudinal grooves representing cloves separation limits (Chang et al., 1986, Yamazaki and Okuno, 2008). On the inferior part of the bulb, multiple thin, fasciculate roots are found, with the help of which the bulb is fixed in the ground and extracts nutritional substances. (Gül et al., 2018). The plant is 30-35 cm high, while the floral stems reach up 100 cm (Chang et al., 1986). Garlic bulbs have elongated shape, with the outer part bulging and the interior one hollower. Garlic bulbs contain 64.4% water, 9.76% albumins, 0.6% fat, 23.03% sugar, 0.77% cellulose and 1.44% ash (Son et al., 2012).

In the process of detaching the garlic bulb into cloves, a series of agrotechnical requirements in which the seeding material (the cloves) needs to fit in arise on one side, and on the other, the agrotechnical requirements to which the experimental model needs to answer. (Samavatean et al., 2011).

The clove for seeding has to: be healthy, have no lesions, have no total or partial ruptures or detachments of tunics, to be single for planting, have the same size in order to avoid uneven development in the crop after planting (Channabasamma et al., 2015, Mudgal and Sahay, 2009, Özkan, and Aydin, 2016, Sati and Lopez, 1994).

The machine for detaching garlic bulbs into cloves has to satisfy the following agrotechnical requirements: the active bodies of the devices have to achieve a complete separation of the bulb into cloves without any of them remaining bonded; peripheral speeds of the rollers to be different and their diameter to be as small as possible thus removing the danger of crushing cloves (James et al., 2015); active bodies to operate in such a manner so that no harm is caused to the cloves (Rahim and Fordman, 1990); during the separation process to eliminate impurities resulted thus obtaining a clean seeding material (Son and Lee, 2010); simultaneously with separation to also clean and sort the cloves on 2-3 size categories.

MATERIALS AND METHODS

For establishing the adequate type of active bodies for detaching the garlic bulb into cloves, a series of experiments were conducted on both varieties, the spring respectively the autumn one. For the experimental researches, the following parameters were determined: the force of detaching cloves from the bulb; the adequate mesh size for sorting cloves before planting. When determining this force of detaching cloves from the bulb, a device formed of a metallic frame, two ragged rubber plates, and a dynamometric scale was used, resulting the forces shown in table 1.

Table 1 Forces for detaching cloves from the bulb

Product name	Value of the force in the moment of detaching the cloves (N)			
	Rep. 1	Rep. 2	Rep. 3	Average
Spring garlic	9.8	9.0	8.7	9.15
Autumn garlic	6.3	7.8	7.5	7.2

For choosing the adequate mesh size for sorting cloves before planting, the diameter and length of garlic cloves were measured, after they were manually detached. It was concluded that it is necessary to have two rows of sieves with different mesh sizes. This was due to the fact that the marginal cloves are always larger than those in the interior of the bulb for all varieties, both for the spring and the autumn one. In was determined that the first sieve of the shaking and pre-sorting system has to be equipped with meshes with a 10 mm diameter, while the second one needs meshes of 7 mm in diameter.

In order to achieve an experimental model of machine that fulfils the above stated requirements, four versions of active bodies were achieved, in order to perform the detachment of garlic bulbs into cloves. These versions had, as a start basis, the theory of dehusking corn cobs. The base operation in the working process of separation rollers is constituted by detaching cloves from the bulbs and passing them through the space between the rollers.

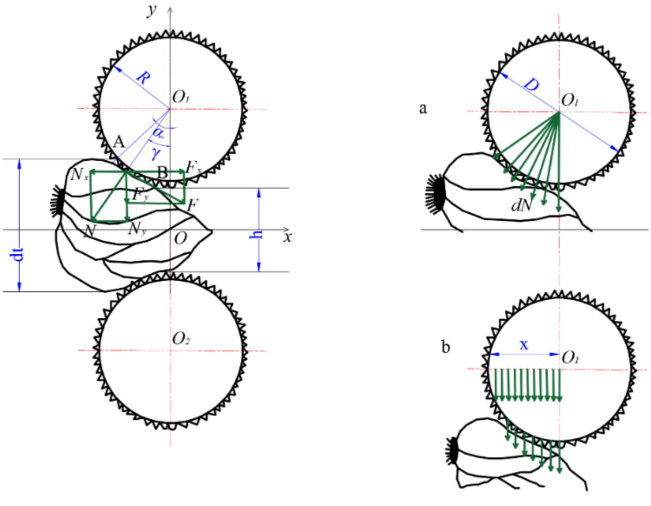

Figure 1 Forces acting on the garlic bulb during the process of detaching cloves

In the process of detaching the garlic bulb, a series of parameters to be taken into consideration during calculations arise. First, an absolute compression D_h appears, compression that causes the bulb to open. It is given by the relation:

$$D_h = d_t - h \tag{1}$$

where:
D_h – absolute compression (mm);
d_t – bulb diameter (mm);
h – distance between rollers (mm).

Another parameter taken into consideration is the contact spring between the bulb and the separation rollers. This is given by the relation:

$$l_c = 2\pi R \frac{\alpha_0}{360} = R \times \alpha_0 \tag{2}$$

where:
l_c – contact spring (mm);
R – radius of separation rollers (mm);
α_0 – clove attachment angle (°).

Another indispensable parameter is the attachment angle of the clove on the bulb, calculated with the relation:

$$\alpha_o = \sqrt{\frac{2(d_t - h)}{D}} = \sqrt{\frac{d_t - h}{R}} = \sqrt{\frac{D_h}{R}} \tag{3}$$

where:

D – rollers diameter, mm.

The above parameters were established using geometrical relations that can be written by analysing figure 1. The force of pressing the bulb between the rollers was determined taking into account the following: the pressing forces are oriented normally on the roller's surface and have an uneven contact distribution (fig, 1.a); the pressing forces are normal on the axis of the stem and are distributed according to the projection of the contact spring (Figure 1.b); the force of pressing the bulb between the rollers.

Considering the width of the contact trace b and the specific pressure p as constant, by integrating elemental forces between the limits 0 and α_0, the components of the pressing force N were obtained, namely N_x and N_y.

$$N_x = \int_0^{\alpha_0} dN_x = \int_0^{\alpha_0} p \cdot R \cdot b \cdot \sin\alpha \cdot d\alpha = p \cdot R \cdot b \cdot (1 - \cos\alpha_0) \tag{4}$$

$$N_y = \int_0^{\alpha_0} dN_y = \int_0^{\alpha_0} p \cdot R \cdot b \cdot \cos\alpha \cdot d\alpha = p \cdot R \cdot b \cdot \sin\alpha_0 \tag{5}$$

$$N = \sqrt{N_x^{\ 2} + N_y^{\ 2}} = pRb\sqrt{2(1 - \cos\alpha_o)} \tag{6}$$

The angle formed by the resultant of the normal pressing N with the line connecting the centre of the two rollers is given by the relation:

$$tg\gamma = \frac{N_x}{N_y} = \frac{1 - \cos\alpha_0}{\sin\alpha_0} = tg\frac{\alpha_0}{2} \tag{7}$$

The friction force F between bulbs and rollers is:

$$F = f \cdot N = f \cdot p \cdot R \cdot b \cdot \sqrt{2(1 - \cos\alpha_0)} \tag{8}$$

Considering that the law of variation of width b depends on the angle α_0 and that in the case of the bulb compression phenomenon it has the value zero in point A and maximum in point B, we established that:

$$b_i = \pi \cdot R(\cos\alpha - \cos\alpha_0) \tag{9}$$

From the graphic analysis of the bulb deformation variation under the action of rollers, we found the following expression between the relative compression and vertical Q, of resultant N:

$$Q = N_y = \frac{c}{2}\left(\frac{d_t - h}{d_t}\right) \cdot k \tag{10}$$

where c and k are coefficients depending on bulb diameter d_r and roller diameter D. It results that:

$$N = \frac{Q}{\cos\gamma} = \frac{c}{2\cdot\cos\gamma}\left(\frac{d_t - h}{d_t}\right)\cdot k \tag{11}$$

In this case, friction force F is given by the relation:

$$F = f\cdot N = f\frac{c}{2\cdot\cos\gamma}\left(\frac{d_t - h}{d_t}\right)\cdot k \tag{12}$$

By applying V.P. Goriacikin's theory on the distribution and direction of normal pressing forces for a wheel rolling on the soil, it results that the pressure of the elementary strip of the contact area between bulb and rollers is:

$$dN = q\cdot b_i\cdot R^2\mu\frac{\cos\alpha}{\cos\alpha_0}\cdot d\alpha \tag{13}$$

Replacing value b_i given by relation 9 and integrating again between limits zero and α_0, the components of total bulb pressing between rollers are obtained in the form:

$$N_x = \pi\cdot q\cdot R^3\int_0^{\alpha_0}\left(\mu\frac{\cos\alpha}{\cos\alpha_0}\right)\cdot(\cos\alpha - \cos\alpha_0)\cdot\sin\alpha\cdot d\alpha \tag{14}$$

$$N_y = \pi\cdot q\cdot R^3\int_0^{\alpha_0}\left(\mu\frac{\cos\alpha}{\cos\alpha_0}\right)\cdot(\cos\alpha - \cos\alpha_0)\cdot\cos\alpha\cdot d\alpha \tag{15}$$

Using relations 14 and 15, after transformations, relation 16 is obtained which determines the value of the angle:

$$tg\gamma = \frac{N_x}{N_y} = \frac{0,75\cdot(1-\cos^3\alpha_0) - 2,25\cdot(\cos\alpha_0 - \cos^2\alpha_0)}{1-\cos\alpha_0\cdot\left[\frac{\alpha_0}{4} + \frac{\alpha_0^{\,3}}{6} + \frac{\alpha_0^{\,5}}{30} - \cos\alpha_0\cdot\left(\frac{\alpha_0}{2} + \frac{\alpha_0^{\,3}}{6}\right)\right]} \tag{16}$$

In the hypothesis of the uniform repartition of pressure on the roller's contact surface and taking into account value b_i given by relation 9, components N_x and N_y are obtained:

$$N_x = \int_0^{\alpha_0}\pi\cdot p\cdot R\cdot R\cdot(\cos\alpha - \cos\alpha_0)\cdot\sin\alpha\cdot d\alpha = \pi\cdot p\cdot R^2\cdot\frac{(1-\cos\alpha_0)^2}{2} \tag{17}$$

$$N_y = \int_0^{\alpha_0}\pi\cdot p\cdot R\cdot R\cdot(\cos\alpha - \cos\alpha_0)\cdot\cos\alpha\cdot d\alpha = \pi\cdot p\cdot R^2\cdot\frac{\alpha_0 - \sin\alpha_0\cos\alpha_0}{2} \tag{18}$$

Value of resultant N of angle y and force F are:

$$N = \sqrt{N_x^{\,2} + N_y^{\,2}} = \frac{\pi\cdot p\cdot R^2}{2}\cdot\sqrt{(1-\cos\alpha_0)^4 + (\alpha_0 - \sin\alpha_0\cos\alpha_0)^2} \tag{19}$$

$$tg\gamma = \frac{N_x}{N_y} = \frac{(1-\cos\alpha_0)^2}{\alpha_0 - \sin\alpha_0\cos\alpha_0} \tag{20}$$

$$F = f \cdot N = \frac{f \cdot \pi \cdot p \cdot R^2}{2} \cdot \sqrt{(1-\cos\alpha_0)^4 + (\alpha_0 - \sin\alpha_0\cos\alpha_0)^2} \tag{21}$$

The condition ensuring the possibility of pulling the clove between the rollers, as integral part of the bulb with the highest resistance to pulling, determines the rollers pulling capacity as well as the choice of minimum roller diameter. From the reaction of rollers to the cloves on the bulb, it results that:

$$N = \frac{P_{tr}}{2 \cdot \sin\alpha_{pn}} \tag{22}$$

where:
P_{tr} – force of pulling the clove (N);
α_{pn} – angle of clove attachment on the bulb (°).

The pulling force of both rollers is:

$$2 \cdot F_x = 2 \cdot \frac{f \cdot P_{tr}}{2 \cdot \sin\alpha_{pn}} \cdot \cos\alpha_{pn} = \frac{f \cdot P_{tr}}{tg\alpha_{pn}} \tag{23}$$

The force pushing the clove from between the rollers is:

$$2 \cdot N_x = \frac{2 \cdot P_{tr} \cdot \sin\alpha_{pn}}{2 \cdot \sin\alpha_{pn}} = P_{tr} \tag{24}$$

In conclusion, for the clove to be caught by the rollers, the following condition needs to be satisfied:

$$2 \cdot F_x \geq 2 \cdot N_x \quad or \quad \frac{F \cdot P_{tr}}{tg\alpha_{pn}} \geq P_{tr} \tag{25}$$

$$f \geq tg\alpha_{pn} \quad or \quad \varphi \geq \alpha_{pn} \tag{26}$$

RESULTS AND DISCUSSION

Analysing the kinematics of the two rollers movements, two construction versions are proposed. Within version "V1" (figure 2) is envisaged to achieve active bodies in the type of rollers made of rubber cylinders, fitted by pressing on them on length, which will operate on the principle of dehusking bodies. In order not to produce harm and crushes to cloves, during the process of detachment is envisaged that rollers diameter (namely the exterior diameter of rubber cylinders) will be as small as possible, and the peripheral speeds chosen adequately, elements that will be established during the testing of the experimental model.

The kinematics of moving the two rollers is chosen so that the rollers operate with reverse rotation directions one compared to the other. Reverse directions were chosen so that cloves detached from the bulb to be eliminated towards the exterior by the extremities of rubber rollers. The two rollers will operate in an inclined plane to the horizontal, this way achieving a composed forwarding and twisting movement of the garlic bulb, thus achieving bulb separation.

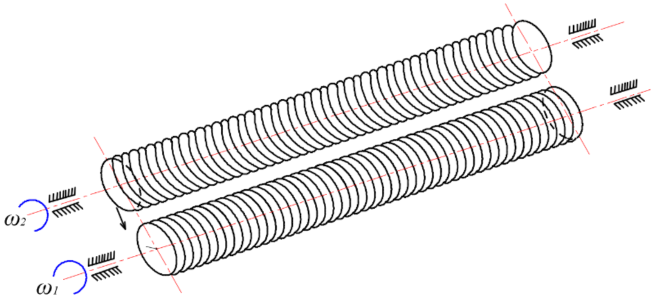

Figure 2 “V1” version – Operating scheme with roller type active bodies

For version V_2 (figure 3), a type of conical rubber corrugated rollers is presented. This type of active bodies operates on the same dehusking principle.

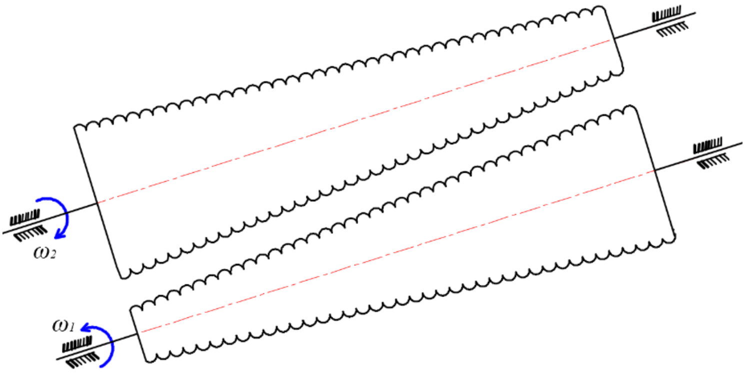

Figure 3 “V_2” version – Conical rubber rollers with protrusions

The two rollers are placed and operate in an inclined plane compared to the horizontal. They were placed in such a manner in the idea that the bulb, entering from the end 1 in the detachment process, will be completed separated until it reaches end 2 of the rollers. Peripheral speeds will be chosen so that this way no harm or crushes are caused to the cloves. At bulb inlet – pos. 1, the distance between the two rollers will be bigger, and at outlet – pos. 2, it will be smaller, namely 25-30 mm respectively 3-5 mm. These rollers were chosen because even if they have the same angular speed, peripheral speeds vary on the length of rollers’ axles, leading to catching and detaching the clove from the bulb.

CONCLUSIONS

Based on this study, it is envisaged to achieve a machine for detaching garlic bulbs, equipped with the two active body versions proposed, and following the laboratory tests to establish the optimum version of active bodies to be fitted on the final machine, which will achieve a complete separation of the bulb into cloves, with minimal harm and crushes.

The detachment of the clove from the bulb takes place only when the angle of catching the clove α_{pn} is smaller than the friction angle φ.

ACKNOWLEDGEMENTS

This work was supported by the Romanian Research and Innovation Ministry, through the project entitled "Researches on achieving integrated systems for the bioeconomy field according to the concept of intelligent agriculture" – PN 19 10 01 01 – Ctr. 5N/07.02.2019, and through Programme 1 – Development of the national research-development system, subprogramme 1.2 – Institutional performance – Projects for financing excellence in RDI, contract no. 16PFE.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Stručni rad
Expert paper

NEW SOLUTIONS FOR THE INTERPHASE TRANSPORT - DECREASING THE DEGREE OF INJURING SEED IN BUCKET ELEVATORS

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ABSTRACT

After harvesting, for any crop, an important role is represented by the creation of adequate conditions for the reception, processing, storing and valorizing the agricultural products obtained. The yield and quality of any agricultural crop is determined both by factors influencing even from the moment of sowing until harvesting, as well as those with direct influence on seeds, before seeding. The paper presents some of the most effective ways to decrease the effect of traumatizing the seeds in the purpose of obtaining a valuable seed material. Specific solutions are presented for an elevator with attenuation, choosing an optimum regime for loading and unloading the buckets, the conditions which need to be fulfilled by a cup with attenuation, the endowments of an exterior and an interior elevator.

Keywords: *seed material, traumatized materials, whole seeds, attenuation.*

INTRODUCTION

The level, quality and cost of agricultural production have been equally determined by the technologies applied, by the quality of the biological material used, by providing the technical-material basis and by informing those who serve it. The production and quality of any agricultural crop is determined both by factors influencing it from the moment of sowing until harvesting, as well as by those that directly influencing the seed prior to sowing.

As a factor of primary importance in increasing agricultural production, the seed enjoys a great deal of attention, many disciplines, institutions and economic agents competing to obtain material for sowing or for consumption as valuable as possible.

In the past, people were thinking about grains as about themselves and were looking for solutions to understand if they were able to encompass and "solve" this issue entirely.

Unfortunately, businesses in the field of producing seeds, storing and transporting them are separated into distinct companies that are not motivated by a common end result (Dumitrașcu et al., 2004; Hapenciuc, 2004; Țucu, 2010,).

As a result, large business owners, in their tendency to make profit, for example, in the field of seed-cleaning machines or seed transport machines, are not concerned about the degree of seed damage, which is a problem for the downstream activity. This explains the existence on the market of a multitude of machines that damage the seeds: elevators with excavation-throwing buckets, pneumatic conveyors, screw conveyors, weighing machines, separators, calibrators and other machines with attributes leading to seed damaging (Averkova et al, 2017; Kim et al., 2017; Richter C., 2017). This will change sooner or later, and those that understand before the others the economic significance of the attenuated handing of seeds will prevail.

According to the research data in the field (Fadeev, 2017), the increase of the micro-deteriorations of the seeds (barley, oats) at one passage through a NPZ-50 type elevator increased by 4%. The things are even worse in the case of crops that are predisposed to damage (corn, rice, peas, sunflower, soy). Thus, according to the data provided by I. G. Stron, the number of external damages caused by the elevator during the transport of maize is about 10%.

The future of seed selection and science does not belong to traumatized, large, heavy seeds but to integral seed (Fadeev L.V., 2017, INMA Collective, 2018). Separately examining each of the components of this issue, namely the traumatizing of seeds, it was inferred that the broken seeds do not emerge in the field, and in the case of weak, traumatized seeds, even if they germinated in field conditions, remained behind in development and gave poor yields.

The difference, compared to the integral grains harvest represents tens of percent. What do the standards say in this regard? Virtually nothing. There is only a limitation on crushed seeds, namely the destroyed seeds that are visible to the naked eye. However, it is known to everyone that hidden micro-traumatisms exist in the seeds sown ten times more. This is known mainly by seed selectors and specialists. And what can they do if designers of seed processing machines treat them not as a living being, but as a friable material, related to sand and gravel? Even 10 years ago this question would have been a rhetorical one. Currently, the image is different. Non-traumatic machinery has been designed and produced, such as slow elevators with attenuation, silage collectors with attenuations, calibrators with low peripheral speed, machines for treating seeds without traumatizing them, etc.

Therefore, if standards for regulating seed sowing qualities that will appear, they will limit the share of traumatized seeds, including microtrauma, then the technical conditions to meet this limitation exist.

MATERIAL AND METHODS

One of the basic requirements in order to call seeds strong is the lack of macro-traumas and, in particular, of microtraumas. The distribution of nutrients in the caryopsis indicates that there is no part that could be sacrificed, any trauma leading to the decrease of nutrients and the reduction of the potential of achene, based on disturbing the processes of starting the breakdown of nutrients and decreasing their quantity (Richter et al, 2017; Fadeev, 2018). When we say that seeds should not be traumatized, it is understood that we are talking about seeds and we think of harm to humans. Cut the seed protection cover (less than 0.1 mm) and storage problems start, "open canteen for microorganisms", destroy the geotropic orientation of the achene and it will not germinate. Moreover, when destroying the shell, the aleuronic layer will be traumatized, its destruction disturbing the main component of the germination process: the fermentation of nutrients (transformation of complex compounds, fats, proteins in sugars, necessary for the embryo's nutrition).

65-75% of the absence of germination in the field is explained by the traumatization of seeds. Nature, over time, creating the miracle called seed, has "provided" that in the germination phase, the first embryonic root should break the casing and "make" it in that spot thinner, soft and elastic to cushion the random strokes and protect the embryo. This is well understood by agronomists and, we can say, that engineers, who treat seeds as friable material, just like sand and gravel do not want to understand. Otherwise, how can machines such as elevators with excavation and throwing, screws, scrapers, pneumatic conveyors, seed throwers, worm gears, other seed-destroying devices (figure 1) be explained?

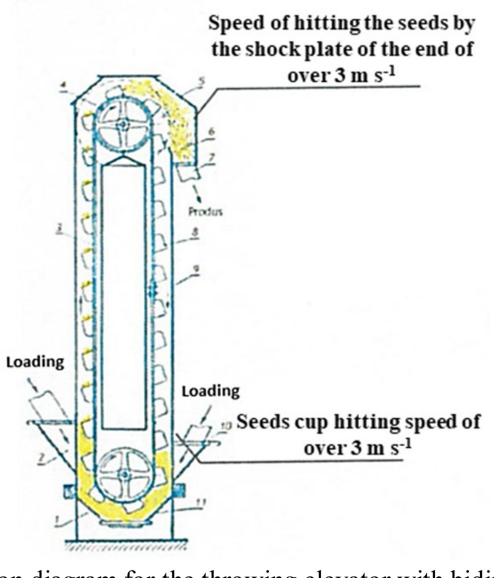

Figure 1 Operation diagram for the throwing elevator with bidirectional loading

For loading and unloading, when the buckets pass over the two drums – inferior and superior, product particles are found under the action of the following forces (Banu, 1999; Kim et al, 2017; INMA, 2018):

Gravitational force: $G = m \cdot g$ and Centrifugal force: $F = m \cdot r \cdot \omega^2$

The extension of resultant **R** meets the vertical drawn from the center **O** to the point **P**, called the ***movement pole***, and the distance between points **O** and **P** is called ***polar distance*** and is noted with **h**.

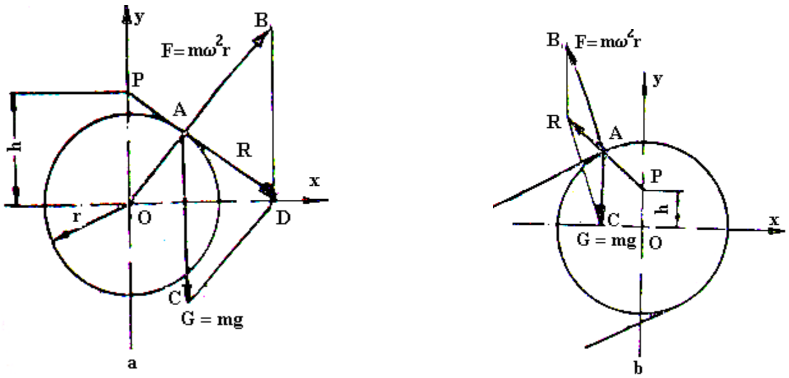

Figure 2 Diagram of the forces acting on the product when unloading from the elevator
a) gravitational unloading; b) centrifugal unloading
(INMA Collective, 2018, Moraru C. et al, 1988)

From triangles **OPA** and **ABD**, results:

$$\frac{h}{r} = \frac{mg}{mr\omega^2} \tag{1}$$

$$h = \frac{mgr}{mr\omega^2} = \frac{g}{\omega^2} = \frac{30^2 g}{\pi^2 n^2} = \frac{30^2 \cdot 9{,}81}{3{,}14^2 n^2} = \frac{895}{n^2} \tag{2}$$

As the speed of the band is higher, distance **h** increases. Product distribution when unloading the buckets is presented in figure 3.

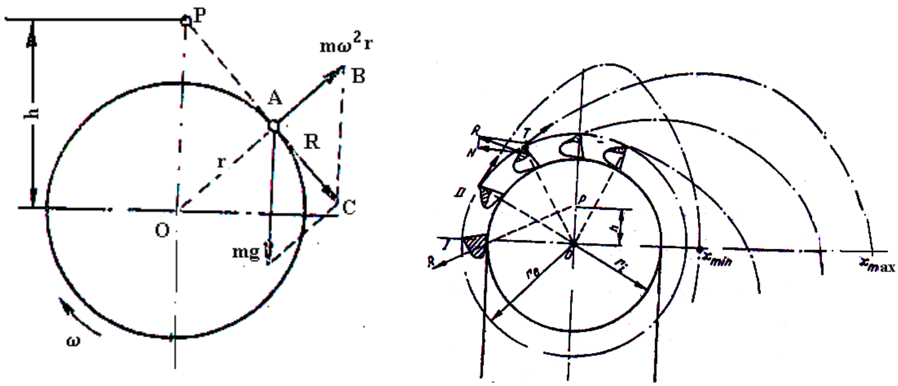

Figure 3 Product spreading when unloading the buckets (Banu et al., 1999)

Depending on the size of polar distance **h** from the inferior radius $\mathbf{r_i}$ respectively the radius of the drum and the exterior radius $\mathbf{r_e}$, respectively the radius of the circle formed on the exterior edge of the bucket, in rotation movement on the drum, there are three situations (Banu et al., 1999; Panțuru D., Bârsan I.G., 1997).

I - h<r$_i$ where the centrifugal force is dominant, unloading is performed centrifugally, and the elevator is of **centrifugal** type;

II - **h> r$_e$**, the material gains the tendency to move towards the interior wall of the bucket. In this case, the unloading is a **free gravitational unloading**;

III r$_i$<h<r$_e$, pole **P** is found between the two radii r_i and r_e, the material is directed towards the inlet of the bucket, unloading beginning close to the vertical passing through the center of the drum. This unloading is called **gravitational-centrifugal or mixed unloading.**

In the situation when is imposed that seeds that need to be transported to "suffer" a minimum degree of traumatisms, an elevator with gravitational unloading and the adequate adaptations is used.

RESULTS AND DISCUSSION

Traditional elevators cannot avoid seed deterioration. High movement speeds of buckets do not allow their filling in 1/15 seconds, remaining a single option, respectively feeding seeds at a speed of 3 m s^{-1} and even above it. The solution consists in decreasing the bucket's movement speed to 0.7 m s^{-1}, simultaneously solving the problem of unloading, namely excluding dropping seeds on the ground. Another solution for rapid elevators does not exist, because in 1/15 of a second the bucket cannot be filled, remaining only one solution, to take seeds from the elevator's foot (figure 1). Seeds are thrown from the buckets under the action of centrifugal force when the drum rotates and each caryopses hits the shock plate of the end with a linear speed much larger than the band's movement speed due to a larger turning radius of the throwing bucket. Researches have shown that 40% of seeds traumatized by elevators are affected in the inferior part and 60% in the superior part, because in the superior part, each caryopses hits shock plate walls (Dumitrascu et al, 2004; Fadeev, 2017). The harm caused by classic elevators is easy to calculate. When traumatizing only 2% of seeds, a elevator with a 50 t h^{-1} productivity will lift 400 t per shift, but in the total mass of seeds in a shift, about 8 tons of damaged seeds will be added and 1.6 t of seed dust (see the graph of seed deterioration in a seed conditioning station in figures 4, 5 and 6).

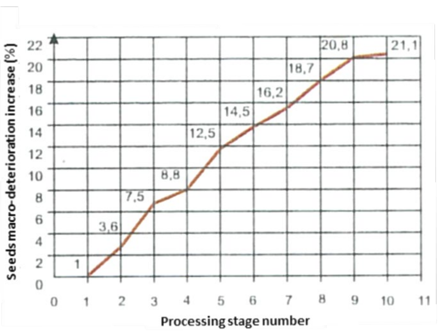

Figure 4 No of deteriorations at a corn seed increase in a conditioning station

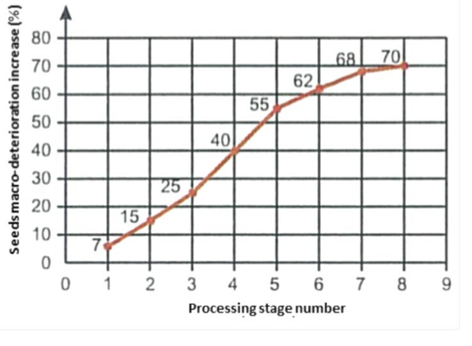

Figure 5 Macro-deterioration in a corn seed conditioning station

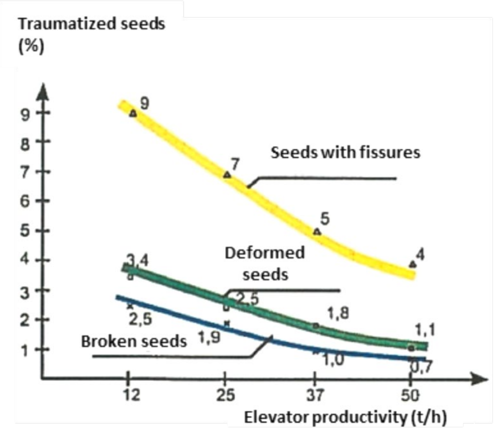

Figure 6 Rice traumatizing at the contact with the buckets of an elevator in a seed conditioning station

In the case of seeds for reproduction, the damage is much higher, the broken seeds and the seed dust becoming in time sources of contamination with microorganisms and hence self-heating outbreaks. In order to remove this impediment, elevators that do not traumatise seeds, do not deform the sun flower seeds, do not crack corn, rice, peas, etc., crops prone to trauma, and thus do not reduce the seed productivity potential and improve their storage. In short, the replacing of elevators with excavation and throwing with those with attenuation was performed.

Elevators are destined for both outdoor locations (for receiving seed after unloading from trucks) as well as for interphase transport from serviced stations. Their main difference lies in the fact that the external elevators have chains and a vertical and an inclined part, which allows the movement of the buckets at low speeds (in the range from 0 to 0.7 m s^{-1}) and the overturn of the seeds into the reception device without shocks. Moreover, the inclined portion of such an elevator allows the seed to be fed to the roof of the rooms, thus avoiding a large length of the seed transport channels (free fall) and significantly simplifying the maintenance of the upper part of the elevator, protected from rainfall and frost (figure 7).

For this type of elevator, the buckets have no pins inside. The interior elevators are made in a vertical version. In their case, the attenuated interaction between the elevator and the seeds is made on the basis of the low speed and the staged discharge of the seeds from the bucket (figure 8). The shape of the bucket and the placement of the buckets on the belt ensures the loading and unloading of the seeds at any speed. On a slow turn of the belt on the upper drum, the seeds in the bucket are not thrown and do not hit the end of the elevator, but spill at first on the surface of the back wall of the previous bucket, made in the form of an open bowl, and then, based on the angle of inclination of this wall towards the horizon (45° and over) in the receiving device. The installation and fixing of the buckets on the belt is such so that they completely cover the surface of the belt, which allows for the reduction of the leakage at loading and the elimination of the traumatization of seeds (characteristic for elevators with excavation) due to their blockage between the bucket and the belt, because in the case of elevators with attenuation there is a larger space than the size of the seeds.

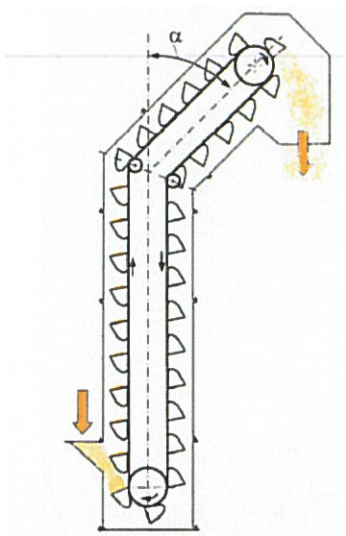

Figure 7 Elevator with attenuation (for exterior placing)

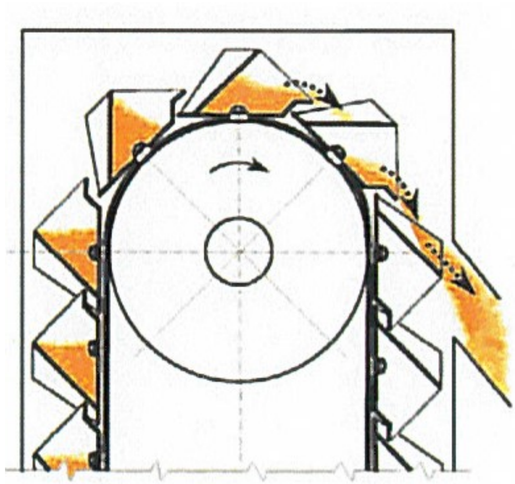

Figure 8 Elevator with attenuation (stage evacuation for closed spaces)

This may be called the "full bucket" elevator or the Fadeev elevator, the first researcher to promote the elevator with attenuation. In order to prevent the caving-in when loading the bucket, a charging repeating device has been provided. The channel on which the buckets move is spherical and the distance calculated between the front edge of the bucket and the channel generator does not change at the stretch of the belt, because at the stretch, the whole aggregate moves along with the spherical bottom.

CONCLUSIONS

Regular elevators with excavation and throwing don't offer the possibility to adjust the bucket movement speed and for any reduction in seed flow at the entrance to the elevator, the buckets are not uniformly filled and the relative share of seeds hit by the edge of the bucket increases. From the graph in fig. 6, it was observed that when reducing the load 4 times, the number of cracked seeds increased 3 times. This is explained by the fact that the number of seeds hit by the front edge of the bucket increases. The attenuator allows a "full bucket" regime to be set at a given productivity, based on the corresponding reduction of movement speed and increasing load time. This lowers the load on the moving parts of the elevator, which increases its service life. Small displacement speeds of the bucket in attenuation elevators allow for the to drop cup shape the bucket and to install buckets of greater capacity and different shape. Such a bucket at the same distance between buckets allows a 1.5 times increase of the minimum elevator output and the elimination of seed leaks at maximum load when turning from the vertical to the oblique side of the elevator.

ACKNOWLEDGEMENTS

This work was supported by the Romanian Research and Innovation Ministry, through the project entitled "Optimizing interphase transport in the food industry, agriculture and zootechny" - PN 18 30 02 02, and through Programme 1 – Development of the national research-development system, subprogramme 1.2 – Institutional performance – Projects for financing excellence in RDI, contract no. 16PFE.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Pregledni rad
Review paper

MANUFACTURING TECHNOLOGY AND MECHANICAL PROPERTIES OF BIODEGRADABLE TABLEWARE MADE FROM CEREAL BRAN

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SUMMARY

Biodegradable and compostable tableware which is made by using agricultural by-products is significantly more environmentally-friendly than is disposable plastic tableware. The aim of this research was to study and compare production technologies that are used in the formation of tableware using by-products from the process of milling cereals, specifically cereal bran, and to determine the level of technology being used. In order to accomplish the aim of this research, various sources of literature and patents were analysed and the mechanical properties of materials that are used to make biodegradable tableware were studied. In this research, specimens were taken from various items of tableware that had been manufactured using wheat bran, palm leaves, and cardboard, and the flexural strength was measured in each sample.

Keywords: *compostable, cereal milling by-products, mechanical strength, flexural strength.*

INTRODUCTION

As we all know, plastic waste is now a global problem. Mankind is living in an era of mindless over-production and over-consumption. Every year about eight million tons of plastic waste reach the oceans (Tullo, 2018). The main polluters of the oceans are China, India, Indonesia, the Philippines, Thailand, Sri Lanka, Vietnam, and Bangladesh (Jambeck et al., 2015; Macrae, 2015; Tullo, 2018). These countries are characterised by undeveloped waste handling systems. However, waste problems are topical not only in developing countries, but also in economically-developed countries. Some of these do not use waste containers for storing ordinary household waste, not to mention the lack of containers for various types of waste. In addition to packaging that pollutes the environment (such as crisp packets and sweet wrappers), packaging for alcoholic drinks (such as bottles), filtered tobacco products (such as cigarette stubs), balloon sticks, straws, plastic cotton buds and plastic bags, and also disposable tableware (cups, plates, forks, knives, and spoons) all constitute a significant amount of the world's waste. According to a twelve-year study in Taiwan, disposable tableware forms one out of every five of the most common man-made waste items in the seas (Walther et al., 2018).

Despite the pollution issues, plastic is a very useful material. It can easily be processed mechanically, it is durable, it has a low bulk density, and it is cheap (Fischer et al., 2010). It is a shame that Mankind cannot always use it reasonably. The beneficial properties of plastic when used irrationally as waste will become fatal to both humans and the environment. Over time, plastic will decompose, and poisonous compounds will be released (Shah et al., 2008; Tosin et al., 1998). Unfortunately, a cardboard plate is no more environmentally-friendly than is a plastic plate. A cardboard plate will have been covered with a thin plastic layer, which means that the plate does not qualify as biowaste and it cannot be recycled. A cardboard plate qualifies as household waste and is sent to a landfill site or is used as a combustible material in an incinerator.

Biodegradable tableware offers an alternative; however, it should be noted that it may not be completely degradable in nature as some versions contain microplastics (Song et al., 2009). According to the available literature, many biodegradable polymers have been developed but, at the moment, they are more expensive than synthetic polymers and this is serving to limit their usage (Siracusa et al., 2008). In addition, biodegradable polymers have usage limitations which are related to their properties (Siracusa et al., 2008). Biodegradability means that the materials are capable of undergoing aerobic and anaerobic degradation which results in the production of CO_2, H_2O, methane, biomass, and mineral salts. Biodegradable materials may not be compostable. The composting process consists of the decomposition of organic waste by microbes in order to produce compost.

Therefore, compostable products are the most nature-friendly ones. Fieschi and Pretato (2018) claim that using biodegradable and compostable tableware in quick service restaurants, for example, will reduce carbon emissions, water usage, and the resource footprint. Such products may be produced from agricultural by-products which are natural in origin and which most probably will decompose completely in nature without resulting in any pollution (Liu et al., 2012; Satyanarayana et al., 2009). These by-products may include the bran and chaff of cereals (Alun et al., 2012), corn (Cornflower, 2018), sugar cane (Xmjeafer, 2018; Shaoneng Group Guangdong Luzhou Paper Mould Packing Products Co., Ltd., 2018) or rice (Liu et al., 2012). According to one source (Atrileaf, 2018), the raw materials may include tree leaves. Studies have shown that tableware which is made of biodegradable plastic can be fully degraded within twelve weeks (Vaverkova et al., 2014; Willett and Howell, 2017). Table 1 presents the technical characteristics of the by-products of milling cereals (Wheat bran, 2018; Sauvant et al., 2002).

Table 1 The characteristics of the by-products of milling cereals

Characteristic	Oat bran	Barley bran	Corn bran	Wheat bran	Rye bran
Dry matter, %	86	86	88	86	86
Raw fibres, %	18.5	15.5	11.5	9.7	10.0
Raw ash, %	5.0	5.5	4.0	5.5	5.0

The tableware lifecycle has been presented in Figure 1.

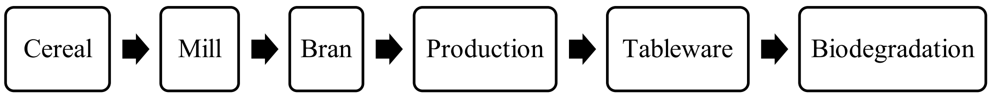

Figure 1 The life cycle of compostable tableware.

The compression of cereal by-products involves the following processes: pressure is applied to the compressible material and its temperature is raised to the desired level; temperature and pressure causes the plant's ligneous cell structure to break down and heat softens the lignin in the material while the lignin glues together the particles of the compressed material (Ivanova et al., 2013; Pietsch, 2002) The production of wood pellets and briquettes is based on roughly the same principle (Olt and Laur, 2009). The amount of lignin in other compressed materials (cereal bran) is not known.

It is known from one source (Heuze et al., 2015) that wheat bran contains an average of 45.8% (22.8%-59.6%) of neutral fibres (cellulose, hemicellulose, and lignin), 13.6% (8.1%-18.7%) of acid fibres (cellulose and lignin), and 3.8% (1.9%-5.2%) of lignin. Another source (Sauvant et al., 2002) claims that the content of neutral fibres averages 47.5% (40.3%-55.0%), with acid fibres at 13.7% (11.1%-17.3%), and lignin at 4.0% (3.1%-4.9%). No such information is available on other brans. At the same time, it is known that 7.94% of wheat straws consists of lignin (Tutt et al., 2012), and other types of straw contains between 5.05-8.76% (Raud et al., 2016). This variation in the lignin content of bran and straw can be accounted for by the fact that bran contains more starch and, therefore, it must contain less lignin than the straw. Sources do not contain information on whether the parameters that are listed in Table 1 may serve to influence the mechanical properties of any product that has been formed by compressing the material.

The introduction of compostable products, including tableware, is feasible only if their mechanical properties are comparable to the mechanical properties of disposable tableware that is made using cardboard and plastic. The aim of this research was to study and compare production technologies that are used in the formation of tableware using by-products from the process of milling cereals, specifically cereal bran, and to determine the level of technology being used.

MATERIALS AND METHODS

In order to be able to determine the level of technology being used in the subject of this topic, specialist literature was used (from the Web of Science and Scopus), along with two databases (from Espacenet and WIPO). The conditions for the patent search were as follows:

1. scope - global;
2. depth - 25 years;
3. keywords used in the search: biodegradable AND bran; degradable tableware; biodegradable tableware; bran AND tableware; disposable AND bran; mouldings AND bran; decomposable AND bran; biodegradable mouldings.

In order to broaden the selection of materials that are available for producing compostable tableware, the mechanical properties of the suitable material must be known. The research involved measuring the mechanical properties of some of the materials being used in the production of tableware - namely the flexural properties being used - by using the three-point flexural test according to the ISO 178:2010 standard. The authors consider the three-point flexural test to be similar to real-life loads which are applied to tableware when it is used in a normal, everyday setting. The specimens that were used for measuring the flexural strength involved in disposable tableware which had been produced using cardboard, palm leaves, and wheat barn. Specimens were taken from the tableware using a laser. Specimens from plates which had been produced using cardboard were tested for their flexural strength on both sides. In one case, the load was applied to the side that was covered in a layer of plastic and vice versa in the other case. Those plates that had been produced using palm leaves were also tested twice as this material is anisotropic. In one case, the edge of the cylinder that applied the load to the material being studied was longitudinal to the fibres of the palm leaf and perpendicular in the other case. The test scheme is shown in Figure 2.

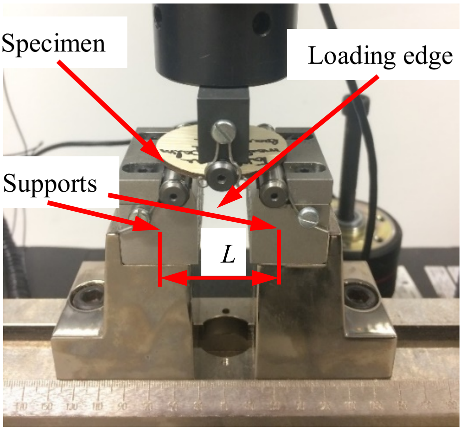

Figure 2 Test scheme for a three-point flexural test

The technical specifications of the flexural tests are given in Table 2.

Table 2 Technical specifications of the flexural tests

Test device	Instron 5969
Load cell	1 kN
Span between specimen supports L	34 mm
Test speed v	1 mm min^{-1}
Radius of the loading edge R_1	5 mm
Radius of the supports R_2	5 mm
Measuring instrument for geometric parameters	Micrometer with a resolution of 0.001 mm
Shape and dimensions of the specimens	Round plate, diameter 50 mm, thickness as it was

As appears in Table 1, the shape and dimensions of the specimens and the radius of the loading edge do not respond completely to the ISO 178:2010 standard due to the existing equipment and the authors' further plans in this research field. The maximum flexural-stress δ_{fm} was calculated using the equation given in the ISO 178:2010 standard.

RESULTS AND DISCUSSION

The number of results in the patent search using the terms and listed keywords are given in Table 3.

Table 3 Keywords used in the patent search and results

Keyword	Results from the Espacenet database, total	Results from the Espacenet database concerning China	Results from the WIPO database, total	Results from the WIPO database concerning China
biodegradable AND bran	83	25	89	25
degradable tableware	50	49	164	147
biodegradable tableware	3	2	84	47
bran AND tableware	25	21	23	17
disposable AND bran	26	12	23	9
moulding AND bran	47	24	12	0
decomposable AND bran	19	0	14	0
biodegradable mouldings	14	3	88	7

The patent search revealed that wheat bran (AU2013324540, CA2885853, DK2900872, CN102993761, KR20150073593, FR2745818, etc), rice bran (CN106618086, CN103013155, KR20160062641, TW200528612, TW219339, etc), and corn bran (CN106046828, CN10600974, etc) have been used as the raw materials in the production of tableware.

This topic has already been addressed in the previous century. In 1997, the US patent, 'A method for producing biodegradable products' (US5688448) was registered, and this was followed by a series of patents along the lines of 'The biodegradable composition in the preparation of tableware, a drink container, mulching film, and packaging, and a method for carrying out that preparation' (US7402618), and 'Recyclable disposable tableware fabricated from rapidly renewable resources' (US201814668).

The production technology has been developed very actively in China, where some examples are as follows: 'A preparation method for biodegradable tableware' (CN104086820), 'Full biodegradable fibre-reinforced starch foaming tableware and a preparation method for it' (CN106947117), along with a great many other technical solutions; in Taiwan (TW411372, TW500746, etc), in South Korea (KR20010091782, KR20100020047, KR201200251, etc), and in Australia (AU2001014230, AU2013324540, etc).

A compostable tableware production technology which meets the stipulations of patent document US9517578 contains, for example, the following steps: brans of a fraction of between 0.01-2.80 mm and a moisture content of at least 14% are mixed; then they are added to a mould which contains a matrix and a mark, at a temperature of 120°C, which is used to compress the material up to a pressure of 10 MPa; this compression results in a product with a density of 1.4 g cm^{-3}.

In order to be able to refer to the product - this in our case being the tableware - as being completely compostable, it must meet the requirements (DIN EN 13432; ASTM D6400; ASTM D6868; ISO 14851). Both of these specifications require that biodegradable/ compostable products must degrade completely in the composting environment within a certain amount of time and are not allowed to leave behind any hazardous residues.

It became clear that there were no sources regarding the use of by-products from the milling of other cereals besides wheat, rice and corn for the production of compostable tableware.

The results of the flexural tests are shown in Table 4.

Table 4 The results of the flexural tests

	δ_{fm}, N mm^{-2}	SD, N mm^{-2}	SE, N mm^{-2}
Cardboard (plastic layer topside)	30.98	8.29	4.14
Cardboard (plastic layer upside down)	20.95	2.83	1.41
Palm leaves (longitudinal)	2.94	0.68	0.40
Palm leaves (crossed)	29.92	8.98	5.19
Wheat bran	9.98	2.30	0.77

Table 4 shows that the plate with the lowest flexural strength is the one that has been made with palm leaves when the edge of the cylinder being used for applying the load was longitudinal to the fibres of the palm leaf. The cardboard plates had the highest flexural strength when the load was applied to the side that was covered with plastic.

CONCLUSIONS

The patent search that was carried out during the research revealed that, despite China being one of the world's largest polluters of the oceans in terms of plastic waste, it is also one of the most active developers of production technology in terms of compostable tableware. Compostable tableware is produced mostly by compressing the agricultural by-products, and the raw materials are primarily wheat bran, rice bran, corn bran and tree leaves; with any of these the density of the compressed products must be at least 1.4 g cm^{-3}.

It became evident during the research that the mechanical properties are different in tableware that had been produced from different materials. It also became evident that the flexural strength of tableware that had been produced from anisotropic materials such as palm leaves tends to vary a great deal. The authors of the article believe that the flexural strength of any material that is suitable for the production of compostable tableware must be at least equal to the flexural strength of those plates that have been made from wheat bran which, in this article, was $\delta_{fm} = 9.98$ N mm^{-2}.

Further research must focus on the possibilities involved in using by-products which are generated by milling other cereals in the production of compostable tableware, with the most important factor being the mechanical properties of the products.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

ESTIMATION OF EFFECTS ON THE WORKLOAD AT DAIRY FARMS CAUSED BY AUTOMATIZATION

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ABSTRACT

The automatization of routine tasks in dairy farming is becoming more and more important, especially family farms in southern Germany. This development may result in a consolidation of decision making, which despite of decreasing working hours per cow could create an increasing workload. Aim of this research is to identify different manifestations of work and their working time requirements in dairy farming. Further a comparison of types of work and working time requirements is created, depending on different levels of automatization on a dairy farm.

For this purpose, three fictional barn systems, a "manual barn", a "semi-automatic barn" and an "automatic barn, are examined regarding the working time requirements and types of work.

From literature, the individual main tasks in dairy production are subdivided into work elements that are consecutively assigned to physical work, mental work and sensorimotor work. Afterwards the barn systems are compared regarding manifestations of work and the working time demands.

Increasing automatization leads to a reduction of total working time requirements. Especially physical work can be reduced. The largest savings can be expected in the milking and feeding processes. The role of mental work increases relatively to the other types of work. This mental work largely consists of management and control tasks, computer work and device operation. Therefore, an increasing strain to the mental skills of farmers needs to be expected.

Keywords: *automatization, workload, dairy farming*

INTRODUCTION

Human labour is one of the most important production factors in dairy farms´ production processes. Despite the fact that the size of livestock at German dairy farms increases, the number of workers is decreasing (Blumöhr, Walsemann, 2004). In consequence, this development leads to increasing workloads. However, innovations in technology within the last years make automatization of production processes in dairy farming possible. These automatization processes for routine tasks are becoming more and more important, especially for Bavarian family farms as they are under pressure to rationalize their workload. Therefore, the main reason for investments in automatic milking systems are the reduction and improved flexibility of workload (Fübbeker, Kowalewsky, 2005).

In consequence, the utilisation of these modern technologies, causes a transformation of types of work and working time requirements in dairy farming. This development may result in a consolidation of decision making (Schlick et al., 2010), which despite of decreasing working hours could create an increasing workload.

This research examines the working time requirements of routine tasks on the basis of literature data for three fictional barn systems with different levels of automatization. The focus is set on changes of working time requirements and types of work for the main tasks in dairy production that are milking, feeding, manure removal and littering.

MATERIAL AND METHODS

Technical equipment of model farms

For the research, three fictional barn systems were examined that are common and representative for agricultural practice in Germany. The size of livestock was 120 cows, as it represents a farm size, which, despite of structural changes, is a presumable fit for the future in southern Germany. All barn systems were freestall barns, with four-rows of cubicles. The most important routine tasks in dairy farming were found in the processes of milking, feeding, manure removal and littering. Therefore, these three main tasks were in the focus of this research. The three barn systems were meant to represent three the different levels of automatization: "manual barn", "semi-automatic barn" and "automatic barn”. The technology used on each farm type is shown in Table 1.

Milking was executed two times every day in the manual and semi-automatic milking systems. In the automatic milking system (AMS) the milking process is flexible and continuous throughout the day. However, each cow needs to be milked at least two times each day. Fresh feed was provided one time and pushed in to the feeding ally three times daily. Additional feeding of concentrated feed via feeding stations was not considered. The manure was removed right after or during the milking and feeding times, every day. In the semi-automatic barn, only the cleaning of the crossing passages was executed manually during these times, while the cleaning of the walkways was automatic with dung scrappers two times daily. In the automatic barn, the cleaning of the walkways and crossing passages was executed automatically. In all three systems, the cleaning of the cubical was executed manually. Littering was automated in the automatic barn system.

The data for working time requirements result from ART-Arbeitsvoranschlag, 2016 and KTBL Betriebsdatensammlung 14/15 (Frisch, 2014). Futher data from other publications

(Schick, 2000) and manufacturer´s instructions were used. If there is no literature data or other secondary data available, the working time requirements were approximated with comparable tasks or extrapolated from smaller scaled technology with Microsoft Excel 2016.

Based on literature each task was divided up in work elements. The work elements were categorized in the types of work "physical work", "mental work" and "sensorimotor work".

Subsequently the working time requirements of the single work elements ware added up according to the mentioned types of work. Afterwards the three barn systems were compared regarding the differences between the claims of workload in the different types of work.

Table 1 Technological equipment of the different barn systems

Barn system	Manual barn	Semi-automatic barn	Automatic barn
Milking system	• Herringbone milking parlor with 2x6 milking places • No technological support	• Herringbone milking parlor with 2x6 milking palaces • Automatic stimulation • Service arm • Automatic stripping • Removal automatic	• Two Automatic milking systems
Feeding technology	• Feed mixer and distribution trailer extra filling-system • Manual feed push in	• Feed mixer and distribution trailer self-filling system • Robotic feed pusher	• Automatic feeding system • Automatic feed push in • Daily filling of feed storage container
Manure removal and bedding system	• Walkways: tractor and sliding shield (2,0 m) • Crosswalk: manual • Cleaning cubical: manual • Litter down cubical: manual	• Walkways: Scraper demanuring • Crosswalk: manual • Cleaning cubical: manual • Litter down cubical: manual	• Walkways and crosswalk robotic slat cleaner • Cleaning cubical: manual • Litter down cubical: automatic

Work elements of the examined tasks

The work elements in milking parlor were very different from the work elements in an automatic milking system (AMS). In consequence, the work elements of the manual and semiautomatic system were different to the AMS work elements. The different work elements of milking and their classification within the three types of work are shown in Table 2 and Table 3.

Table 2 Work elements for milking in a 6x2 herringbone milking parlor with working time requirement and categorization in types of work (according to Schick (2000) and (ART-Arbeitsvoranschlag, 2016))

Work elements	Type of work	Manual barn (h/cow/year)	Semi-automatic barn (h/cow/year)
Let in cows	physical	1.02	1.02
Udder preparation	sensorimotor	2.80	0.92
Milking cluster put on	physical	1.02	0.86
Milking cluster alignment	physical	0.15	-
Milking-out	physical	1.02	-
Milking cluster removal	physical	0.41	-
Udder control and dipping	sensorimotor	0.31	0.31
Let out cows	physical	0.76	0.76
Walking in milking parlor	physical	1.07	0.51
Other (preparation, cleaning work, waiting times, cow pushing)	physical	10.22	9.91

Table 2 Work elements for milking AMS with working time requirement and categorization in types of work (according to KTBL (2013))

Work elements	Type of work	h/cow/year
Preparation of milking	physical	0.20
Milking of separated cows	physical	1.51
Cow control / observation	sensorimotor	1.25
IT-tasks	mental	2.43
Milking box cleaning	physical	1.71
Teach new cows	sensorimotor	0.39
Clearance of error	mental	0.99
Cleaning of milk tank	physical	0.53

For the feeding, the differences of work elements were mostly regarding the technological implementation in the working process. The detailed classification of the single work elements is shown in Table 4. With the step from the manual system to the semiautomatic system, the working process changed, as the operator did not have to switch between the wheel loader and the tractor with the feed mixer. The mental tasks include, for the most part, the ration management, which was assumed to be identical for the three systems as this work is independent and not affected by automatization of routine tasks. Therefore, it was not mentioned especially in the list of work elements. The controlling tasks for the autonomous feeding and pushing in of the feed is assumed to be negligible, as it would be programmed onetime and further run automatically. On the other hand, more complicated service tasks can not be executed by the farmer himself, therefore, these tasks were assumed to be outsourced to a technical service partner.

Table 3 Work elements for feeding with working time requirement and categorization in types of work (according to Grothmann et al. (2010) and Nydegger et al. (2005))

Work elements	Manual barn		Semi-automatic barn		Automatic barn	
	Type of work	h/cow/year	Type of work	h/cow/year	Type of work	h/cow/year
Feed ration management	mental	0.62	mental	0.62	mental	0.66
Filling of feed mixer / storage container	sensori-motor	2.83	sensori-motor	2.83	sensori-motor	1.84
Feeding	sensori-motor	0.71	sensori-motor	0.71	mental	-
Pushing in of feed	physical	0.78	mental	-	mental	-
Clarification of feeding table	physical	0.81	physical	0.81	physical	0.81

The workings steps of the manure removal and bedding systems are identic for the three different barn systems. The main differences are in the technological implementation of the automatic systems and the workload of these technologies regarding the farmer. The single steps and their classification are shown in Table 5. The field of farm management tasks is assumed to be not affected by the automatization of the production processes. Therefore, these tasks are not considered in this research.

Table 4 Work elements for manure removal and littering with working time requirement and categorization in types of work (according to Schick, Moritz (2004))

Work elements	Manual barn		Semiautomatic barn		Automatic barn	
	Type of work	h/cow/year	Type of work	h/cow/year	Type of work	h/cow/year
Cleaning cubicle, with litter	physical	1.83	physical	1.83	physical	1.83
Cleaning of crossings	physical	0.61	physical	0.61	mental	0.00
Cleaning of walkways	sensori-motor	1.83	mental	0.50	mental	0.12
Littering manual/ Filling of automatic littering system	physical	1.70	physical	1.70	sensori-motor	0.25

RESULTS

Changes of the main tasks

The comparison of the three barn systems shows decreasing working time requirement in context with increasing automatization of routine tasks in all considered main tasks (Figure 1).

Compared to the manual milking system, in the semiautomatic milking system, only a slight reduction of physical and sensorimotor tasks can be expected (Figure 1a). Exclusively mental tasks are not observed in both systems. On the other hand, large effects on working time claims and types of work can be expected with the automatic milking system. Besides, the total reduction of working time requirements, especially the work load of physical work is decreasing. However, the number of mental tasks regarding management, information technology (IT) and cow control and observation increase. This leads to equal working time requirements of mental and physical tasks in the automatic milking system.

In the feeding tasks, decreasing working time requirements can be expected with the automatization of the feeding process (Figure 1b). The most working time requirements are in the form of sensorimotor work. This results from operation task with tractor, autonomous feed mixer or wheel loader. As the physical work of pushing in the feed is taken by an autonomous robot, the amount of physical tasks is cut in half in the semiautomatic and automatic feeding system. The remaining physical work results from the removal of feed residues.

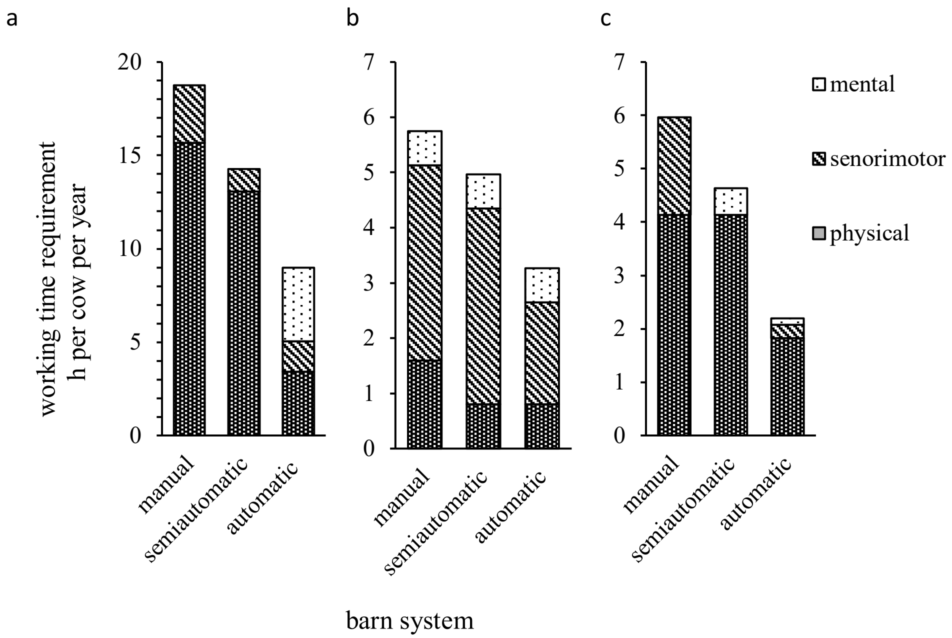

Figure 1 Change of working time requirements and claims of types of work for a) milking; b) feeding; c) manure removal and littering

The automatization of the manure removal system shows a high potential for the reduction of working time requirements (Figure 1c). The most physical work occurs during the cleaning of cubicles. In the manual and semiautomatic system the physical task “Cleaning of crossings” additionally shows high working time requirements of physical work. However, the sensorimotor work of cleaning with the tractor and sliding shield is shifted into the mental working form, by using the manure scrapper in the semiautomatic system. Also a reduction of total working time can be realized by this system. Highest potential for the reduction of working time requirements provides the robotic slat cleaner. The physical task of littering is only observed in the manual and semiautomatic system. It is replaced in the automatic system with the sensorimotor task of “Filling of automatic littering system”. However, the automatic littering leads to a reduction of physical work and the total working time requirements.

Reduction of total workload

The increasing usage of automatic systems for the execution of routine tasks shows high potentials for the reduction of total working time requirements. Therefore, the total working time requirements decrease between the manual barn and the semiautomatic barn as well as between the semiautomatic and the automatic barn (Figure 2).

Additionally, the working time requirements change regarding the types of work. In consequence the working time requirements for physical and sensorimotor work are decreasing with an increasing degree of automatization, as well as the working time requirements for mental tasks are increasing.

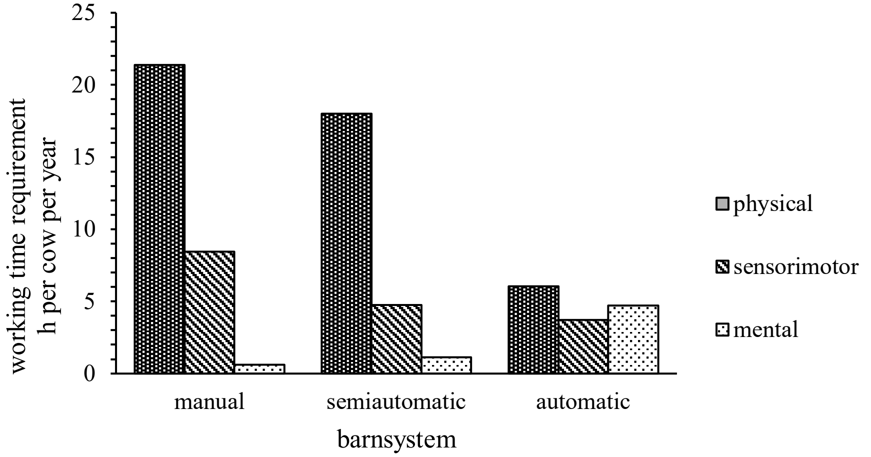

Figure 2 Total working time requirements of the three examined barn systems divided by the work forms physical, sensorimotor and mental work

DISCUSSION

The literature data given by Frisch (2014) ranges between the calculated values for the manual and the semiautomatic milking system. Therefore, it can be assumed that in the mentioned literature there was no differentiation between milking parlor with or without automatic support systems. It is also likely, that many automatic support systems only have a low direct effect on the working time for a certain work element. For this reason, the work relief might be mainly in the process optimization.

The low working time requirements with the AMS arise from the fact, that the whole milking process is executed by the autonomous system. The main tasks in this system are IT- and controlling tasks. (Fübbeker, Kowalewsky, 2005)

A decreasing physical workload is the consequence of this automatization. However, an increasing workload of mental tasks needs to be assumed based on this development, which is also indicated by increasing working time requirements for mental tasks. Further confirmation of this assumption is given by a survey of Fübbeker, Kowalewsky (2005).

The reduction of workload between the manual feeding system and the semiautomatic feeding system results from the automatization of pushing in feed. With the step from the manual system to the semiautomatic system, the working process changes, as the driver doesn´t have to switch between the wheel loader and the tractor with the feed mixer. However, the effect on working time and working form caused by this change of process structure is negligible. Effects in this task field are more affected by operational structures characteristic for each farm (Fübbeker, 2014).

In the task field of manure removal and littering, the most working time requirements are accounted for the cubicle maintenance. This physical task remains in the working process, independent of the automatic technologies. New technologies regarding an automatic cleaning of cubicles were not considered in this research, but should be considered in further studies.

CONCLUSIONS

The comparison of the total working time requirements indicates an overall reduction of working time requirements caused by automated production systems. Additionally, this development indicates an increasing ratio of mental tasks compared to the types of work of manual and sensorimotor work. This leads to a work relief on the ergonomic based tasks but rising workload by mental tasks and higher claims on the mental abilities of the farmers can be expected in the future development. However, for further studies, it is important to consider farm structures that determine the progress of work elements.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

POTENTIAL REDUCTION OF ECOLOGICAL FOOTPRINT, CO_2 EMISSIONS AND GWP USING AUTO TANDEM PARLOUR SYSTEM WITH HEAT EXCHANGER

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ABSTRACT

The intensification of milking production has led to activities that profoundly influence the ecosystem not only due to the fodder processing and farm management but also in milking and milk cooling, thus the estimating of environmental impact is essential. In our study, the Sustainable Process Index (SPI) was used for estimating ecological footprint, CO_2 emissions and Global Warming Potential (GWP) on two farms equipped with different milking and milk cooling systems. On the farm 1 the old milking pipeline with 2 jars, electric boiler and refrigerating system is used. Contrary, the farm 2 is equipped with modern 2 x 3 auto tandem parlour system with heat exchanger, which serves for cooling down the milk and successively heat the water for cleaning the systems. The farm 1 produces annually on the average 6,000 kg of milk per cow, while on the farm 2 the average annual production is 8,000 kg of milk per cow. On the first farm the ecological footprint for milking and cooling of 1 litre of fresh milk amounts to 8.3846 m^2 anno/l and on the second farm to only 2.7050 m^2 anno/l. Moreover, on the farm 2 also the total CO_2 and GWP emissions for milking and cooling of 1liter of milk is smaller for 67.67% and 67.82%, respectively, than on the farm 1. The results of our research proved that the modern milking systems not only requires less time and manual labour, but also significantly reduce negative effects on the environment.

Keywords: *milking pipeline, auto tandem parlour, ecological footprint, Sustainable Process Index*

INTRODUCTION

Increasing demand for daily fresh milk products has tremendously driven on increase in milking production in Europe since 1960s till nowadays. However, in the new century a fundamental objective of milk production is to assure net income for dairy farmers (VandeHaar and St-Pierre, 2006). Due to the wagging milk prices, in many parts of the developed world, dairy producers aim to increase farm income by maximizing milk yield per cow. This is usually accomplished by offering cows nutritionally precise diets in confinement and through improving genetic merit (Arsenault et al., 2009; Capper et al., 2009).

Besides other inputs, energy usage on dairy farms has grown gradually in the past 20 years due to increases in farm sizes, use of automated equipment, and around-the-clock operation. Dairy farms in the USA consume between 800 and 1,200 kilowatt-hours (kWh) per cow annually. About 50% of the total energy used on a dairy farm is spent for milk-production equipment, which includes milk cooling 25%, vacuum pump 17%, and water heating. Lighting and ventilation account for most of the remainder of energy used. In Ireland, for instance, electricity accounted for 60% of the direct energy use, whereby mainly resulted from milk cooling (31%), water heating (23%), and milking (20%).

Because of the large number of processes that contribute to electrically driven equiment, the evaluation of the whole value chain would extend the knowledge about the broader environmental performance of ecological impact cauased by milking and cooling of milk on fram. In early 1990s life-cycle assessment (LCA) was introduces for evaluating the environmental effects (air, water, and land) associated with any given activity, beginning with the initial gathering of raw materials from the environment to the point at which all residuals are returned to the environment known also as cradle-to-grave analysis (Romero-Gámez et al. 2012).

The Sustainable Process Index (SPI) belongs also to ecological footprint family and it was specially developed and customized for agriculture by Krotscheck and Narodoslawsky (1996). The concept of calculating the ecological footprint assumes that a sustainable economy might be built only on solar radiation as natural input and the earth's intact surface as the resource for the conversion of solar radiation into products and services. Since the global surface area is a limited resource, the area required to embed a certain process sustainably into the ecosphere is a appropriate measure for ecological sustainability.

To assess the ecological footprint of milk from particular dairy systems, it would be necessary to adopt a life cycle approach. This approach, referred to as life-cycle assessment (LCA), involves quantifying CO_2 and GHG emissions generated from all stages associated with a milk, from raw-material extraction through production, use, recycling, and disposal within the system boundaries (ISO, 2006a,b). Several studies have applied LCA methods to compare carbon footprints of milk from confinement and grass-based dairy farms (Belflower et al., 2012; O'Brien et al., 2012, Flysjö et al., 2011b). However, the results of these studies have been inconsistent.

The main goal of our research was focused on ecological footprint, CO_2 emissions and global warming potential (GWP) caused during milking and cooling of milk on two types of farm tipically represented in Slovenian dairy production; i) a tied-stall system with pipeline and 2 milking units and ii) the free-housing system with auto-tandem milking parlour (2 x 3).

MATERIAL AND METHODS

Farm 1

The milking system consists of a tied-stall system with pipeline and 2 milking units. The milked milk flows directly into the 1000 l refrigerating cooling tank, placed in the special part of the dairy. The milk is cooled to 4 ° C and stored for 48 hours before it is pumped to the collecting tank on the van. In the same room, a washing machine with associated washing heads for soap units is attached to the wall, and there is also a vacuum pump. The milking begins by cleaning the udder and obligatory removal of the first jets. Whole herd milking of 17 cows lasts about 1 hour. The most important task is to prepare milking units and equipment for the next milking. Immediately after milking, milking units and equipment are cleaned using a washing machine. In the majority of cases, the system is cleaned in the morning with basic, and in the evening with acid detergent. Washing machine works approximately 90 minutes. After the washing was completed, the machine automatically switches off and the equipment is ready for the next milking. In addition, every second day, when the cooling tank is empty, then cleaning of tank is done. The tank is not cleaned with the washing machine but manually. Like other equipment, the cooling tank is cleaned alternatively once with basic and secondly with acid cleaner.

Farm 2

This farm owns a new free-housing system with auto-tandem milking parlour (2 x 3). In the adjacent area of the dairy, there is the cooling tank with a volume of 2000 litres, and a washing machine with washable heads. The milking begins with the automatic opening of the gate to the dairy. When the cows are ready for milking, the wipes are washed and wiped off with paper towels, followed by the obligatory removal of the first jeans; then the dairy unit is installed in the wake. The entire herd's milking of 42 cows lasts for about 1.5 hours. After that the milking units are roughly washed to remove larger, rough dirt, which lasts for about 45 minutes. The overall cleaning of the system depends mainly on the water temperature. When the washing is complete, the machine is switched off automatically. Milk is stored in the tank for approximately 48 hours, and the removal to the dairy is guaranteed for at least another day. The milk that comes directly from the parlour system to the tank has got temperature between 22 and 23 ºC. Milk is cooled to 4 ºC temperature.

SPIonWeb tool

The SPIonWeb tool developed at TU Graz (http://spionweb.tugraz.at) is a license free software for estimating the ecological footprint, CO_2 emissions and GWP. The ecological footprint of each milking and cooling system was estimated by including environmental impacts related to fossil-C, air, water, soil, non-renewable, renewable and area resources.

Calculation of fossil-C assumed sedimentation of carbon to ocean beds, which requires about 500 m² of sea ground per year to put 1 kg of carbon back into the long-term (fossil) storage of the seabed.

The footprint for emissions to water is based on a replenishment rate, which is calculated on the precipitation rate in a specific geographic region of the compartment and a natural concentration of the emitted substance. In the SPI concept, the concentrations found in ground water are the reference for each natural compartment. The footprint of a given emission flow is therefore the area that is necessary to provide so much pure water via the seepage rate that may dilute the emission to the reference concentration of the emitted substance in ground water.

The footprint for emissions to soil is similar to the footprint for emissions to water, and it is calculated based on the regeneration rate of the compartment soil calculated as compost generated from grassland and the natural concentrations of the emitted substances in the top soil.

The footprint for emissions to air does not have a natural replenishment rate as do the other compartments, but the natural emissions of gaseous substances by forests are taken as a reference. The footprint for emissions to air is calculated as the area of forest that emits the same amount as the emission in question

One kilogram of CO_2 emissions or releases are calculated from the “Area for fossil carbon”, where the extracted fossil carbon and carbon based materials are assumed to be oxidized to CO_2 over the life cycle and finally to end up as CO_2 emission to the atmosphere.

GWP (global warming potentials) are calculated on the basis of GWP factors i. e. carbon dioxide equivalent (CO_{2e}), where exhausts gases components are converted to CO_{2e} by multiplying their amounts for instance (CH_4 has 25 and N_2O 298 higher GWP then CO_2 itself). The sum of CO_2 life-cycle-emissions equivalents of all input processes and other GWP relevant impacts is the total GWP measured in kg CO_2 equivalent Kettl (2013).

Input data

Data for this study was retrieved from interviews as well as measurements of working process on two different types of milking farm, whereby the one-week lasting chronometric measurements were considered as a basis for estimation of ecological footprint. The following input parameters were first measured chronometrically: time of milking per cow (min), amount of milk per cow (l), the average amount of energy spent for milking one cow (kW), the average amount of energy spent for 1 liter of milk per cow (kW), the amount of energy spent for cooling of 1 liter milk (kWh) and the amount of water required per washing of all equipment (l).

RESULTS AND DISCUSSION

The average quantity of milk per cow

Table 1 represents the average quantity and standard deviation of milk per cow per one milking on each farm. As seen, on average 9.55 l per cow was produced on farm 1 and 11.43 l per cow on farm 2. The difference of 1.88 l depends on better fodder quality, variety, day of lactation as well as type of housing, which is strongly connected with animal behavior.

Table 1 Average quantity of milk per cow

	Cows (n)	Average (l)	St. deviation (l)	CV (%)
Farm 1	17	9.55	2.18	22.82
Farm 2	42	11.43*	3.26	28.52

*significant t-test at $p<0.05$

The average time of milking per cow

The total time of milking took on average 1 hour for herd on farm 1 and 1 hour and 30 minutes for herd on farm 2 (Table 2). Contrary, the milking of one cow took 7.46 minutes on farm 1 and 6.42 minutes per cow on farm 2, respectively, which means that the outflow of milk was quicker in herd 2. The main reason lies probably in the varieties of cow, because 20% of all animals is Holstein-Frisien breed on the farm 2, while on farm 1 all cows belongs to Simmental breed.

Table 2 Average time of milk per cow

	Cows (n)	Average (min)	St. deviation (min)	CV (%)
Farm 1	17	7.46	2.27	30.43
Farm 2	42	6.43 $^{n.s.}$	2.43	37.79

$^{n.s}$ not significant t-test at $p<0.05$

The average electricity consumption per milking of one cow

The average electricity consumption amounts to 0.083 kWh per one milking of one cow on farm 2 and 0.088 kWh per one milking of one cow on farm 1 (Table 3). The quantity of electrical energy is directly correlated to average time of milking, since the nominal power of vacuum pumps is similar on both farms.

Table 3 Average amount of electrical energy per cow and one milking

	Cows (n)	Average (kWh)	St. deviation (kWh)	CV (%)
Farm 1	17	0.088	0.027	30.68
Farm 2	42	0.083 $^{n.s.}$	0.032	38.55

$^{n.s}$ not significant t-test at $p<0.05$

However, the outflow of milk differs significant between the cows inside the same herd. For instance, on the farm 1, for milking of cow 'Boka' only 0.048 kWh was spent and contrary 0.142 kWh per milking of cow 'Riba'.

The average electricity consumption per milking of 1 liter of milk

The average electricity consumption amounts to 0.0073 kWh per milking of one liter of milk on farm 2 and 0.0092 kWh per one milking of one cow on farm 1, respectively (Table 4). The smaller amount of electrical energy per one liter of milk on herd 2 is primary connected with higher average quantity of milk per cow and quicker milk outflow and not with milking system itself.

Table 4 Average amount of electrical energy per cow and one milking

	Cows (n)	Average (kWh)	St. deviation (kWh)	CV (%)
Farm 1	17	0.0092	0.0020	22.73
Farm 2	42	0.0073 $^{n.s.}$	0.0023	28.92

$^{n.s}$ not significant t-test at $p<0.05$

The electricity consumption for cooling of 1 liter of milk

On the farm 1 for cooling and storage of milk in 1000 l tank 5.956 kWh was spent on average in 48 hours during our measurements, which means 0.0059 kWh per 1 liter of milk. However, in warmer part of the year the energy consumption can be even for 12% higher. On the other side, for cooling the milk in the modern 2000 l tank on average 61.45 kWh was spent on farm 2, which amounts to 0.0031 kWh per 1 liter of milk.

Water consumption for cleaning the system

The average consumption of water per one cleansing of pipeline system amount to 56 l, while per cleansing of parlour system 50 liters or 10.6% less is spent after each milking, so annual amount is 4.380 liters less than on the farm 1.

Table 5 Average split of dairy farm electricity use in kWh per 1 liter of milk/lactation

	Farm 1 1 litre milk (n=17)	Farm 2 1 litre milk (n=42)	Farm 1 Lactation (n=17)	Farm 2 Lactation (n=42)
Water heating	0.0079	Heat exchanger	47.3143	Heat exchanger
Water pumping	0.0076	0,0002	45.3429	1.5762
Milk cooling	0.0059	0.0031	35.4857	24.8000
Milking	0.0092	0.0073	55.2000	58.4000
Lighting	0.0010	0.0000	5.9143	0.2056
Other	0.0013	0.0000	7.8857	0.0010
Total	0.0329	0.0106	197.1429	84.9828

Estimation of ecological footprint and other emissions

Estimated ecological footprint, CO_2 release and GWP caused by all processes on a dairy farm (Table 5) during milking, cooling and storage of 1 litre milk on two different milking systems is represented in Table 6. Despite higher lactation of the average cow on farm 2, the ecological footprint for milking on auto-tandem parlour system is for 67.74% smaller than on the pipeline system. The main reason represents the innovative cooling system of milk on one side and heating of processing water on other side, which is based on the heat exchanger and thus save approximately 0.0079 kWh per each litre of milk. The footprint of processing the fresh water needed for cleaning of the milking system is in both cases practically the same and amount to 0.0005 m^2 anno/ for l litre of milk.

The estimated CO_2 release for auto-tandem parlour system is also for 67.67% smaller than the one emitted for milking with milking pipeline (8.3846 m^2 anno/ l). The main reason lies in the SPIonWeb assuming that the fossil fuels is still a dominant energy for producing of electricity.

In the case of global warming potential 0.0102 kg of CO_2 equivalent was estimated for milking on the parlour system and 0.0317 kg of CO_2 equivalent when milking on pipeline system. On this way 67.82% smaller GWP is emitted on the farm 2.

Table 6 Ecological footprint, CO_2 emissions and GWP for all operations during milking and cooling of 1 litre milk

Milking system	Footprint (m^2 anno/ l)	CO_2 (kg)	GWP (CO_{2eq})
Pipeline	8.3846	0.0300	0.0317
Auto tandem parlour	2.7050	0.0097	0.0102

CONCLUSIONS

Slovenian dairy production depends very much on the European market prices, which are wagging for almost second year after the milk quotas were abandonee, so dairy producers aim to increase farm income by maximizing milk yield per cow. However, this is not connected only with higher and better fodder demand, but also with increase cost of energy, manual labor and not least with rising of ecological impact of diary production. In the presented study the ecological footprint, CO_2 emissions and GWP was estimated with SPIonweb software on two Slovenian dairy farms. The results showed significant decrease of all ecological impacts whenever a newel milking and cooling technique (parlour milking system with heat exchanger) is used instead of old milking pipeline and refrigerator system, is used. On the farm 1 the old milking pipeline is used for milking 17 cows, and on the farm 2 42 cows is milked with modern 2 x 3 auto tandem parlour system. It was shown that ecological footprint for the average lactation of 6,000 liters of milk per cow annual footprint amounts to 50,307.6 m^2 anno/ l and it is for 57.99% bigger than on the farm 2 producing on the average 8,000 liters of milk per cow annual. Moreover, despite higher average lactation on the farm 2, the total emissions of CO_2 caused by electricity and water consumption amount to 77.5 kg, which for 56.89% less than on the farm 1. Also, the GWP on the farm 1 is almost double of that on the farm 2 (190.2 kg versus 81.6 kg).

ACKNOWLEDGEMENTS

The authors also acknowledge the vital contributions made by Marko Pliberšek. The results presented are an integral part of the project CRP V4-1815 entitled "Reducing of draught stress and increasing of soil fertility by introducing conservation (conservation) soil tillage into sustainable agriculture", which is financed by the Slovenian Research Agency and the Ministry of Agriculture, Forestry and Food of the Republic of Slovenia.

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POTENCIJALNO SMANJENJE EKOLOŠKOG OTISKA, EMISIJE CO_2 I POTENCIJALA GLOBALNOG ZAGRIJAVANJA (GWP) KORIŠTENJEM AUTOMATIZIRANOG TANDEM IZMUZIŠTA S IZMJENJIVAČEM TOPLINE

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SAŽETAK

Intenzivnija proizvodnja mlijeka dovela je do aktivnosti koje značajno utječu na ekosustav ne samo zbog proizvodnje i dorade krme, nego i zbog mužnje te hlađenja mlijeka, pa je procjena da će u budućnosti utjecaj mljekarstva na okoliš biti značajan. U našoj studiji je korišten indeks održivosti procesa (SPI) za procjenu ekološkog otiska, emisije CO_2 i potencijala globalnog zagrijavanje (GWP) na dvije farme opremljene različitim sustavima za mužnju i hlađenje mlijeka. Na poljoprivrednom gospodarstvu 1 koristi se stari mljekovod za mužnju u 2 staklene posude, električni bojler te rashladni sustav s kompresorom. Nasuprot tome, farma 2 opremljena je modernim 2 x 3 auto tandem izmuzištem s izmjenjivačem topline, koji služi za hlađenje mlijeka i zagrijavanje vode za čišćenje sustava. Na farmi 1 godišnje se proizvodi prosječno 6.000 kg mlijeka po kravi, a na farmi 2 prosječna godišnja proizvodnja iznosi 8.000 kg mlijeka po kravi. Na prvoj farmi ekološki otisak za mužnju i hlađenje 1 litre svježeg mlijeka iznosi 8,3846 m^2 /god. l, a na drugom gospodarstvu samo 2,7050 m^2 /god. l. Štoviše, na farmi 2 također su ukupne emisije CO_2 i GWP za mužnju i hlađenje 1 litre mlijeka manje za 67,67% odnosno 67,82% u usporedbi sa farmom 1. Rezultati naših istraživanja pokazali su da moderni sustavi za mužnju nisu nužni samo zbog manjeg utroška vremena i ručnog rada, nego i značajno smanjuju-negativni utjecaj na okoliš.

Ključne riječi: *mljekovod, auto tandem izmuzište sustav, ekološki otisak, indeks održivosti procesa (SPI)*

47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

ENERGY PRODUCTION FROM THE WALK OF THE ANIMALS IN PADDOCK BY THE USE OF PIEZOELECTRIC ELEMENTS

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SUMMARY

This paper focuses on finding an optimum solution that uses piezoelectric elements (integrated in panels, called walking parts), PE, to exploit the mechanical energy resulting from the walking of animals in paddock. For measurement of the results a special device was designed. Three different piezoelectric elements were used for fabrication of platform walking parts (Ceramic plate-2,85 MHz, PZT5 21x21x0,7 mm; Ceramic plate-41,5 KHz, PZT5X 70x10x0,48 mm; Ceramic plate-21 KHz, PZT Φ30x0,27 mm), fixed in different positions on the panels, charged at the same speed (200 N·s^{-1}) and the same different values for pushed forces (10, 20, 30, 40, 50 N), tested individually. By comparing theoretical and experimental values, was made a calculation of energy production which can be used at estimating of economic efficiency that clearly expresses the recovery period of investment costs in condition of low exploitation cost, corresponding to use of piezoelectric panels. The numerical results showed that the use of a harvester energy PE generates reasonably well electrical power outputs. The results can be used to develop new solutions for complementary energy resources in such farms necessities.

Keywords: *mechanical energy, piezoelectric panels, energy production, optimization*

INTRODUCTION

The energy crisis, together with environmental demands and increasing of consumption, imposes, imperatively the necessity for extend the use of renewable energy and promotion of new ways for obtaining such kind of energy, according with depleting of fossil fuels reserves, and taking into consideration the polluting effects on the ecosystem and global heating (Tucu and Filipovici, 2014; Tucu, 2014).

One important extensive research could be considered the technology to use different transducers, realized from different piezoelectric elements, manufactured for transform mechanical energy into electrical energy, however, for specific applications, but commercially expensive (Forero-Garcia et al., 2019; Anwar et al., 2017; Deterre et al.; 2012; Ismail and Ghani, 2013; Nelson, 2010; Oy and Ozdemir, 2016; Sodano et al., 2004 (1); Sodano et al., 2004 (2); Szarka et al., 2012; Toprak and Tigli, 2014; Abidin et al., 2018).

Such applications involve different aspects, from fundamental researches (the use of finite element model specific (De Marqui et al., 2009), introduction and use of bimorph cantilever model for piezoelectric energy harvesting from base excitations (Erturk and Inman, 2008; Erturk and Inman, 2009; Franco and Varoto, 2017), analysis under an elastic wave (Han and Huh, 2017), etc.), to practical solutions of special parts and modules, with different functions: parts for frequency tuning (Al-Ashtari et al, 2012), micro harvester for low level of acceleration fabricated with a CMOS compatible process (Defosseux et al., 2012), energy harvester for high power output at low frequencies (Dhakar et al., 2013), MEMS-based piezoelectric power generator for vibration energy harvesting (Fang et al., 2006) etc.

Starting from previous experience in micro energy harvesting technology based on mechanical vibration and mechanical stress and strain (pressure) (Nayan, 2015), present paper proposes a solution for optimize the use of piezoelectric elements, PE, to exploit the mechanical energy resulting from the walking of animals in paddock.

MATERIAL AND METHOD

For evaluate the performance of different piezoelectric pieces, three different piezoelectric elements were used for fabrication of platform walking parts (Ceramic plate-2,85 MHz, PZT5 21x21x0,7 mm (position 1 in figure 1); Ceramic plate-41,5 KHz, PZT5X 70x10x0,48 mm (position 3 in figure 1); Ceramic plate-21 KHz, PZT Φ30x0,27 mm (position 2 in figure 1)), those characteristics, based on deliver information, are presented in table 1. The sensors were fixed in different positions on the parts' panels. Each part was charged at the same speed (200 $N \cdot s^{-1}$), and different values for walking forces (10, 20, 30, 40, 50 N), five times in the same conditions. For the present study the piezoelectric elements were tested individually (without any connection between them: series, parallel or mixt).

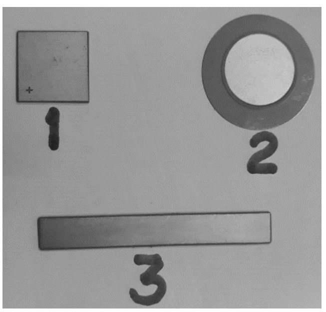

Figure 1 Piezoelectric pieces tested: 1-PZT5, 2-PZT, 3-PZT5X

The resulted impulses were registered on Oscilloscope HAMEG Type HM 1508 during the discharge on 360 Ω resistance (was established after testing different values by a variable electrical resistance). The structure of the experimental equipment is presented in figure 2, where 1- resistance variable, 2-panel parts with sensors and connectors, 3-oscilloscope.

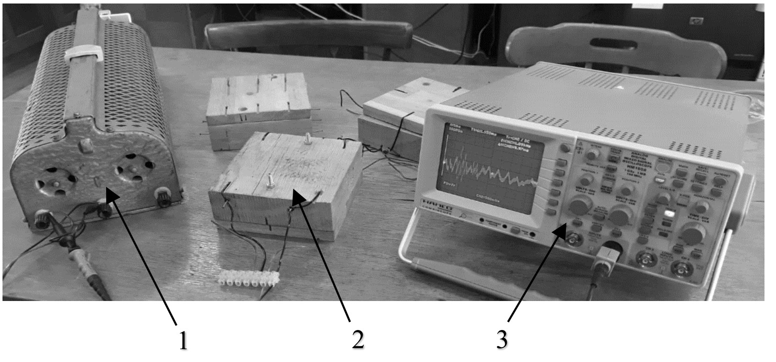

Figure 2 Structure of the experimental equipment

The surfaces of the oscillograms Si, were evaluated by planimetry. In hypothesis of the equivalence of practical surfaces determinate by planimetry and a rectangular surface, the rectangular resulted surfaces will be $S_i = U_i \cdot t_i$ (U_i - voltage, [V]; t_i – impulses duration), results the practical equivalent values for impulses duration $t_{ip} = S_{ip}/U_{ip}$).

Based on these values was calculated the harvest energy, Ehi, with relationship:

$$Ehi = \frac{{U_{ip}}^2}{R} t_{ip}, \text{ [J]} \quad (1)$$

To estimate the possibility for recovery of the investment were calculate the number of pulses necessarily, n_p, considering the equivalence 1 J = $2.777778 \cdot 10^{-7}$KWh, and the price 0.1 EUR·KWh^{-1}.

Table 1 Characteristics and price of piezoelectric elements

Characteristics	UM	PZT5	PZT5X	PZT
Dielectric constant, ε	$F \cdot m^{-1}$	3800±10%	4500±10%	2600±10%
Capacitance, C	$F \cdot 10^{-12}$	19000±10%	51000±10%	12000±10%
Curie Temperature, Tc	^0C	160	200	150
Dissipation factor, tgδ	%	≤ 2.0	≤ 2.5	≤ 2.8
Thickness Frequency, Fr	$Hz \cdot 10^6$	2.85±10%	0.021±5%	0.0025±5%
Resonant impedance, Zr	Ω	≤0.5	≤2.5	≤0.4
Electromechanical coupling coefficient, Kt	%	≥ 48	≥ 35	≥ 48
Mechanical quality factor, Qm	-	≥100	≥50	≥100
Piezoelectric Charge Constants, d33	10^{12}MeV	620	650	490
Price	EUR	3.44	9.24	0.35

RESULTS AND DISCUSSIONS

In figure 3 and 4 are presented two oscillograms, respectively from the tests of PZT Φ30x0,27 mm, corresponding to charging at 10 N, and PZT5 21x21x0,7 mm, corresponding to charging at 30 N (maximum voltage=5,05V). Table 2 presents the final results for tested piezoelectric pieces, presented in figure 1 and having characteristics from table1 (the initial values are the averages of five experimental determination).

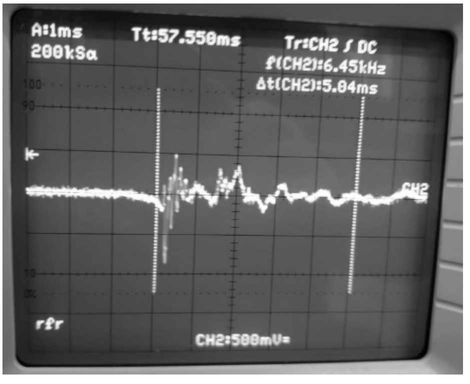

Figure 3 Oscillogram resulted for test of PZT Φ30x0,27 mm, 10 N

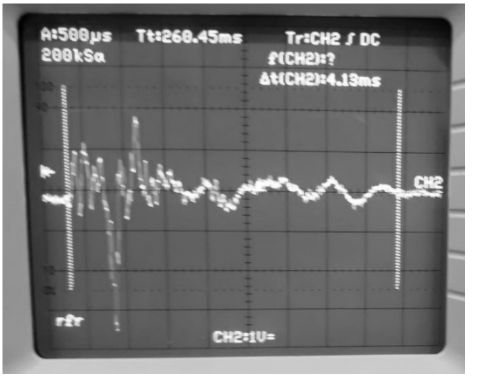

Figure 4 Oscillogram resulted for test of PZT5 21x21x0,7 mm, 30 N

Table 2 Final results for energy and investments recovery

Sensor	Price [EUR]	Force [N]	Ui [V]	t_{ip} [s]	E_{ip} [J]	Pulses for Investment recovery, n_p
1	3.44	10	1.45	0.0001482	8.654E-07	1.43099E+14
		20	3.54	0.0001419	4.939E-06	2.50740E+13
		30	5.05	0.0001454	1.030E-05	1.20195E+13
		40	5.82	0.0001474	1.387E-05	8.92737E+12
		50	6.67	0.0001401	1.732E-05	7.15044E+12
2	0.35	10	1.04	0.0001474	4.427E-07	2.84604E+13
		20	2.53	0.0001419	2.522E-06	4.99532E+12
		30	3.61	0.0001454	5.265E-06	2.39333E+12
		40	4.16	0.0001474	7.084E-06	1.77877E+12
		50	4.75	0.0001401	8.777E-06	1.43550E+12
3	9.24	10	1.98	0.0001471	1.602E-06	2.07674E+14
		20	4.81	0.0001417	9.109E-06	3.65193E+13
		30	6.87	0.0001452	1.903E-05	1.74790E+13
		40	7.90	0.0001474	2.556E-05	1.30163E+13
		50	9.02	0.0001402	3.167E-05	1.05018E+13

The results confirm the recommendation for the use of PZT Φ30x0,27 mm. Also, during the experiments was observed the excessive fragility of the other two type of piezoelectric elements that didn't recommend also their use and maintenance (observed in the same mentioned experimental conditions).

For practical efficiency of such solutions must group (serial connection) two or more sensors in the same position on the panel parts. It will be necessarily to adapt the animals walking process on paddocks for increase economic efficiency.

CONCLUSIONS

The results confirm the feasibility of such solutions as new ways for obtaining renewable energies, but it will be necessary to adapt the farm organization and integrate the investments.

A lot of connected experiments will be necessary for realize the optimum solutions: optimize of piezoelectric elements position on panel parts, the connections between elements, the structure of electric circuit, etc.

The most efficient solution is to use piezoelectric elements cheaper, with low life-cycle costs, simple construction and exploitation, low effect on environment (energy balance and waste) and safety use. The investments recovery must be considered as essential criteria, calculated according with life-cycle costs.

The authors calculus effectuated in actual conditions for developing a co-financed project (maximum 40%), shows for a 1000 pig's farm a term of recovery of the supplementary investment of 12 years.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

THE USE OF SELF-ASSESSMENT IN OCCUPATIONAL RISK MANAGEMENT SYSTEM IN SMES FROM AGRICULTURE

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SUMMARY

Occupational health & safety (OHS) risk management becomes an important part of management, especially in small and middle-size enterprises (SMEs) from agriculture, in obvious conditions of disproportionately work-related injuries and deaths risks. Nowadays, a variety of standards have been developed to implement OHS risk management: ISO 45 000, ISO 31 000, CAN/CSA-Z1000 OHSAS 18001, etc. Sometimes it is difficult to apply both, due their content small contradictions and between law and economic conditions and/or enterprises resources. The main goal of the paper was to measure the efficiency and impact of work conditions by self-assessment of employees in SMEs from agriculture. The research analyzes the employees' perception on the work conditions using a questionnaire with 22 indicators (including technical, organizational and legal requirements), distributed at 34 employees in 14 SMEs specialized in agriculture from Timis and Arad counties, west side of Romania, based on its own methodology. The statistical analysis made by Microsoft Excel 2016 and STATGRAPHICS Centurion revealed differences between opinions, maximum values in the case of "presentation of work accidents", P4 (Average 4,76 and Standard Deviation 3,58) and "knowledge of health problems generated by incidents", P6 (Average 4,69 and Standard Deviation 3,51). The conditions most important ranked were "first-aid kit on each section", P1 (average 8,81, median 9,5 and standard deviation 1,67) and "fire extinguishers in each space", P2 (average 8,73, median 10 and standard deviation 1,72). The results were used to recommend elements for optimization of OHS risk management system specific SMEs from agriculture.

Keywords: *ranking, efficiency, impact of work conditions, perception, optimization*

INTRODUCTION

Occupational health & safety (OHS) risk management, nowadays takes a crucial role in every technological process in agriculture environments, especially in small and middle-size enterprises (SMEs) from agriculture, especially in obvious conditions of disproportionately work-related injuries and deaths risks (Crisan et al., 2017). Work in agriculture was classified as "hazardous occupation with high rates of injury and death" (Morgaine K.C. et al., 2014). In this kind of enterprises (SMEs), not only the work conditions are highly important, but also economic aspects, the insufficient resources could seriously affect the functionality of occupational health & safety (OHS) risk management (Mnerie et al., 2008).

Many OHS risks can be generated by external aspects as migration and immigration (Liebman et al., 2016; Neitzel R.L. et al., 2014), youth farm workers (Perla M.E. et al., 2015) and absence of OHSAS certification of accreditation.

On the other hand, OHS risk management systems may become a critical tool that can significantly improve safety and operating performance only after implementation of the OHSAS standards, (may be part of investments with strategic impact), but it is necessary to involve "empiric" evaluation methods (Abad, 2013).

Furthermore, auditors are often uncertain as to how they should handle psychosocial risks, which are only briefly mentioned in the standard, and the question therefore remains whether audits in practice cover these risks to a sufficient extent. Usually auditing practices do not ensure a consistent and encompassing coverage of such issues in their reports, and the results call for stronger inclusion of the psychosocial work environment in the standard, as well as in the accreditation and audit processes (Hohen and Hasle, 2018).

Classical approach has been adapted and enriched with new opportunities, thank to IT system evolution, especially in built up of online, real time and augmented reality (AR) systems (Tatic, 2018; Tatic and Tesic, 2015). All are designated for mobile devices as a tool for safeguarding health and safety, and the secure performance of tasks in a technological process by following virtual instructions in the workplace.

But, even the evolution of OHS risk management systems (OHSRMS), it is necessary to evaluate their efficiency based on safety performance and labor productivity, paying special attention to the returns to certified safety experience and employments perceptions (Abad, 2013).

The main goal of the paper was to measure the efficiency and impact of work conditions by self-assessment of employees in SMEs from agriculture, taking into consideration the possibilities to use the results for propose elements for optimization of theirs OHSRMS.

MATERIALS AND METHODS

The team used the questionnaires for evaluation of workers' perceptions about works' conditions.

The methods' items are presented in figure 1, and were established based on previous experience presented in other papers (Crisan et al., 2017; Gusetoiu et al., 2013; Gusetoiu et al., 2012).

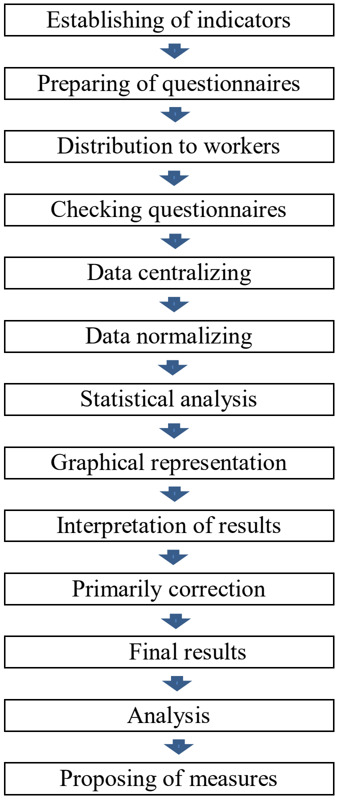

Figure 1 Research methodology

The indicators were established related to statistic of fatal accidents, injuries, and work illness, after a Brainstorming with 10 specialists in OHS risk evaluation and management (22 indicators (P1-P22), presented in table 1, columns1 and 2). The indicators were grouped in next sections:

- Section I: emergency situations (P1-P3);
- Section II: work accidents (P4-P6);
- Section III: tests of knowledge (P7-P8);
- Section IV: nonconformities (P9-P14);
- Section V: risks assessment (P15-P16);
- Section VI: work colleagues (P17-P19);
- Section VII: ITM (Territorial Labor Inspectorate) activities (P20-P22).

In the study 34 workers (noted L1-L34), from 14 SMEs specialized in agricultural activities (all have the same activities code, and dimensions from 6 to 19 workers – typical for small enterprises according to Romanian law), from Timis and Arad counties, west side of Romania. Each questioned person made ranking by given significance quotas from 0 (lowest level of importance) to 10 (highest level of importance), without any restriction.

There were took into consideration the following hypotheses:

- Workers have equilibrated interest on the chosen indicators;
- Could be a dependence between low level of significance of some indicators and workers less interesting, or vice-versa, according with own importance of OSH;
- No one methodology for evaluation of indicators were distributed, only worker opinion.

Microsoft Excel 2016 and STATGRAPHICS Centurion were used for the statistical analysis.

The results brought to light the differences between employees' opinions, maximum values and indicators hierarchy.

RESLTS AND DISCUSSION

Table 1 presents the results of factors' ranking, according to average of received points (column 3, noted "Aver."). Also, in table 1 there are presented the values of median (column 4, "Med."), standard deviation of received points (column 5, "STD.P") and variance (column 6, "Var.P").

After reception and analyzing of questionnaires, several aspects have been observed:

- The maximum sum of received points was at P2 (297 points), but, 2 questioned persons (workers), didn't give points for P1, and the average has maximum in this situation (for P1);
- The average of points given per one indicator was 127,68 points, approx. 128 points (17 persons (workers) raked over average and 17 below average);
- 10 workers have quoted all indicators over 6 points, awarding over 75% from maximum possible points;

Because two workers have underestimated the indicators and two workers overrated the indicators, a new statistical analysis was made after exclusion of their opinions, but the ranking was not modified.

Actually in relevant scientific literature such approach is poorly represented, because usually specialists in occupational risk are almost dedicated to middle and big enterprises (Weissbrodt et al, 2018; Bruhn and Frick, 2011; Filer and Golbe, 2003; Johnstone et al, 2011), or to specific risk factors (Nordgren and Charavaryamath, 2018; Buralli et al, 2018; Crowe et al, 2010; Damacus, 2014). According to the legal provisions and law enforcement procedures, in such enterprises the OHS responsibilities are in charge of administrator and of one of workers, already specialized.

For optimization of the OHSRMS, even there were some differences between opinions, the most important results were:

- Workers gave much more points for clearly formulated indicators (firefighting equipment, first-aid kit, exercises for evacuation, qualified workers);
- Indicators that needs high level of knowledge (work accidents, nonconformities, identification of dangers, ITM), were poorly classified;
- Also, misunderstanding generated poorly classification of some indicators that can increase significantly the working conditions (Protection & Prevention Plan, identification and remediation of nonconformities and dangers and risk assessment).

Table 1 Indicators of performance for work conditions

No.	Indicators	Average	Median	St. Dev.	Variance
1	2	3	4	5	6
P1	If exist first aid kit	8.813	9.5	1.667	2.777
P2	If exist firefighting equipment in each room	8.735	10	1.720	2.959
P18	Knowledge of seniority at present workplace of colleagues	7.824	8	1.706	2.910
P19	Knowledge of seniority at present workplace for total work period of colleagues	7.824	8	1.947	3.792
P3	Periodical exercises for evacuation	7.529	8.5	2.523	6.367
P17	Knowledge of qualified workers from total workers of SME	7.235	7.5	2.521	6.356
P8	Knowledge about qualification received at yearly tests regarding Prevention and Protection Plan and charges according to job description in last year	7.206	8	2.374	5.634
P7	Knowledge about qualification received at yearly tests regarding emergency situations for last year	6.824	8	2.854	8.145
P16	Assessing of number of risks for accident identified at risk assessing	5.824	6	3.365	11.322
P20	Knowledge about ITM (Territorial Labor Inspectorate) controls	5.375	5.5	3.199	10.234
P15	Assessing of global risk level for workplace	5.294	5	3.241	10.502
P21	Knowledge about level of penalty given by ITM after controls	5.065	5	3.331	11.093
P9	The existence of nonconformities at workplace	4.970	6	3.233	10.454
P22	Knowledge about existence of nonconformities identified by ITM	4.969	5	3.349	11.218
P11	Rapidly repairing of identified nonconformity at workplace	4.882	4.5	3.197	10.221
P4	Presentation of work accidents	4.758	5	3.576	12.790
P6	Knowledge about health problems, consequences of some incidents	4.697	5	3.512	12.332
P13	Identification of nonconformities	4.647	4.5	3.047	9.287
P12	Rapidly assessing of costs for repair a nonconformity	4.559	4	2.932	8.599
P14	Remediation of nonconformities	4.559	4.5	2.932	8.599
P10	Knowledge of nonconformities at workplace already repaired	4.500	4	3.031	9.188
P5	Knowledge about persons accidents at workplace	3.970	1	3.316	10.999

CONCLUSIONS

Optimization of OHSRMS, with an eye to increase the efficiency of resources' consumption must consider the workers' opinion and to be interested by perception at every workplace. There are necessarily not only legal and statute measures, and also specific action for improve the understanding of OHSRMS' own terms, procedures and actions (eq. PDCA (plan-do-check-act) or others).

Friendly language will be also strongly necessary.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

POLJOPRIVREDNA PROIZVODNJA REPUBLIKE HRVATSKE PRIJE I NAKON PRISTUPANJA EU

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SAŽETAK

Poljoprivredna proizvodnja Republike Hrvatske (RH) sudjeluje s manje od 1% u ukupnoj vrijednosti poljoprivredne proizvodnje Europske unije (EU). Tako mali udio navodi na zaključak da u okviru EU hrvatski poljoprivredni sektor ne igra značajnu ulogu. Međutim, zato tržišni trendovi na zajedničkom tržištu EU itekako utječu na relativno malo tržište poljoprivrednih proizvoda u Hrvatske. Temeljni je cilj ovog rada utvrditi promjene u proizvodnji najvažnijih poljoprivrednih proizvoda u RH prije (2000.–2013.) i nakon pristupanja Hrvatske Europskoj uniji (2014.–2017.). Pretpostavljeno je kako se ulaskom u EU ukupna poljoprivredna proizvodnja u RH količinski povećala, ali se i istovremeno vrijednosno smanjila, zbog promjene proizvodne strukture i smanjenja proizvođačkih cijena. Istraživanje je pokazalo da u strukturi ukupne hrvatske poljoprivredne proizvodnje dominira biljna proizvodnja (oko 65%) u odnosu na stočarsku (oko 35%). Poljoprivredna proizvodnja u odnosu na pretpristupno razdoblje povećala se količinski za 2,6% (od toga npr. proizvodnja žita za 1,2%, industrijskog bilja za 40,8% te krmnog bilja za 26,8%). Istovremeno, smanjena je proizvodnja povrća (za 15,8%), voća i grožđa (za 32,1%) te stočarska proizvodnja (8,8%). Posebno zabrinjava smanjenje govedarstva i svinjogojstva, koji su često pokazatelj stanja poljoprivrednog sektora. Značajno je smanjena vrijednost poljoprivredne proizvodnje (za oko 24%) što za posljedicu ima i smanjenje udjela hrvatske poljoprivrede u ukupnoj poljoprivredi EU za oko 32%. Hrvatska poljoprivredna politika mora pronaći odgovore za negativne trendove u stočarskoj proizvodnji što bi potaklo i promjenu proizvodne strukture kod biljne proizvodnje s povećanjem udjela stočnih krmiva, posebno žita.

Ključne riječi: *Hrvatska, Europska unija, poljoprivredna proizvodnja, zajedničko tržište*

UVOD

Republika Hrvatska (RH) je 1. srpnja 2013. postala punopravna članica EU, a s tim je datumom pokrenut niz promjena u mnogim društvenim i gospodarskim segmentima pa i u poljoprivrednom sektoru. Ulaskom u EU, Hrvatska je prestala primjenjivati dotadašnje sporazume o slobodnoj trgovini, uključujući i Srednjoeuropski ugovor o slobodnoj trgovini (engl. Central European Free Trade Agreement, skraćeno CEFTA). Istodobno, kao nova punopravna članica preuzela je važeće trgovinske sporazume Europske unije s trećim zemljama, između ostaloga i s članicama CEFTA-e.

Udio poljoprivrede, šumarstva i ribarstva RH u ukupnom bruto domaćem proizvodu (BDP) za razdoblje 2000./2017. godine iznosi oko 4%, dok je u bruto dodanoj vrijednosti (BDV) oko 5%. Sama poljoprivreda u BDP-u i u BDV- u sudjeluje s oko 3%. Vanjsko trgovinska bilanca hrvatske poljoprivrede je negativna (deficit od 0,9 milijardi eura, 2016.). Vrijednost vanjskotrgovinske razmjene poljoprivredno-prehrambenih proizvoda u 2016. godini čini 13,9 % vrijednosti ukupne robne razmjene (MP, 2016).

Hrvatski poljoprivredni sektor u okvirima EU, nije od veće važnosti te je vrijednost poljoprivredne proizvodnje manja od 1% ukupne vrijednosti poljoprivredne proizvodnje EU. Zbog toga promjene u poljoprivredi Hrvatske ne utječu značajnije na poljoprivrednu proizvodnju EU. Međutim, tržišni trendovi sa zajedničkog tržišta EU uključujući i kretanje cijena značajno utječu na relativno malo hrvatsko tržište poljoprivrednih proizvoda. No, ulaskom u EU Hrvatskoj se pružaju mogućnosti koje prije nismo imali, od tehnoloških i financijskih do prodajnih. Budući je EU najvažniji trgovinski partner pristupom se proširilo izvozno tržište ali i liberalizirao sam protok trgovine (Kersan, 1998)

Cilj rada je utvrditi promjene u poljoprivrednoj proizvodnji Hrvatske nakon njenog pristupanja EU.

MATERIJAL I METODE

U radu su korišteni podaci Državnog zavoda za statistiku (DZS), Statističkog ureda Europskih zajednica (EUROSTAT), Ekonomskih računa u poljoprivredi, Agencije za plaćanje u poljoprivredi, ribarstvu i ruralnom razvoju (APPRRR), FAOSTAT-a (The Food and Agriculture Organization Corporate Statistical Database) te dostupna znanstvena i stručna literatura. Kao metode analize prikupljenih podataka su se koristile deskriptivna metoda a od statističkih metoda: metoda trenda, stope promjene te metoda indeksa.

Poljoprivredna proizvodnja računata je primjenom žitnih jedinica (Anonimno 2013). Rezultati rada su prikazani grafički i tablično.

Rad se temelji na analizi i usporedbi prosječne poljoprivredne proizvodnje Hrvatske u pretpristupnom razdoblju i u razdoblju nakon ulaska u EU. Navedena su razdoblja specifična jer obuhvaćaju razdoblje prilagodbe i same integracije na tržištu EU. Vrijednost proizvodnje obuhvaća razdoblje 2005/2017., a proizvodnja 2000/2017. godina.

REZULTATI I RASPRAVA

Vrijednost poljoprivredne proizvodnje Hrvatske u pretpristupnom razdoblju je iznosila 2.775,87 milijuna eura odnosno 0,74% vrijednosti poljoprivredne proizvodnje EU. U razdoblju članstva u EU vrijednost poljoprivredne proizvodnje se smanjila za 24,04% što je dovelo i do smanjenja udjela u EU za 31,89% (Tablica 1.).

Tablica 1 Vrijednost poljoprivredne proizvodnje u Hrvatskoj od 2005. do 2017. godine
Table 1 Value of agricultural production in Croatia from 2005 to 2017

Razdoblje *Period*	Prosjek (mil. €) *Average (EUR mil)*	Verižni indeks *Chain index*	Udjel RH u EU *The share of the Republic of Croatia in the EU*	Verižni indeks *Chain index*
Pretpristupno Pre-accession	2.775,87	-	0,74	-
Članstvo u EU *Membership in the EU*	2.108,46	75,96	0,50	68,11
Prosjek 2005./17. *Average 2005/17.*	2.442,17		0,62	

Izvor: Autor prema podacima Eurostata
Source: Author according to Eurostat data

Udio poljoprivrede, šumarstva i ribarstva RH u BDV-u Republike Hrvatske u pretpristupnom razdoblju iznosio je 4,9%, a u razdoblju članstva 3,7%. Udio poljoprivrede, šumarstva i ribarstva RH u BDP-u Republike Hrvatske u pretpristupnom razdoblju je bio 4,07%, dok je u razdoblju članstva 3,03%. Razmjena poljoprivredno-prehrambenih proizvoda RH većinski se odvija s država članicama EU, kao što je to bilo u razdoblju prije pristupa (Grgić, Zrakić i Županac, 2012).

Vrijednost same poljoprivrede bilježi smanjenje u BDP-u i BDV-u u razdoblju nakon ulaska RH u EU. U pretpristupnom razdoblju vrijednost poljoprivrede je iznosila 1.285 milijuna eura a u razdoblju članstva smanjila se za 28,9% te je iznosila 912 milijuna eura. Udio poljoprivrede RH u BDV-u u pretpristupnom razdoblju je iznosio 3,5% te u BDP-u 3%, a nakon ulaska u EU udio u BDV-u smanjio na 2,3% te u BDP-u na 1,9%.

Poljoprivredna proizvodnja

Najveći dio poljoprivredne proizvodnje 2000./2017. čini biljna proizvodnja (žita, industrijsko bilje, krmno bilje, povrće i voće i grožđe) s oko 65%, dok je udjel stočarstva oko 35% (DZS, Biljna proizvodnja, 2018).

Poljoprivredna proizvodnja RH, preračunata preko žitnih jedinica, u razdoblju članstva povećala se za 2,6%. Najveće povećanje ostvarila je proizvodnja industrijskog bilja i to za 40,8%, ali istodobno bilježimo smanjenje kod povrća (15,8%), stočarstva (8,8%) te najviše kod voća (32,1%) (Tablica 2.).

Tablica 2 Poljoprivredna proizvodnja, tisuća tona ŽJ
Table 2 *Agricultural production, GU (grain unit) thousand tons*

Razdoblje *Period*	Žita *Grains*	Indu. bilje *Industrial crops*	Krmno bilje *Fodder*	Povrće *Vegetables*	Voće i grožđe *Fruit and grapes*	Stočarstvo *Livestock*	Ukupno *Total*
Pretpristupno *Pre-accession*	2.892	712	702	99	228	2.662	7.294
Članstvo u EU *Membership in the EU*	2.926	1.003	890	83	155	2.427	7.483
Promjena, % *Change*, %	1,2	40,8	26,8	-15,8	-32,1	-8,8	2,6

Izvor: Isti kao za Tab. 1
Source: Same as for Tab. 1

Žita

U pretpristupnom razdoblju na žetvenoj površini od 557.611 ha proizvedeno je ukupno 2.892.415 tona žitarica s prirodom po hektaru od 3,95 tona. U razdoblju nakon ulaska u EU žetvene površine su se smanjile za 11%, ali se proizvodnja povećala za 1,2% uglavnom zbog povećanja priroda. Najveće povećanje proizvodnje od ulaska u EU ostvareno je kod proizvodnje ječma (7,5%), dok je najveće smanjenje u istom razdoblju zabilježeno kod raži (37,3%) (Tablica 3.).

Tablica 3 Proizvodnja žita u Republici Hrvatskoj, tisuća tona ŽJ
Table 3 Production of cereals in the Republic of Croatia, GU (grain unit) thousand tons

Razdoblje *Period*	Pšenica *Wheat*	Raž *Rye*	Ječam *Barley*	Zob *Oat*	Kukuruz *Maize*	Ukupno *Total*
Pretpristupno *Pre-accession*	806	5	208	65	1.808	2.892
Članstvo u EU *Membership in the EU*	762	3	223	69	1.868	2.926
Promjena, % *Change*, %	-5,4	-37,3	7,5	6,1	3,3	1,2

Izvor: Isti kao za Tab. 1
Source: Same as for Tab. 1

U strukturi proizvodnje žita najvažniji je kukuruz (Zrakić i sur., 2017.). Udio kukuruza u proizvodnji žita povećao se s 62,1% u pretpristupnom na 63,8% u razdoblju nakon ulaska u EU. Pšenica je po udjelu druga kultura, ali bilježi smanjenje s 28,2% u pretpristupnom na 26,0% u razdoblju nakon ulaska u EU.

U pretpristupnom razdoblju proizvedeno je 1.808.404 t kukuruza na 301.449 ha, a prirod po ha bio je 5,99 tona. U razdoblju nakon ulaska u EU proizvodnja kukuruza se povećala za 3,3%, dok su se površine smanjile za 15,8%, u odnosu na promatrano pretpristupno razdoblje. Primjena kvalitetnih agrotehničkih mjera uz povoljne klimatske prilike za uzgoj kukuruza omogućile su povećanje prinosa na 7,35 t ha^{-1}.

Pšenica je u pretpristupnom razdoblju zauzimala 172.078 ha proizvodnjom od 805.890 t i s prinosom od 4,66 t ha^{-1}. U razdoblju nakon ulaska u EU površine su se smanjile za 2,6%, proizvodnja za 5,4% dok se prirod povećao na 5,30 t ha^{-1}.

Ječam je treće žito (oko 7% ukupne proizvodnje žita). U pretpristupnom razdoblju proizvodnja ječma je bila 207.515 tona na 58.216 hektara i s prirodom 3,56 t ha^{-1}. Nakon ulaska u EU proizvodnja se povećala za 7,5%, površine su se smanjile za 14,1% uz povećanje priroda za 24,4%.

Industrijsko bilje

Industrijsko bilje zauzima treće mjesto s prosječno 11% poljoprivredne proizvodnje. U pretpristupnom razdoblju na površini od 126.155 ha, proizvedeno je ukupno 712.308 tona industrijskog bilja s prirodom po hektaru od 10,86 tona. U razdoblju nakon ulaska u EU površine su se povećale za 32,1%, proizvodnja za 40,8%, te se povećao i prirod na 15,07 t ha^{-1}. Najveće povećanje u proizvodnji od ulaska u EU su ostvarili uljana repica, soja i suncokret, dok je duhan jedina kultura koja bilježi smanjenje proizvodnje.

Tablica 4 Proizvodnja industrijskog bilja, tisuća tona ŽJ
Table 4 Production of industrial crops, GU (grain unit) thousand tons

Razdoblje *Period*	Šećerna repa *Sugar beet*	Uljana repica *Rapeseed*	Suncokret *Sunflower*	Soja *Soybean*	Duhan *Tobacco*	Ukupno *Total*
Pretpristupno *Pre-accession*	284	77	154	170	27	712
Članstvo u EU *Membership in the EU*	288	188	210	292	24	1.003
Promjena, % *Change*, %	1,4	145,0	35,9	72,4	-12,7	40,8

Izvor: Isti kao za Tab. 1
Source: Same as for Tab. 1

Proizvodnja šećerne repe je od iznimne važnosti za RH. U pretpristupnom razdoblju na površini od 25.261 ha proizvedeno je 284.327 tona šećerne repe s godišnjim prirodom od 45,09 t ha^{-1}. U razdoblju članstva površine su se smanjile za 29,9%, a proizvodnja se povećala za 1,4% zahvaljujući prirodu koji se povećao za 44,1%. Udio šećerne repe u proizvodnji industrijskog bilja smanjio se s 39,6% u pretpristupnom na 28,8% u razdoblju članstva.

U pretpristupnom razdoblju na površini od 48.433 ha proizvedeno je 469.626 tona soje s godišnjim prirodom od 2,34 t ha^{-1}. U razdoblju članstva površine su se povećale za 54,7%, proizvodnja za 72,4% zahvaljujući povećanju priroda.

Suncokret se uglavnom koristi za proizvodnju jestivog ulja, a osim toga, nusproizvod prerade suncokreta (suncokretova pogača) koristi se kao kvalitetna stočna hrana za tov junadi. U pretpristupnom razdoblju na površini od 31.208 ha proizvedeno je 154.481 tona suncokreta s godišnjim prirodom od 2,47 t ha^{-1}. U razdoblju članstva površine su se povećale za 17,6% te proizvodnja za 35,9%.

Krmno bilje

U strukturi poljoprivredne proizvodnje, krmno bilje zauzima četvrto mjesto s prosječnim udjelom od oko 10%. U pretpristupnom razdoblju na površini od 384.439 ha, proizvedeno je ukupno 701.731 tona krmnog bilja s prirodom po hektaru od 10.67 tone. U razdoblju nakon ulaska u EU površine su se povećale za 74,8%, proizvodnja za 26,8%, a prirod se povećao na 12.63 t ha^{-1} u odnosu na pretpristupno razdoblje.

Najveće povećanje u proizvodnji ostvario je kukuruz za zelenu krmu, a slijede ga lucerna i trajni travnjaci, dok djetelina i mješavine bilježe smanjenje proizvodnje za 46% u odnosu na pretpristupno razdoblje.

Proizvodnja kukuruza za zelenu krmu je veća 50,1%, površina 24% te prirod 23,5%.

U pretpristupnom razdoblju na površini od 316.811 ha proizvedeno je 216.731 tona trajnih travnjaka s godišnjim prirodom od 2,35 t ha^{-1}. U razdoblju članstva površine su se povećale za 92,7%, proizvodnja samo za 11,7%, a jedan od razloga je što se prirod smanjio za 44,7% u odnosu na pretpristupno razdoblje. Iako se u razdoblju članstva bilježi veliko povećanje površine trajnih travnjaka, udio proizvodnje trajnih travnjaka u ukupnoj proizvodnji krmnog bilja smanjio se s 31,9% u pretpristupnom na 27,5% u razdoblju članstva.

Površine lucerne smanjile su za 0,5%, ali zahvaljujući povećanju priroda za 13,9%, povećala se proizvodnja za 13,3%.

Povrće

Najmanji udio u ukupnoj poljoprivrednoj proizvodnji ima proizvodnja povrća (Hadelan i sur. 2015.). U pretpristupnom razdoblju na površini od 26.866 ha, proizvedeno je ukupno 98.535 tona povrća s prirodom po hektaru od 18,37 tona. U razdoblju članstva površine su se smanjile za 35,6%, ali se povećala proizvodnja (15,8%) zbog povećanja priroda. Najveće povećanje u proizvodnji ostvarila je mrkva čija se proizvodnja povećala za 80% u odnosu na pretpristupno razdoblje, dok je najveće smanjenje u istom razdoblju zabilježeno kod graha (suho zrno) za 58,6%.

U strukturi proizvodnje povrća najvažnije mjesto ima krumpir koji bilježi smanjenje udjela u proizvodnji povrća s 68,2% u pretpristupnom na 61,6% u razdoblju članstva. U pretpristupnom razdoblju na površini od 14.941 ha proizvedeno je 67.459 tona krumpira s godišnjim prirodom od 15,19 t ha^{-1}. U razdoblju članstva površine su se smanjile za 33% te je zbog povećanja priroda manje smanjenje proizvodnje (za 24,2%). Domaća proizvodnja krumpira ne pokriva domaću potrošnju, s istom tendencijom i u budućem srednjoročnom razdoblju (Gugić i sur., 2014).

Luk i češnjak u strukturi proizvodnje povrća zauzimaju drugo mjesto s oko 6,5% ukupne proizvodnje povrća. U pretpristupnom razdoblju proizvodnja luka i češnjaka je bila 5.648 tona na površini od 1.037 hektara i s prirodom od 18,18 t ha^{-1}. U razdoblju članstva proizvodnja se povećala za 35,3%, površine za 4,7%, a prirod za 29%.

U pretpristupnom razdoblju proizvedeno je 4.937 t kupusa na 1.649 ha uz prirod od 20,36 tona. U razdoblju članstva proizvodnja se smanjila za 7,4%, površine za 22,3% dok se povećao prirod za 22,9%.

Voće i grožđe

Hrvatska ima izvrsne klimatske, pedološke i hidrološke potencijale za proizvodnju voća i grožđa (Grgić, Gugić i Zrakić, 2011). Unatoč tome, proizvodnja voća i grožđa sudjeluje s 2 do 3% u ukupnoj poljoprivrednoj proizvodnji.

Od voćnih kultura značajna je proizvodnja jabuka. Analiza grupe autora Cerjak i sur. (2016) ukazuje na pozitivne trendove na tržišta jabuke u razdoblju 2000./2008., ali i nedostatke vezane uz nedovoljnu samodostatnost domaće proizvodnje odnosno značajan uvoz jabuke. Prema autorima državna potpora dala određene rezultate (veće površine pod jabukom), strukturni problemi sektora jabuka nisu riješeni. Pristupanjem Republike Hrvatske u punopravno članstvo Europske Unije (2013), rezultiralo je povećanjem inozemne konkurencije na domaćem tržištu (ukidanje carinskih zaštita za proizvode iz EU) jabuka, te smanjenjem prodajnih cijena (Čagalj i Strikić, 2017).

U pretpristupnom razdoblju na površini od 67.542 ha, proizvedeno je ukupno 227.628 tona voća i grožđa. U razdoblju članstva bilježi se smanjenje površina za 1,5% te proizvodnje za 32,1%.

U pretpristupnom razdoblju površine vinograda su bile 30.077 ha te proizvodnja 71.173 t. U razdoblju članstva površine su se smanjile za 19,7% te proizvodnja za 44,2%.

U pretpristupnom razdoblju na 5.769 ha proizvedeno je 39.210 t jabuka, da bi došlo do smanjenja površina za 2,8% te proizvodnje za 2,6%.

U pretpristupnom razdoblju proizvedeno je 16.121 t mandarinki na 1.330 ha te se proizvodnja mandarinka u doba članstva povećala za 33,6%, a površine za 58,2%.

Prerada maslina u maslinovo ulje postupno se povećava, a hrvatsko maslinovo ulje sve više postaje gospodarski važan potencijal u poljoprivrednoj proizvodnji mediteranske Hrvatske, i to znatno poboljšane kakvoće.

U pretpristupnom razdoblju pod maslinama je bilo 14.235 ha, a proizvodnja 9.011 t maslina odnosno 60.664 t maslinovog ulja. U razdoblju članstva površine su povećane za 31,8%, ali se proizvodnja smanjila za 19,1% te maslinovog ulja za 36,8%.

Stočarstvo

Prema Kraliku i Zmaiću (2013) rezultati njihova istraživanja pokazali su da mjere agrarne politike kao i državne potpore prije ulaska RH u EU nisu dali adekvatne rezultate. Posljedica toga bio je značajan uvoz tijekom cijelog razdoblja, goveđeg, svinjskog i peradskog mesa.

Udio stočarstva u ukupnoj poljoprivrednoj proizvodnji bilježi smanjenje s 36,8%, u pretpristupnom razdoblju na 32,5% u razdoblju članstva (Grgić i Zrakić, 2015.).

U pretpristupnom razdoblju prirast goveda je bio 461.817 t, a proizvodnja kravljeg mlijeka 512.835 t, ali se u vrijeme članstva prirast goveda smanjio za 12,3%, a proizvodnja mlijeka za 9,7% ili ukupno za 10,9%.

Tablica 5 Proizvodnja prirasta goveda i kravljeg mlijeka, tisuća tona ŽJ
Table 5 Production of the increase of cattle and cow's milk, *GU (grain unit) thousand tons*

Razdoblje *Period*	Prirast goveda – t *Increase of cattle-t*	Kravlje mlijeko - t *Cow's milk-t*	Ukupno -t *Total-t*
Pretpristupno *Pre-accession*	461.817	512.835	974.651
Članstvo u EU *Membership in the EU*	405.104	462.963	868.066
Promjena, % *Change*, %	-12,30	-9,70	-10,90

Izvor: Izvor: Isti kao za Tab. 1
Source: Same as for Tab. 1

U ukupnoj poljoprivrednoj proizvodnji, prosjek 2000./2017. godina, svinjogojstvo zauzima oko 11,5%. a u stočarskoj proizvodnji oko 32%.

U pretpristupnom razdoblju svinjogojstvo je oko 12,3% ukupne poljoprivredne proizvodnje, dok je u razdoblju članstva 9,2%.

U pretpristupnom razdoblju prirast svinja je bio 885.445 t, da bi se smanjio za 22,5%.

U ukupnoj poljoprivrednoj proizvodnji 2000./2017. godine, peradarstvo u prosjeku sudjeluje s 9% te 25,2% ukupne stočarske proizvodnje pri čemu na meso peradi otpada 24,8%, i na kokošja jaja 0,4%.

U pretpristupnom razdoblju prirast peradi je bio 644.049 t, a prosječna proizvodnja kokošjih jaja 11.885 t da bi se u vrijeme članstva povećao za 2,6% te proizvodnja kokošjih jaja smanjila za 19,4%.

Ovčarska i kozarska proizvodnja su grane koje se sve više razvijaju u Hrvatskoj (Antunović, Novoselec i Klir, 2013). Autori navode da je prilagodbom zakonima EU i uvođenjem novih znanstvenih, stručnih i tehnoloških dostignuća u području ovčarske i kozarske proizvodnje došlo do izrade novih uzgojnih programa iz područja ovčarstva i kozarstva (Antunović i sur., 2013).

ZAKLJUČAK

Istraživanje je pokazalo da se ukupna poljoprivredna proizvodnja RH u razdoblju nakon ulaska u EU povećala za 2,6% u odnosu na analizirano pretpristupno razdoblje.

Poljoprivreda Hrvatske sudjeluje u BDP-u RH s manje od 3%, U strukturi poljoprivredne proizvodnje prevladava biljna proizvodnja (oko 65%), dok stočarstvo sudjeluje s oko 35%.

Proizvodnja žita bilježi povećanje za 1,2% u odnosu na pretpristupno razdoblje. Proizvodnja industrijskog bilja povećala se za 40,8% pri čemu najveće povećanje bilježe uljana repica (za 145%) i soja (za 75%). Krmno bilje također bilježi povećanje proizvodnje (26,8%) u odnosu na pretpristupno razdoblje. Proizvodnja povrća se smanjila za 15,8% u odnosu na pretpristupno razdoblje. Najveće smanjenje od ulaska u EU dogodilo se kod voća i grožđa i to za 32,1% u odnosu na pretpristupno razdoblje.

Stočarska proizvodnja ostvarila je smanjenje za 8,8% u odnosu na pretpristupno razdoblje. Najveće smanjenje u proizvodnji bilježi svinjogojstvo, zatim govedarstvo, dok peradarstvo i ovčarstvo bilježe blago povećanje.

NAPOMENA

Rad je izvod iz diplomskog rada studenta Stjepana Krznara, mag. ing. agr., studenta diplomskog studija Agrobiznis i ruralni razvitak na Agronomskom fakultetu u Zagrebu.

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AGRICULTURAL PRODUCTION OF THE REPUBLIC OF CROATIA BEFORE AND AFTER EU ACCESSION

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ABSTRACT

Agricultural production of the Republic of Croatia (RH) accounts for less than 1% of the total value of agricultural production of the European Union (EU). So small share suggests that the Croatian agricultural sector does not play a significant role in the EU. Therefore, market trends in the common EU market have a profound impact on the relatively small market of agricultural products in Croatia. The aim of this paper is to identify changes in the production of the most important agricultural products in Croatia before (2000-2013) and after Croatia's accession to the European Union (2014-2017). It was assumed that by entering the EU, total agricultural production in the RH increased in quantity, but at the same time it decreased in value, due to changes in the production structure and the reduction of producer prices. Research has shown that the structure of total Croatian agricultural production is dominated by plant (about 65%) in relation to livestock production (about 35%). Agricultural production compared to the pre-accession increased in quantity by 2.6% (including e.g. cereals by 1.2%, industrial crops by 40.8%, and fodder by 26.8%). At the same time, vegetables production (by 15.8%), fruit and grapes (by 32.1%) and livestock production (8.8%) were reduced. There is concerning situation in the reduction of cattle and pig production, which are often an indicator of the agricultural sector state. The value of agricultural production significantly decreased (about 24%), which results in the reduction of the share of agriculture in total Croatian agriculture EU by about 32%. Croatia's agricultural policy must find answers to negative trends in livestock production, which would also trigger a change in the production structure in plant production with an increase in the share of livestock feed, particularly grains.

Keywords: *Croatia, European Union, agricultural production, common market*

47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

ANALIZA KORIŠTENJA SREDSTAVA IZ PROGRAMA RURALNOG RAZVOJA REPUBLIKE HRVATSKE 2014. – 2020. DO KRAJA 2017. GODINE

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SAŽETAK

Program ruralnog razvoja Republike Hrvatske 2014.-2020. odobren je 26. svibnja 2015. godine od Europske komisije. Programom ruralnog razvoja RH definirano je 6 prioriteta s 18 mjera čiji je cilj povećanje konkurentnosti hrvatske poljoprivrede, šumarstva, prerađivačke industrije, te unaprjeđenje životnih i radnih uvjeta u ruralnim područjima. Program je vrijedan oko 2.4 milijarde €, a do 2018. godine je doživio četiri izmjene. U fokusu ovoga rada su Mjera 4- Ulaganja u fizičku imovinu s podmjerama 4.1. Potpora za ulaganja u poljoprivredna gospodarstva i 4.2. Potpora za ulaganja u preradu, marketing i/ili razvoj poljoprivrednih proizvoda, te Mjera 6- Razvoj poljoprivrednih gospodarstava i poslovanja s podmjerama 6.1. Potpora mladim poljoprivrednicima i 6.3. Potpora razvoju malih poljoprivrednih gospodarstava. Kroz proteklo vremensko razdoblje za Mjere 4 i 6, potporu je zatražilo 10.058 korisnika, od čega su 2.922 korisnika isplaćena u ukupnom iznosu od 111.386.493,51 €. Izdano je 3.570 odluka o dodjeli sredstava u vrijednosti od 321.508.937,42 €, dok je ukupni iznos traženih potpora iznosio 999.190.504,63 € od čega je izdana 1.861 odluka o odbijanju u vrijednosti od 406.032.671,15 €. Od ukupnog zatraženog iznosa potpora, odobreno je 32,18%, dok ih je isplaćeno 34,64 %.

Ključne riječi: *Program ruralnog razvoja RH 2014.-2020., Mjera 4, Mjera 6, EAFRD*

UVOD

U Republici Hrvatskoj (RH) 99,24 % površine (56 594 km²) je ruralno (EUROSTAT, 2018), te na tom području živi 43% ukupnog stanovništva RH (1,82 milijuna stanovnika) (Ex-ante evaluacija, 2018). Nakon završetka IPARD-a (pretpristupni program Europske unije za razdoblje 2007. – 2013. godine koji je sastavni je dio IPA-e, Instrument pretpristupne pomoći, eng. Instrument for Preaccession Assistance), koji je za osnovne ciljeve imao pomoći državama kandidatima i državama potencijalnim kandidatkinjama u njihovom usklađivanju i provedbi pravne stečevine EU te pripremama za korištenje budućih EU fondova, Republika Hrvatska je od 26. svibnja 2015. godine odobrenjem Europske komisije započela Program ruralnog razvoja Republike Hrvatske (PRR RH) za razdoblje od 2014.-2020. godine. PRR RH definirano je 18 mjera koje imaju za cilj povećanje konkurentnosti hrvatske poljoprivrede, šumarstva i prerađivačke industrije, ali i unaprjeđenja životnih i radnih uvjeta u ruralnim područjima uopće. Ukupna vrijednost PRR RH za razdoblje 2014. – 2020. je oko 2.4 milijarde €, a sami PRR RH je dosada doživio četiri izmjene (http://ruralnirazvoj.hr). Ukupna predviđena EU sredstva za PRR RH u razdoblju 2014.-2020. iznose 2.026.222.500 €, dok ukupna javna sredstva potpore (EU i HR sredstva) iznose 2.383.294.500 €. PRR RH sastavni je dio Europskog poljoprivrednog fonda za ruralni razvoj (eng. European Agricultural Fund for Rural Development, EAFRD) koji se financira sredstvima Zajedničke poljoprivredne politike (ZPP) i pridonosi ostvarivanju ciljeva strategije Europa 2020 promicanjem održivog ruralnog razvoja u cijeloj Europskoj uniji (http://europski-fondovi.eu/eafrd). Republika Hrvatska je nakon iskorištavanja sredstava iz IPARD-a, pristupanjem u punopravno članstvo u EU (1. srpnja 2013. godine) stekla pravo na korištenje sredstava iz EAFRD-a. Sredstva fonda EAFRD predviđena su za korištenje poljoprivrednim gospodarskim subjektima, poljoprivrednim organizacijama, udrugama i sindikatima, udrugama za zaštitu okoliša, organizacijama koje pružaju usluge u kulturi zajednice, uključujući medije, udruge žena, poljoprivrednike, šumare i mlade. PRR RH sastoji se od 66 tipova operacija (TOP-ova) iz 40 pod-mjera unutar 18 mjera. Tipovi operacija su podijeljeni u 15 žarišnih područja, a unutar 6 prioriteta (Godišnje izvješće, 2017). Prioriteti su podijeljeni u skladu s aktivnostima iz EAFRD:

PRIORITET 1: Promicanje znanja i inovacija u poljoprivredi, šumarstvu i ruralnim područjima;

PRIORITET 2: Jačanje konkurentnosti svih vrsta poljoprivrede i jačanje održivosti poljoprivrednih gospodarstava;

PRIORITET 3: Promicanje organiziranja prehrambenog lanca i upravljanje rizicima u poljoprivredi;

PRIORITET 4: Obnavljanje, očuvanje i poboljšavanje ekosustava ovisnih o poljoprivredi i šumarstvu;

PRIORITET 5: Promicanje učinkovitosti resursa i pomaka prema klimatski elastičnom gospodarstvu s niskom razinom ugljika u poljoprivrednom, prehrambenom i šumarskom sektoru;

PRIORITET 6: Promicanje socijalne uključenosti, smanjenje siromaštva i gospodarski razvoj u ruralnim područjima.

Tipovi operacija 4.1.1. i 6.3.1. PRR RH odnose se na prioritet 2; jačanje konkurentnosti svih vrsta poljoprivrede i jačanje održivosti poljoprivrednih gospodarstava, pod žarišnim područjem 2A.. Žarišno područje 2A odnosi se na poljoprivredna gospodarstva kojima je dodijeljena potpora u okviru PRR RH za ulaganja u restrukturiranje ili modernizaciju. Tip operacije 6.1.1. PRR RH također ulazi u prioritet 2, ali pod žarišnim područjem 2B. Žarišno područje 2B odnosi se na poljoprivredna gospodarstva kojima je dodijeljena potpora u okviru PRR RH za plan razvoja poslovanja ili ulaganja za mlade poljoprivrednike. Tip operacije 4.2.1. PRR RH odnosi se na prioritet 3; promicanje organiziranja prehrambenog lanca i upravljanje rizicima u poljoprivredi, pod žarišnim područjem 3A. Žarišno područje 3A odnosi se na poljoprivredna gospodarstva koja primaju potporu za sudjelovanje u programima kvalitete, lokalnim tržištima i kratkim lancima opskrbe

Važna obilježja ruralnih gospodarstava u RH su da se sastoje od uglavnom malih i srednjih poljoprivrednih gospodarstava, od kojih se velika većina mikrosubjekata s visokim udjelom samozapošljavanja. Obzirom da mala i srednja poljoprivredna gospodarstva imaju visoki potencijal za stvaranje novih radnih mjesta u ruralnim područjima i jačanju gospodarstva, ona čine bazu potencijalnih korisnika PRR RH, što je i u skladu s prioritetima Zajedničke poljoprivredne politike (ZPP) gdje su takva gospodarstva označena kao ključni element gospodarskog razvitka EU.

MATERIJAL I METODE

Rezultati rada temelje se na podacima Godišnjih izvješća o provedbi PRR RH za razdoblje od 2014.-2020. godine (2014. – 2017.), Evaluacijskim izvješćima, Dokumentima za praćenje i evaluaciju PRR RH, Izvješćima Agencije za plaćanje u poljoprivredi, ribarstvu i ruralnom razvoju (APPRRR). U radu su analizirani podaci odabranih Mjera 4- Ulaganja u fizičku imovinu s podmjerama 4.1. Potpora za ulaganja u poljoprivredna gospodarstva i 4.2. Potpora za ulaganja u preradu, marketing i/ili razvoj poljoprivrednih proizvoda, te Mjera 6- Razvoj poljoprivrednih gospodarstava i poslovanja s podmjerama 6.1. Potpora mladim poljoprivrednicima i 6.3. Potpora razvoju malih poljoprivrednih gospodarstava. Od svih tipova operacija i mjera ove su u fokusu obzirom da se ruralna gospodarstava u RH sastoje od uglavnom malih i srednjih poslovnih subjekata s potencijalom stvaranja novih radnih mjesta, te da su u ovim tipovima operacija prihvatljivi troškovi nabavke mehanizacije i opreme.

U promatranim operacijama fokus je na objavljenim natječajima po godinama za navedene operacije, broju prijavljenih, odobrenih i odbijenih projekata, izdanim odlukama o dodjeli sredstava i njihovim vrijednostima, izdanim odlukama o odbijanju projekata i njihovim vrijednostima, broju isplaćenih projekata i njihovom vrijednostima.

Podaci se odnose na razdoblje od 2014. do 2018. godine. Za statističku obradu podataka korišten je statistički analitički softver SPSS (ver. 25.0).

REZULTATI I RASPRAVA

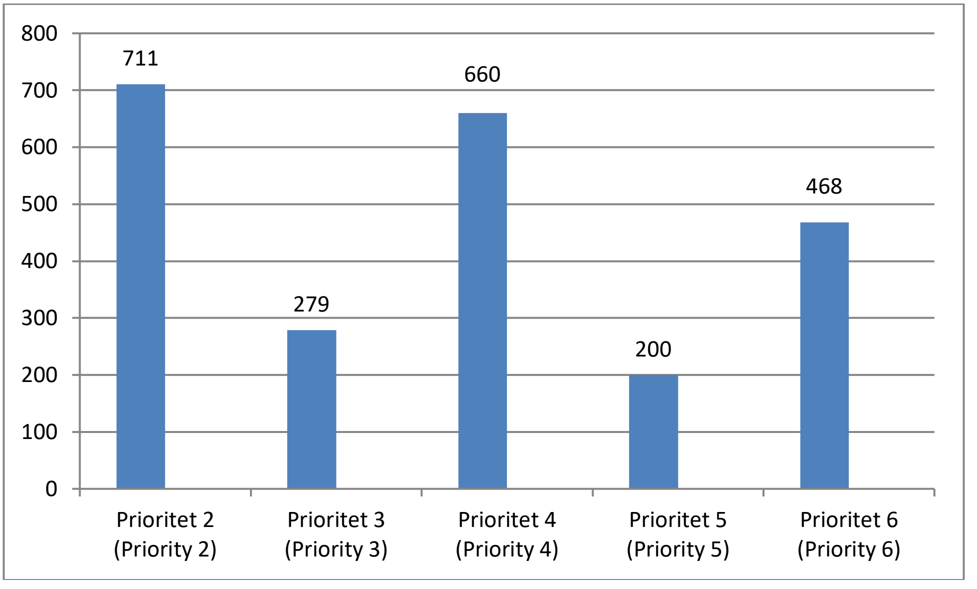
Od početka provođenja PRR RH pa do kraja 2017. godine (31. prosinca 2017.) RH je započela s provedbom 16 mjera, odnosno 29 podmjera kroz 48 TOP-a pod svih 16 žarišnih područja. Od ukupnih predviđenih javnih sredstava i sredstava EU u iznosu od 2.383.294.500 €, u promatranom razdoblju odobreno je 34 % javnih sredstava (813.372.640,78 €). Od ukupno odobrenih javnih sredstava, u 2017. godini odobreno je gotovo 50% sredstava (405.787.165,91 €) (Tablica 1).

Od početka provođenja PRR RH alocirano je za Prioritet 2 ukupno 711.003.205,43 €, od čega za žarišno područje 2A 592.135.000,00 €, dok je za žarišno područje 2B alocirano ukupno 54.339.869,28 €. Za prioritet 3 alocirano je ukupno 278.956.380,04 €, od čega za žarišno područje 3A 104.165.359,48 €. Za prioritet 4 alocirano je ukupno 659.748.724,27 €, prioritet 5 ukupno 200.597.894,12 €, te prioritet 6 ukupno 468.241.752,40 € (Grafikon 1). Najviše sredstava alocirano je za Prioritet 2 (31%), Prioritet 4 (28%), dok je najmanje sredstava alocirano za Prioritet 5 (9%).

Tablica 1 Alocirana, ukupno ugovorena i isplaćena sredstva u PRR RH po žarišnim područjima (€)
Table 1 Alocated, total contracted and paid funds for Programme of Rural Development for the Republic of Croatia for the period 2014-2020 (€)

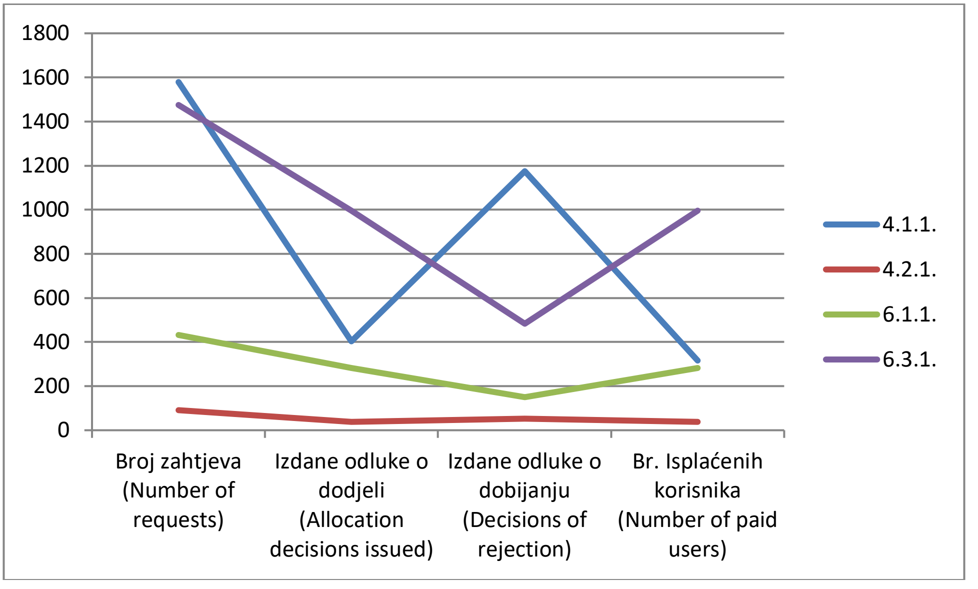
Žarišno područje *Focus area*	Alocirano *Alocated*	Ukupno ugovoreno *Total contracted*	Ugovoreno *Contracted* (2017)	Ugovoreno/ Alocirano *Contracted/ Alocated* (%)	Ukupno isplaćeno *Total paid*	Isplaćeno *Paid* (2017)	Isplaćeno/ Alocirano *Paid/Alocated* (%)
2A	592.135.000,00	361.266.780,15	130.656.507,63	61,01	174.916.602,45	54.188.048,57	29,54
2B	54.339.869,28	14.147.236,86	597.236,86	26,03	11.384.756,76	7.955.565,44	20,95
2C	64.528.336,15	13.025.817,44	13.025.817,44	20,19	195.822,93	195.822,93	0,30
3A	104.165.359,48	66.798.708,43	35.469.420,97	64,13	22.995.122,41	17.443.550,25	22,08
3B	174.791.020,56	54.331.601,53	19.548.926,77	31,08	49.667.913,18	23.105.165,24	28,42
P4	659.748.724,27	155.129.401,55	80.005.825,29	23,51	151.780.599,43	76.657.023,17	23,01
5C	94.055.294,12	1.263.817,23	1.263.817,23	1,34	-	-	0,00
5D	89.310.000,00	35.768.787,15	20.422.184,94	40,05	8.489.800,84	5.021.500,65	9,51
5E	17.232.600,00	9.497,93	6.872,22	0,06	9.497,93	6.872,22	0,06
6A	134.818.674,46	37.892,06	37.892,06	0,03	-	-	0,00
6B	333.423.077,94	106.073.586,07	100.920.418,45	31,81	6.385.206,09	4.116.547,67	1,92
TA	64.746.543,59	5.519.514,38	3.832.246,05	8,52	5.519.514,98	3.832.246,05	8,52
Ukupno *Total*	2.383.294.499,8	813.372.640,78	405.787.165,91	34,13	431344837,00	192522342,19	18,10

Izvor: Kalkulacije autora i prilagođeni prikaz Godišnje izvješće PRR RH (2017)
Source: Author calculations and adjusted review Annual report for Programme of Rural Development for the Republic of Croatia for the period 2014-2020 (2017)



Grafikon 1 Alocirana sredstva po prioritetima PRR RH 2014.-2020. u milijunima €
Graph 1 Alocated resources within priorities for Programme of Rural Development for the Republic of Croatia for the period 2014.-2020. in million €
Izvor: Kalkulacije autora / Source: Author calculations

U dosadašnjem razdoblju provođenja PRR RH, najviše zahtjeva 5.664 za potporu pristiglo je za Mjeru 6.3.1. „Potpora razvoju malih poljoprivrednih gospodarstava“ kroz 2 objavljena natječaja (Grafikon 2). Za drugi natječaj koji je bio otvoren do ožujka 2017. godine, administrativna kontrola je završila, ali nije bilo isplata. U prvom natječaju, od 1.475 zahtjeva, za 996 korisnika su izdane odluke o dodjeli sredstava (67.26 % od ukupno prijavljenih), a ukupno je isplaćeno svih 996 korisnika (100%). Druga mjera s najviše prijava 1.579 za potporu je Mjera 4.1.1. „Restrukturiranje, modernizacija i povećanje konkurentnosti poljoprivrednih gospodarstava“ kroz 7 objavljenih natječaja. Od 404 izdane odluke o dodjeli sredstava, što je 25.59 % od ukupno pristiglih zahtjeva, isplaćeno je ukupno 316 korisnika, odnosno 78.22 % (Grafikon 2). Za Mjeru 6.1.1. „Potpora mladim poljoprivrednicima, kroz 2 natječaja, pristiglo je ukupno 1.245 zahtjeva za potporu. Za drugi natječaj, koji je bio objavljen do veljače 2017. u cijelosti je završena administrativna obrada, ali nije bilo isplata. U prvom natječaju, na koji je pristiglo 432 zahtjeva, izdane su 282 odluke o dodjeli sredstava (65.28 % od ukupno pristiglih zahtjeva), dok je isplaćeno svih 282 korisnika (100%) (Grafikon 2). U promatranom vremenskom razdoblju, najmanje prijava 191 pristiglo je kroz 3 objavljenja natječaja za Mjeru 4.2.1. „Povećanje dodane vrijednosti poljoprivrednim proizvodima“. Za drugi i treći natječaj, administrativne kontrole do kraja 2017. godine su bile u tijeku. Na prvom natječaju pristigao je 91 zahtjev, a izdana je 41 odluka o prihvaćanju (45.01 % od ukupno pristiglih zahtjeva), dok je ukupno isplaćeno 36 korisnika (87.80 %) (Grafikon 2).



Grafikon 2 Ukupan broj predanih zahtjeva,izdanih odluka o dodjeli i odluka o odbijanju, te broj isplaćenih korisnika po odabranim mjerama za PRR RH od 2014.-2017. godine
Graph 2 The total number of submitted requests, issued decision of acceptance and issues of rejection, and the number of paid beneficiaries by selected measures for Programme of Rural Development for the Republic of Croatia in the period of 2014.-2017.
Izvor: Kalkulacije autora / Source: Author calcuations

Najviše prijava za potporu (5.644) bilo za Mjeru 6.3.1. „Potpora razvoju malih poljoprivrednih gospodarstava“, kroz 2 objavljena natječaja, dok je najmanje prijava (191) bilo za Mjeru 4.2.1. „Povećanje dodane vrijednosti poljoprivrednim proizvodima“, kroz 3 objavljena natječaja (Tablica 2). Najveći broj natječaja (7) u dosadašnjem vremenskom razdoblju objavljen je za Mjeru 4.1.1. „Restrukturiranje, modernizacija i povećanje konkurentnosti poljoprivrednih gospodarstava“, za koju je i zatraženo najviše potpore u iznosu od 643.726.495,76 €, od čega je odobreno ukupno 37.88% sredstava, dok ih je isplaćeno 30.240.642,05 € odnosno 12.40% imajući u vidu da je do kraja 2017. godine za 4 natječaja administrativna kontrola još bila u tijeku te da nije bilo isplata. Također, kao mjera s najviše prijava, Mjera 6.1.1. ima i najveći postotak prijava s izdanim odlukama o odbijanju (56.16 %). Najviše isplaćenih korisnika (996) je za mjeru 6.3.1. i to u ukupnom iznosu od 10.334.823,61 € (Tablica 2).

Tablica 2 Analiza odabranih mjera po natječajima i sredstvima u razdoblju 2014.-2017. godine
Table 2 Analysis of selected measures by tenders and funds from 2014-2017 year

Mjera *Measure*	Godina *Year*	Broj zahtjeva *Number of requests*	Tražena potpora *Requested funds*	Izdane odluke o dodjeli *Issued decisions*	Odobrena potpora *Approved funds*	Izdane odluke o dobijanju *Issued rejection decisions*	Broj Isplaćenih korisnika *Number of paid beneficiaries*	Iznos plaćene potpore *Amount of paid support*
4.1.1.	2015.	1.107	283.415.501,91	381	112.680.065,69	726	209	28.214.699,75
	2015.	373	148.017.166,35	23	10.660.606,43	350	4	636.163,58
	2016.	99	69.761.162,83	10	10.541.582,68	89	2	1.389.778,72
	2017.	246	58.768.295,70	30	9.0003.299,73	16	-	-
	2017.	53	28.813.729,84	11	8.626.666,94	-	-	-
	2017.	215	48.900.979,83	10	6.309.529,43	-	-	-
	2017.	10	6.049.659,30	10	5.001.937,21	-	-	-
Ukupno / *Total* 4.1.1.		2.103	643.726.496	475	243.823.688,11	1.181	215	30.240.642,00
4.2.1.	2015.	91	53.566.330,69	41	30.859.467,10	50	36	22.995.122,41
	2017.	88	42.828.895,33	30	17.935.183,72	-	-	-
	2017.	12	22.287.303,28	7	15.364.997,89	-	-	-
Ukupno / *Total* 4.2.1.		191	118.682.529,3	78	64.159.648,71	50	36	22.995.122,41
6.1.1.	2015.	432	21.900.577,01	35	14.104.605,34	150	282	11.302.743,57
	2016.	813	40.849.456,00	-	-	-	-	-
Ukupno / *Total* 6.1.1.		1.245	62.750.033,01	35	14.104.605,34	150	282	11.302.743,57
6.3.1.	2015.	1.475	22.391.254,33	996	15.053.818,56	479	996	10.334.823,61
	2017.	4.189	63.331.815,4	-	-	-	-	-
Ukupno / *Total* 6.3.1.		5.644	85.723.070,00	996	15.053.818,56	479	996	10.334.823,61

Izvor: Godišnje izvješće o provedbi PRR RH 2017.
Source: Annual report for Programme of Rural Development for the Republic of Croatia for the period 2014-2020 (2017)

ZAKLJUČAK

Za analizirane mjere i potpore iz PRR RH postoji veliki interes poljoprivrednika, što potvrđuje i veliki broj prijava po natječajima, dok je iskoristivost sredstava za pojedine mjere iznimno niska u odnosu na broj prijavljenih potpora. Od ukupno objavljenih 14 natječaja za analizirane mjere, do kraja 2017. godine bila je u tijeku administrativna kontrola za njih 8. Imajući u vidu činjenicu da je dodana vrijednost poljoprivrednog gospodarstva među najnižima u EU, svakako više pozornosti bi trebalo posvetiti Mjeri 4.2.1. „Povećanje dodane vrijednosti poljoprivrednim proizvodima“, za koju je u promatranom razdoblju bilo najmanje prijava. Od 2018. godine poljoprivrednicima u RH na raspolaganju su i mikro i mali zajmovi, te investicijski krediti, koji bi svakako trebali poboljšati konkurentnost poljoprivrednika kako na domaćem, tako i na inozemnom tržištu poljoprivredno – prehrambenih proizvoda.

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ANALYSIS OF ABSORBED FUNDS TILL THE END OF 2017 FROM THE RURAL DEVELOPMENT PROGRAMME OF THE REPUBLIC OF CROATIA FOR THE PERIOD 2014.-2020.

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ABSTRACT

The Program of the Rural Development of the Republic of Croatia for the period of 2014-2020 had been approved by the European Commission on May 26, 2015. The Rural Development Program of the Republic of Croatia defines 6 priorities with 18 measures aimed at increasing the competitiveness of Croatian agriculture, forestry, processing industry and improving living and working conditions in rural areas. The program is worth about 2.4 billion €, and have been four time changed until 2018. The focus of this paper is on the Measure 4 - Investments in Physical Property with sub measures 4.1. Aid for investments in agricultural holdings, and 4.2. Support for investment in the processing, marketing and /or development of agricultural food products, and Measure 6 - Development of farms and operations with sub measures 6.1. Support to young farmers and 6.3. Support to the development of small agricultural holdings. Over the past period for Measures 4 and 6, 10.058 beneficiaries were requested, of which 2.922 users were paid in the total amount of 835,398,701.29 kn. There were 3.570 decisions on allocation of funds in the amount of 2,411,317,030.68 kn, while the total amount of the requested grants amounted to 7,493,928,784.69 kn, of which were issued 1.861 rejection decisions worth 3,045,245,033.60 kn. Out of the total requested amount of aid, 32.18% was approved, while 34.64% was paid out.

Keywords: *Rural Development Programme of the Republic of Croatia for the Period 2014.-2020., Measure 4, Measure 6, EAFRD*

47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Pregledni rad
Review paper

ROMANIAN'S EXPERIENCE AND PERSPECTIVES REGARDING TO EDUCATION IN BIOSYSTEMS ENGINEERING

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ABSTRACT

The paper is an analysis regarding to the effect on the development of MSc in Biosystem Engineering at the Technical University of Cluj-Napoca. Contextually, starting with the European premise in this direction, educational partnerships and experience exchanges for this purpose, is being set up. Detailed statistics on the profile of recruited students and their employability are also presented. This is an argument for the need to develop studies in the Engineering of Biosystems for Agriculture. The experience gained in the development of this study program is quantified in the orientation directions of the specialist profile in this field and in identifying the future requirements imposed on the didactic process.

Keywords: *biosystems engineering, education, master's degrees, education, employment.*

INTRODUCTION

The concept of Biosystem Engineering has been used for the first time in the academic world since the 1960s, in the US, designating an area on the borderland between life sciences (biology, environment) and engineering. Specifically, the concept of biosystem engineering referred to the application of methods and principles of engineering in biology, for a better understanding, modeling of biological systems.

The subsequent evolution, the development of the concept and its application in more and more fields was achieved in accordance with the necessities of the major structural changes faced by society: climate change, increasing population, increasing environmental pollution, technological reorientation of agriculture, building a close relationship between human and nature.

In the ERABEE program, "Biosystem Engineering" is defined as "a field of engineering that integrates engineering science and design with applied biology, environmental and agricultural sciences. It represents an evolution of the Agricultural Engineering discipline applied to all living organisms not including biomedical applications. Therefore, Biosystems Engineering is the branch of engineering that applies engineering sciences to solve problems involving biological systems." (ERABEE, 2007).

In order to implement the above-mentioned principles, a new professional field, a specialist engineer in the Biosystem Engineering, was created. This will be able to apply the engineering principles and methods for solving problems involving biological systems in the field of agriculture, food industry, etc. This created the premises of the university curriculum orientation towards a new field, Biosystems Engineering in agriculture and food industry (Ros et al., 2005).

The context of the development of Master's degree in Biosystem Engineering

In the European Union Context, the emergence and development of university degree programs in the field of Biosystems Engineering applied in agriculture and food industry was slower, being required by two basic components: the evolution of the European educational framework and the technological reorientation of agriculture and the necessity to implement the principles of bio-system engineering in agriculture and food industry (Kosutic et al., 2006).

Also, the European tendency towards technological reorientation in the field of agriculture has led to the assimilation of a new approach to the Human - Soil - Agricultural machine, including the environmental condition as a component of equal importance. The necessity to implement the principles of Biosystem Engineering in practice, also required the creation of a new qualification on the labor market, a specialist engineer in systems bioengineering (Briassoulis and Panagakis, 2005). Efforts to promote these new concepts have resulted in initiatives to harmonize the curriculum for the training of specialists in this field, and also the need to define new occupational profiles. In this context, programs such as ERABEE have provided support for the development of a platform for dialogue between universities throughout the European continent.

The Romania representation in the ERABEE project is carried out by the Technical University of Cluj-Napoca, the Faculty of Mechanics, which represents a national pawn in the development of Biosystem Engineering education. In 2009 was developed an Msc program named “Engineering of Mechanical Biosystems for Agriculture and Food Industry” but in the context of what the labor market demands and current trends in the field of bio-system engineering, was renamed “Biosystems Engineering in Agriculture and Food Industry”. The Master's program has been developed in line with European trends in the modification of the curriculum specific to the training of specialists in agriculture and food industry, due to the demand of specialists applying the principles of bio-system engineering in agriculture and food industry and as a extension of bachelor education in the agricultural machinery field at Technical University from Cluj-Napoca, Mechanics Faculty (Filip, 2010).

Starting from these prerequisites, the main aim of the specialization "Biosystems Engineering in Agriculture and Food Industry" is: the formation of highly qualified specialists - engineers, graduates of the master cycle, in the field of mechanical engineering, according to the current economic and social needs of Romania, capable of responding to the social order in the agriculture and food industry, whose professional and scientific capacity meets the required quality criteria (Filip, 2008). There were also two components that formed the basis of the managerial analysis of the opportunity and the didactic and scientific potential to support this new program:

- investigating the need for training in the field, starting from the principles of a modern, sustainable agriculture;
- didactic capacity quantified by lecturers' training and applied scientific level defined by the level of endowment of the specialized laboratories in order to ensure adequate training, according to the principles agreed in ERABEE.

Of course, before these steps, were didactic and research initiatives that ensured the initiation and development of the field (Şahin et al., 2016).

MATERIALS AND METHODS

In order to investigate the training requirements of the specialists in the field of Agricultural Mechanics and Biosystem Engineering, starting from the principles of a modern and sustainable agriculture (Fuchs, 2007), was materialized in 2011 through an initiative of the Technical University of Cluj-Napoca, Faculty of Mechanics, respectively a study conducted at the national level. In this way, it has been tried to investigate the situation of agriculture at national level, the influencing main factors of Romanian farms efficiency, the national interest fields in agriculture and, the importance of implementing the principles of Biosystems Engineering for Romanian farmers.

Thus, a nationwide survey with a regional distribution was carried out, covering the regions with intensive agricultural activity. The survey was conducted in medium and large farms in 14 Romanians counties. The analysis of the data obtained from the survey shows that:

- young generations of agriculture and food industry specialists need to know the latest news in the field of agriculture and bio-systems (50% of respondents agree or totally agree with it);
- agricultural specialists must have knowledge in the field of Biosystem Engineering and they must be able to implement them in practice (57% of respondents agreed with this statement);
- one of the main factors that will lead to the efficiency of Romanian farms is the green energy and biomass production (65% of respondents are agreed with this statement, 0,7% of respondences being in full agreement with this);
- the production and use of renewable energy sources in agriculture, in line with the area potential is an important aspect in the future development of agriculture in our country (57,17% of respondents agreed with that: this aspect is very important and 43,83 % said it was just important. Noteworthy is that no farmer among the respondents did not respond negatively to this statement, which demonstrates the importance of acquiring knowledge and abilities in this field of young specialists).
- the production of raw material for the production of biomaterials for industry was also considered as an important aspect for farmers (64,28% of the respondents considered this important or very important, the remaining 35,74% having no opinion on this statement).

In this context (Figure 1), the development of Master's studies in the field of Biosystems Engineering for Agriculture and Food Industry has become a necessity dictated by the need of specialists with solid knowledge in the field of bioengineering of systems, production of bio-raw materials for industry, production of biofuels, alternative energy sources for farm efficiency. These issues were the basis for developing the educational framework specific to the Master's program "Biosystem Engineering in Agriculture and Food Industry".

The educational framework of the Romanian Biosystems Engineering

The vision of the Msc program "Biosystem Engineering in Agriculture and Food Industry" is to deepen basic concepts (acquired by students during their undergraduate studies) in closely areas related to hardware and its applications in the industrial and research fields (Filip and Ros, 2008). Thus, the aim of the program are to train highly qualified specialists - engineers, graduates of the master cycle - in the field of bio-system engineering, according to the current economic and social needs of Romania, with competences in research, development and exploitation of complex products requiring knowledge interdisciplinary.

The specialization's perspective consists in training the specialists in a modern, continuously developing and unprofessionally developed field all over the world. This Master's program aims to provide students in the second cycle, to deepen their knowledge and to develop skills in the field of bachelor studies or in a close field, or to obtain complementary competencies for those who have been licensed in other fields.

A basic principle in the development of the specialization was the provision of a common basic platform, which would ensure a more generous accessibility to the graduates interested in the specialization in the field.

In this context, the specific objectives of the specialization were defined:

- to ensure the university communities, the beneficiaries and the public in general that the education providing organization, accredited or authorized to organize a study programme, proves to comply with the minimum quality standards of a higher education institution;
- to support higher education institutions in order to develop a quality management and culture and to demonstrate their state, by relevant proof and documents;
- to determine the education providing organization to self-valuate and to cooperate in its external evaluation in order to ensure and increase quality;
- to identify and publish any functioning attempt of a programme that does not comply with the minimum standards of academic quality.

The specific objectives defined are related to the formation of highly qualified specialists for the particular fields directly or indirectly related to the themes of the courses proposed for this study program.

The thematic directions of the courses related to the specific objectives, reflected in the acquired competencies, refer mainly to the following aspects:

- Current fundamental knowledges regarding the construction and operation of machinery and installations in agriculture and food industry;
- Basics knowledges of the effect of the use of equipment and installations on the environment and the legislative framework that monitors the environmental impact;

- Advanced fundamental knowledges, based on the assimilation of modern concepts regarding the dynamics of the development of the agricultural and food industry equipment;
- Basic elements on biodegradable materials used in the food industry;
- A distinct set of disciplines addresses the field of advanced interdisciplinary knowledge related to: techniques and equipment for design and technological development through the automation of processes and installations in agriculture and food industry; control and reduction of chemical and noise pollution caused by specific equipment and installations.

The benefits of the carried-out grants consist in development of material basis and certain specialized laboratories, where the students can attend the applicative courses according to syllabus. The educational infrastructure consists of specialized laboratories where the teachers and students carry out the application class and at the same time the research.

RESULTS AND DISCUSSION

The Master's Degree Program "Biosystem Engineering in Agriculture and Food Industry" provides training on level 7 of the EQF (Bologna cycle II - master studies) mainly for students who have graduated from the Bachelor Cycle of the Agriculture and Food Engineering Studies Program and the Food Industry in the field of Basic Engineering Sciences, but also for graduates of related study programs such as Fine Mechanics and Nanotechnologies, Heat and Thermal Equipment, Mechatronics and Agricultural Sciences.

The main requirements of direct beneficiaries, young engineers, are related to successful integration into the labor market. In this respect, the study program enjoys an undeniable success due mainly to the collaboration relations with Romanian and foreign companies interested in the development of mechanical engineering oriented towards the engineering of bio-systems for agriculture and food industry. These collaborative relationships are materialized by involving students in solving projects launched by companies and firms active in the field, thus integrating young graduates into the national and European economic environment.

Biosystem Engineering Education is 8 years old, currently the sixth graduate course preparing the dissertation. Statistically, the annual evolution of the number of students compared to the number of those who completed the studies is shown in Figure 1.

The number of students enrolled in the first year of the master's program remained relatively constant between 2009 and 2011, recording a slight increase between 2011 and 2018. As shown in Figure 1, from of a total 20 students enrolled in the first year of study, in 2009 (the first year of the specialization), in 2011 graduated a total of 15 students, ie a higher percentage (93.75%) of the students promoted in the second year of study. Compared with students enrolled in the first year in 2011, the number of students promoted since the first year of the second year increase (13 graduates from 20 enrolled in the first year of 2011). In 2012, the graduation degree of students from the first year of studies in the 2nd year of study is growing again (20 promoted students), but the percentage of graduates drops to 75%. In 2014, the degree of graduation increases again, reaching 85.71%.

In conclusion "Biosystems Engineering in Agriculture and Food Industry" master's program enjoys the attention of the young graduates of the bachelor programs, as evidenced by the number of students enrolled in the first year of the study program. Also, the high percentage of graduate students (over 75%) demonstrate that a significant percentage of the students enrolled in the first year of the study program, promoted in the second year, successfully completing the final study exam.

The statistical data presented demonstrate that:

- A high percentage of master students enrolled in the first year of study of the specialization promoted in the second year of studies, successfully completing the final examination;
- The dynamics of the students during the Master's degree demonstrates their good preparation in terms of the necessary initial knowledge and the increased interest in the professional training in the field of bio-system engineering, coming from the labor market conditions and needs imposed by the orientation of the field of agricultural engineering towards biology.
- Regarding the initial engineering training of the students of this program, the graph in Figure 2 highlights the following aspects:
- There is a significant percentage of graduates of agricultural faculties (in the first year of specialization 20% of the candidates came from the field of agricultural engineering, the percentage then rising to 69.1% in 2013) that have accessed this program, presenting significant elements of education in agricultural mechanical engineering. The reason for this is the need to deepen knowledge about the amount of equipment used to apply agricultural technology;
- A moderate percentage of trainees already have a basic mechanical engineering training (60% in 2009, which drops to 38.10% of 1st year students from mechanical engineering), continuing to an advanced level of initial training;
- Environmental Faculty graduates (in 2009, 15% of students enrolled in the first year coming from other fields in general, of which a significant percentage came from the environment) found in this program the opportunity to deepen knowledge on applicability in particular on renewable energies.

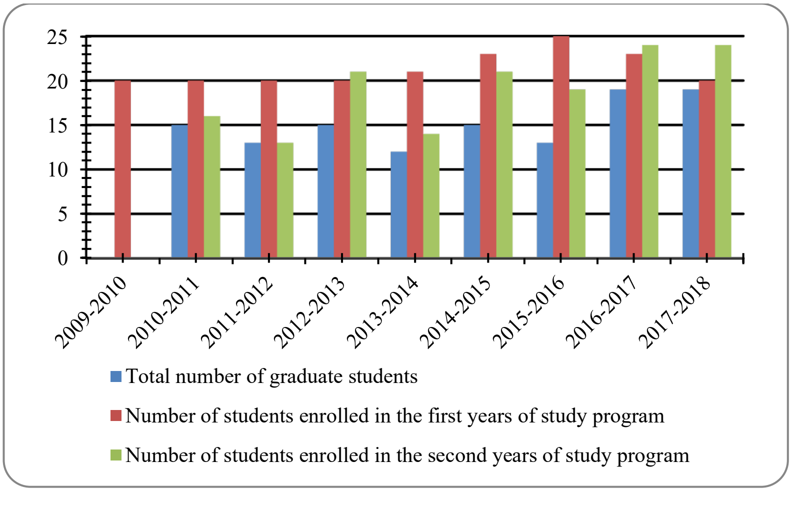

Figure 1 The annual evolution of master students compared with number of graduates

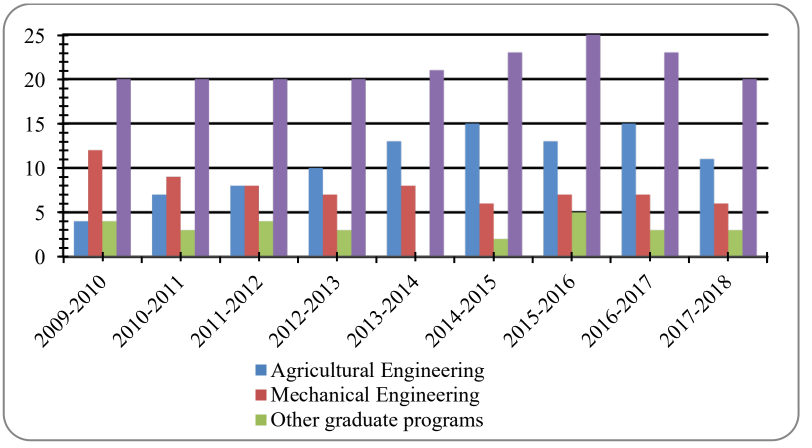

Figure 2 Initial engineering training of the students of the Msc program

Another priority in order to investigate this specialization was employability of the graduate's students. As can be seen from the statistics shown in Figure 3:

- The degree of employability of graduate students is moderate in the earliest graduates (20% of students are engaged in the field), registering an increase starting with the third graduate promotion (the percentage rises to 38.10% in 2014), indicating an increase of the employers' interest for bioengineering specialists;
- The analysis of the data presented also shows an increasing interest for the graduates of the specialization, not only of the employers in the field of agricultural engineering but also in other fields of the labor market. The dynamics of the evolution of the number of students in the field shows a positive trend, the degree of employability in the field at graduates increasing from 30% in 2010 (graduation of the first promotion) to 38,10% in 2014;
- Also, the increase in the employability of the graduates at 6 months from the graduation (from 60% in 2010 to 66,67% of the third promotion - 2014) shown in Figure 4, indicates the recognition of their good training in the agriculture field, the demonstration of high-level of theoretical knowledge, the ability to apply them in practice and the demonstration of skills, competences acquired and learned during the study years.

The dynamics of the percentage of graduates employed in the field versus the total number of graduates (Figure 5) indicates:

- From the first graduate students (2010-2011), a moderate percentage of master students were employed in mechanical engineering / bioengineering immediately after they graduated master's studies (30% of all graduates). But the situation was changed at least 6 months after graduation, when the number of graduates employed in the specialization field is growing significantly (6 months post graduation statistics indicate that 60% of all graduates have been involved in the specialization field). This is due to the increase in the visibility of master program on the labor market and the high degree of graduate education demonstrated by them;

- The dynamics of the employability degree of the graduates of the specialization in the following years demonstrates the increased visibility of the Msc program and the increasing interest of the employers for the bioengineering specialists, but at the same time it is also influenced by the economic conditions during 2010-2018.

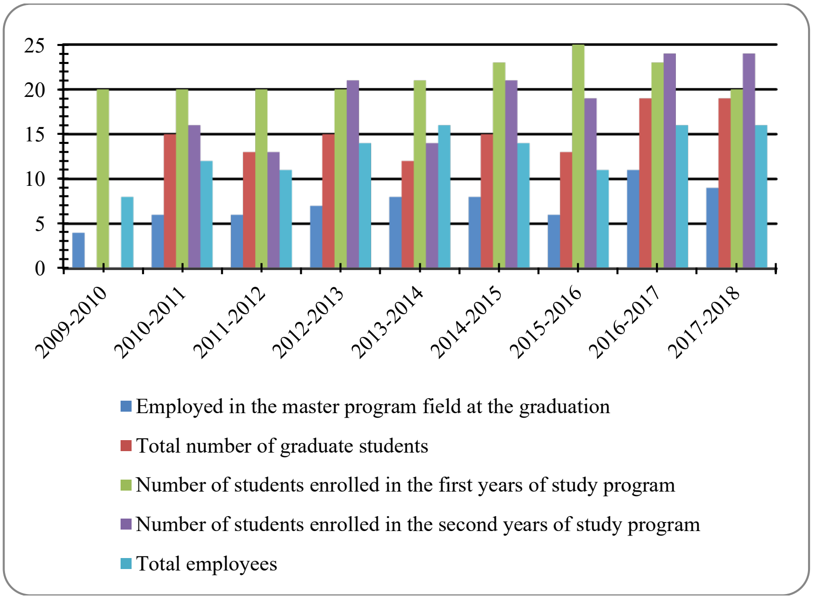

Figure 3 Employabylity of graduate students

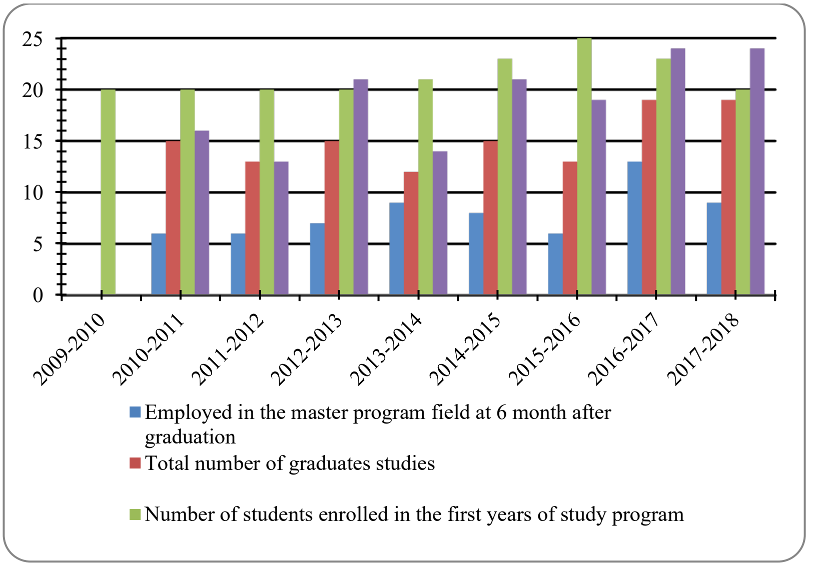

Figure 4 Employability of graduated students at 6 months after graduation

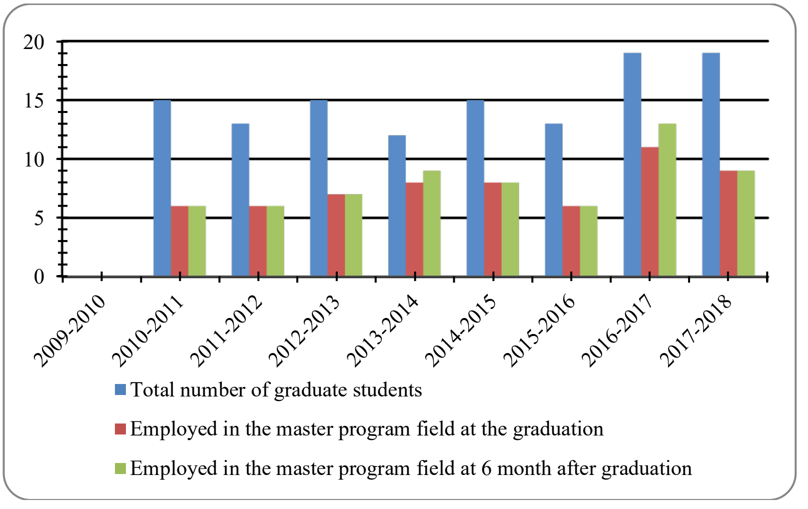

Figure 5 The dynamics of the percentage of graduates employed in the field at the end of master studies, respectively 6 months after the graduated versus the total number of graduate's students

Trends in qualitative development and continuity of study program

The qualitative development of the study program "Biosystems Engineering in Agriculture and Food Industry", is carried out in accordance with the requirements imposed by the Standards and Guidelines for Quality Assurance in Higher Education in Romania as part of the European Higher Education Area (Briassoulis and Panagakis, 2006). The trends in the development of master's degree program follow the European trend of teacher development in the field of mechanical engineering in general, presenting particularities of the field of bioengineering. On the other hand, the objectives established at institutional level for the future development of the university curriculum are related to the correlation of the study subjects with the development of the field of bioengineering in Romania and the requirements of the employers in the field. Thus, in order to highlight the qualitative development and ensure the continuity of the study program (Weir, 2017), it is envisaged to intensify the collaboration relations with employers in the field of bioengineering in order to ensure the graduates have the highest knowledge and abilities.

Also, in the next period will be the development of the university curriculum so as to offer the graduates high quality-oriented knowledge, both theoretical and practical, mainly to the field of bioengineering applied in agriculture in general and in the field of bioenergy production, biofuels and last but not least of biomaterials. The elaboration of the discipline records will be done in full compliance with the Standards and Guidelines for Quality Assurance in National Higher Education, respectively with European Standards and Methodologies for Quality Assurance in Higher Education (European Commision, 2009).

An important objective assumed in the qualitative development and continuity of the study program is to increase the degree of insertion of the graduates in the economic and social environment as a result of the quality of the knowledge and abilities gained from the university curriculum. The future trends of development aim to intensify the collaboration relations with the companies, generally international companies, which are active in the field of bioenergy, biofuel production.

Thus, we can say that for the Romanian education, the training of bioengineering specialists is a real challenge. The continuity of the study program or the training of the bioengineering specialists is ensured by the growing demand of specialists in the field from the economic environment. One argument that supports the aforementioned is that over the last four years, more than 240,000,000 euros have been invested in the production of biofuels by national and international companies. As a result, the national biofuel market is constantly growing and growing, leading to an increase in the demand for specialists in the field. Also, in recent years there has been an increase in agricultural land cultivated with energy plants (over 500000 ha). In this context, an immediate demand was created by specialists, engineers with competences in the field of biofuels and energy crop production. Thus, it is expected that in the near future, there will be a significant increase in demand by companies of such specialists. This is a new argument in order to ensure the continuity of the study program.

CONCLUSIONS

The development of the Master's program "Biosystem Engineering in Agriculture and Food Industry" was carried out, first of all, in the context of the major changes (globalization, climate change, population aging) and secondly in the European tendency towards technological reorientation in the field agriculture.

In this context, the specialization of Master's (Bachelor's cycle 2) developed at the Technical University of Cluj-Napoca, Faculty of Mechanics, answers the need to define new educational profiles imposed by the economic realities, based on services and the role of knowledge and innovation in ensuring competitiveness.

As a participant in the European projects (eg ERABEE) developed to create platforms for dialogue between European universities, in order to harmonize the educational curriculum for the training of bioengineering specialists, our university is a national pawn to develop education in Biosystem Engineering.

The developed university curriculum has been achieved both in accordance with the objectives established by the European projects mentioned above and following the meetings with representatives of the economic environment, national and international companies active in the field of bioengineering in general and the production of energy plants or biofuels in particular.

The quality of the graduates' training is demonstrated by the high degree of employability both at the end of the studies, especially after 6 months. Also, the statistics regarding the number of students enrolled in the 1st year, indicate an increase in the degree of visibility of the specialization during the whole functioning period.

Regarding the fields of study (Master's degree I) from which the master students come, the future specialists in the field of Bioengineering, observe an increased interest from the engineers from the field of agricultural engineering and mechanical engineering, but not only, to be noted the number of those who come from the field of environmental protection.

For the purpose of the qualitative development and the continuity of the study program it is envisaged to increase the degree of insertion of the graduates in the economic and social environment as a result of the quality of the acquired knowledge and abilities as well as the intensification of the relations with the economic environment, the direct beneficiary of the result obtained at the completion of the studies.

In accordance with the development of bioengineering at European level and especially at the national level, as well as the rapid increase of investments in energy production from energy crops and biofuel production, a significant increase of the demand of specalists with competences in bioengineering is expected in the near future.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

STAVOVI STUDENATA O ULOZI AGROTURIZMA U OČUVANJU RURALNOG PROSTORA

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SAŽETAK

Ruralni prostor Europe doživljava značajne promjene pri čemu je najizraženiji proces depopulacije. Posljedica toga su promjene u strukturi djelatnosti pri čemu nestaju mnoga tradicijska zanimanja. Značajne promjene su i kod poljoprivrede koja je dugo bila glavna djelatnost ruralnog prostora. U okviru brojnih načina revitalizacije ruralnog prostora važna je uloga agroturizma, posebno u povećanju dohotka poljoprivrednika što omogućava zadržavanje stanovništva. Cilj rada je utvrditi stavove studenata diplomskih studija na Szent Istvan Sveučilištu u Gödöllu u Mađarskoj i Agronomskom fakultetu u Zagrebu o ulozi agroturizma u očuvanju ruralnog prostora. U istraživanju je sudjelovalo 98 studenata i to 33 studenta u Gödöllu te 65 studenata u Zagrebu. Istraživanje je provedeno tijekom mjeseca travnja 2017. godine. U istraživanju se polazi od pretpostavke da studenti percipiraju agroturizam kao priliku u očuvanju ruralnog prostora te da ne postoje statistički značajne razlike među stavovima dviju skupina ispitanika. Većina ispitanih navodi da agroturizam omogućava razvoj ruralne ekonomije, povećava vrijednost postojeće poljoprivredne proizvodnje, doprinosi zadržavanju ljudi u ruralnom prostoru, obogaćuje ukupnu turističku djelatnost države te omogućuje stvaranje novih radnih mjesta. Također, njih 42% se u potpunosti slaže kako bi agroturizam trebalo poticati novčanim potporama od strane države te se u istom postotku slažu i s izjavom da se kroz agroturizam povećava konkurentnost poljoprivrednog gospodarstva te da poljoprivrednici lakše plasiraju svoje proizvode i usluge kroz agroturizam.

Ključne riječi: *agroturizam, revitalizacija ruralnog prostora, mišljenje studenata*

UVOD

Ruralni prostor mnogih europskih država doživio je svekoliku devastaciju te se kao mjera njegove revitalizacije navodi i poticanje razvitka agroturizma. Jedan od glavnih ciljeva agroturizma je povećanje dohotka poljoprivrednika što omogućava zadržavanje stanovništva u ruralnom prostoru te je potpora njegovoj ukupnoj održivosti. Agroturizam nudi proizvode koji se ne mogu u potpunosti standardizirati čime se njegova privlačnost još više povećava na turističkom tržištu. Agroturizam omogućuje samozapošljavanje i ostanak mladih na selu, čime postaje bitan instrument demografske revitalizacije ruralnih prostora. I samo lokalno gospodarstvo se može unaprijediti razvitkom agroturizma zbog toga što on educira javnost o važnosti poljoprivrede i njezinom doprinosu ukupnom gospodarstvu. Istovremeno, razlike između urbanih i ruralnih sredina se smanjuju te se naglašava potreba za očuvanjem ruralnih sredina (Bršćić, 2016.).

Agroturizam čuva lokalni identitet i okoliš, jača autohtonu, tradicijsku i ekološku proizvodnju. Važnost mu se najviše očituje u kombiniranju temeljnih resursa poljoprivredne proizvodnje: tradicionalnih proizvoda, tradicije te gastronomije. Ciljani potrošači za proizvode i usluge agroturizma su stanovnici urbanih središta.

Cilj rada je utvrditi stavove studenata diplomskih studija na Szent Istvan Sveučilištu u Gödöllu u Mađarskoj i Agronomskom fakultetu u Zagrebu o ulozi agroturizma u očuvanju ruralnog prostora. U istraživanju se polazi od pretpostavke da studenti percipiraju agroturizam kao priliku za očuvanje ruralnog prostora i da ne postoje statistički značajne razlike među stavovima skupina ispitanika.

MATERIJAL I METODE

Za potrebe istraživanja anketirani su studenti diplomskih studija Agronomskog fakulteta Sveučilišta u Zagrebu te Sveučilišta Szent Istvana u Gödöllu, Mađarska. Pitanja u anketnom upitniku su bila otvorenog i zatvorenog tipa, a za mjerenje stavova korištena je Likertova ljestvica koja omogućuje doznati stupanj suglasja ispitanika s određenom tvrdnjom. Istraživanje je provedeno tijekom mjeseca travnja 2017. godine. Rezultati rada su prikazani grafički i tablično, a obrađeni pomoću SPSS (Statistical Package for the Social Science) programa.

REZULTATI I DISKUSIJA

Ukupno je anketirano 98 osoba, više ženskih (53) nego muških te je većina odrasla u urbanom središtu.

Ispitanicima je ponuđeno nekoliko obilježja koja bi važila za ruralni prostor. Primjetne su razlike između grupa ispitanika uvjetovane povijesnim razvojem poljoprivrede i ruralnog prostora u Hrvatskoj i Mađarskoj.

Karakteristika koju ispitanici smatraju najrelevantnijom je „depopulacija“. Ruralni prostor najčešće napuštaju mlade, obrazovanije i nezaposlene osobe te osobe koje još nisu zasnovale obitelj (Žutinić i sur. 2008.). Najčešći razlozi migriranja iz sela u grad jesu nezaposlenost te težnja za poboljšanjem životnog standarda, a čije ostvarenje oni vide jedino u odlasku u veća urbana središta.

Drugo, po jakosti, obilježje ruralnog prostora za ispitanike je proces senilizacije odnosno proces starenja stanovništva. Mnoga ruralna područja su bila pod prijetnjom demografskog „pražnjenja“ i starenja već u prvoj polovici 20. stoljeća. Nažalost, selo u sve većem postotku postaje mjesto staračkih gospodarstava i domaćinstava bez potencijalnih nasljednika, a nakon sadašnjih stanovnika, selo postaje samo geografski pojam. Kod populacije gdje prevladava starije stanovništvo, smanjena je ekonomska aktivnost, a zapostavljen je i društveni i kulturni život. Manje se ulaže u gospodarstvo, obradivo zemljište se slabije obrađuje, a gospodarski i stambeni objekti polako propadaju zbog neodržavanja. Općenito, u takvim ruralnim sredinama prevladava depresivna i nostalgična atmosfera. Kako bi se usporilo starenje ruralnog stanovništva, potrebno je poduzeti neke mjere pronatalitetne populacijske politike čime bi se ravnoteža među dobnim skupinama uravnotežila.

Tablica 1 Percipirane karakteristike ruralnog prostora
Table 1 Perceived characteristics of the rural area

		Zagreb	Gödöllő	Ukupno *Total*	Hi kvadrat (p) *Chi-square (p)*
Depopulacija *Depopulation*	N	56	24	80	F=2,632(0,105)
	%	86,2	72,7	81,6	
Senilizacija *Senilization*	N	51	14	65	F=12,727(0,000)
	%	78,5	42,4	66,3	
Smanjenje poljoprivredne proizvodnje *The reduction of agricultural production*	N	44	13	57	F=7,203(0,007)
	%	67,7	39,4	58,2	
Niža obrazovna struktura u odnosu na prosjek populacije *Lower educational structure in comparison to the average population*	N	36	14	50	F=1,471(0,225)
	%	55,4	42,4	51, 0	
Prilika za razvoj turizma *Opportunities for tourism development*	N	23	12	35	F=0,009(0,924)
	%	35,4	36,4	35,7	
Moguć razvoj nepoljoprivrednih djelatnosti *Possible development of non-agricultural activities*	N	19	7	26	F=0,722(0,395)
	%	29,2	21,2	26,5	
Generacijska obnova stanovništva *Generational renewal of the population*	N	1	2	3	F=1,508(0,219)
	%	1,5	6,1	3,1	

Izvor: Anketa / Source: Survey

U provedbi takve politike nužno je ispunjene tri temeljna cilja i to povećanje nataliteta, doseljavanje pučanstva te povećanje zaposlenosti mladih radi sprečavanja njihova odlaska u gradove ili inozemstvo. Dakle, da bi se usporila tendencija starenja stanovništva ruralnih prostora, potrebno je povećati natalitet, čime bi se usporedno pomladio dobni sastav. Također, nužno je poticati doseljavanje iz urbanih središta te povećanje mogućnosti za zaposlenjem mladih radi sprečavanja njihova odlaska u urbana središta ili inozemstvo (Nejašmić i sur., 2013.).

Kao drugu po važnosti karakteristiku ruralnog područja ispitanici percipiraju smanjenje poljoprivredne proizvodnje, zatim nižu obrazovnu strukturu u odnosu na prosjek države. Ruralni prostor se ne smatra velikom prilikom za razvoj turizma i razvoj nepoljoprivrednih djelatnosti te ga najmanje percipiraju kao prostor kojega karakterizira generacijska obnova stanovništva.

Kod svih navedenih percepcija postoji razlika između grupa ispitanika kao posljedica različitosti u povijesti razvitka poljoprivrede i ruralnog prostora u Hrvatskoj i Mađarskoj.

Ispitanici primjećuju relativno smanjenje značenja poljoprivrede u ekonomskoj strukturi, ali i jakost veze s drugim sektorima te posebno ističu komplementarnost poljoprivrede s turizmom. I sam ruralni prostor je vrlo pogodan za odvijanje turističke djelatnosti. Ispitanici primjećuju da danas ruralna područja privlače sve veći broj urbanog stanovništva koje traži raznoliku ponudu što može ponuditi „ruralno“. Ruralni prostor pruža mnogo; od netaknute prirode do brojnih autohtonih i tradicionalnih proizvoda.

Kod toga mora se voditi računa o održivom razvoju jer su ruralni i održivi razvoj pojmovi koji su u vrlo uskoj vezi. Održivo podrazumijeva očuvanje i zaštitu posebice neobnovljivih resursa. Dakle, nikakvo kratkoročno forsiranje razvoja nije dozvoljeno jer bi takvim pristupom okoliš i netaknuti prirodni resursi počeli propadati. Kako bi se ruralni održivi razvoj mogao provoditi, on mora biti temeljen na izravnoj vezi s tradicijom koja se mora uvažiti kao glavni resurs za različite poduzetničke i gospodarske aktivnosti u ruralnom prostoru. Takvim pristupom omogućilo bi se stvaranje novih djelatnosti i poslova, posebice u turističkom sektoru. Stanovništvo bi dobivalo veće šanse za zaposlenje, a mogućnosti za obrazovanje ruralnog stanovništva bi se značajno povećale. Razumljivo je da bi se time mladi „prisilili“ na ostanak u takvim područjima (Čavrak, 2003.).

Dvije trećine ispitanika smatra da je upravo agroturizam tip ruralnog turizma za kojeg su čuli, a definiraju ga različito. Njihove odgovore možemo svrstati u četiri skupine i to:

Prva: *„Agroturizam je pojam uži od ruralnog turizma, odvija se na poljoprivrednim gospodarstvima na kojima je i dalje aktivna poljoprivredna djelatnost te je to dodatna djelatnost kojom se povećava prihod gospodarstva.“*

Druga: *„Agroturizam je seoski turizam koji omogućuje turistima privremeni boravak na seoskom prostoru. Pruža im se mogućnost kušanja i kupnje domaćih proizvoda kao i doticaj s domaćim životinjama.“*

Treća: *„Agroturizam je oblik turizma u kojem je glavni motiv povratak čovjeka prirodi.“*

Četvrta: *„Agroturizam je oblik turizma koji vraća čovjeka prirodi. Aktivnostima čovjeka, ruralni prostor se nastoji učiniti živim. Sam po sebi takav oblik djelatnosti nastoji zadržati ljude u ruralnim područjima, ali i privući ljude da se nasele u ruralna područja.“*

Tablica 2 Stavovi ispitanika prema agroturizmu (1 - uopće se ne slažem, 2 - ne slažem se, 3 - niti se slažem, niti ne slažem, 4 - slažem se, 5 - u potpunosti se slažem)
Table 2 Respondents attitudes to agritourism (1 - strongly disagree, 2 - disagree, 3 - neither agree or disagree, 4 - agree, 5 - strongly agree)

	Zagreb		Gödöllő		Ukupno / *Total*	
	Prosjek *Average*	SD *St. Dev.*	Prosjek *Average*	SD *St. Dev.*	Prosjek *Average*	SD *St. Dev.*
Agroturizam pridonosi novim radnim mjestima *Agrotourism contributes to new jobs*	4,4	0,84	4,1	1,12	4,3	0,95
Agroturizam potiče razvoj ruralne ekonomije *Agrotourism encourages the development of rural economy*	4,3	0,78	4,1	1,24	4,2	0,96
Agroturizam obogaćuje ukupnu turističku ponudu države *Agrotourism enriches the total tourist supply of the state*	4,4	0,70	3,9	1,22	4,2	0,93
Agroturizam treba novčano poticati *Agritourism should be financially stimulated by the state or local government*	4,3	0,82	4,1	1,00	4,2	0,89
Agroturizam povećava konkurentnost poljoprivrednih proizvođača *Agrotourism increases the competitiveness of agricultural producers*	4,3	0,88	4,0	1,09	4,2	0,96
Agroturizam doprinosi zadržavanju stanovništva *Agrotourism contributes to the retention of the population*	4,3	0,69	3,8	1,06	4,2	0,86
Agroturizam povećava vrijednost poljoprivredne proizvodnje *Agrotourism increases the value of agricultural production*	4,2	0,82	3,9	1,13	4,1	0,94
Poslovno povezivanje poljoprivrednih proizvođača pozitivno utječe na razvoj agroturizma *The business connection of agricultural producers positively affects the development of agrotourism*	4,2	0,81	3,7	0,84	4,03	0,88
Poljoprivrednici lakše prodaju proizvode i usluge kroz agroturizam *Farmers sell products and services through agritourism easier*	4,2	0,79	3,7	1,07	4,01	0,92
Voditelji agroturističkih gospodarstava trebaju multidisciplinarno obrazovanje *Leaders of agritourism farms need a multidisciplinary education*	3,8	0,87	3,8	0,93	3,8	0,89
Mlađi su više zainteresirani za usluge agroturizma *Younger people are more interested in agrotourism services*	3,6	0,95	2,8	1,11	3,3	1,1
Agroturizam potiče bolje korištenje prirodnih resursa *Agrotourism encourages better use of natural resources*	3,6	1,10	2,7	0,94	3,3	1,12
Agroturizam onečišćuje okoliš *Agrotourism pollutes the environment*	2,0	0,80	2,3	0,96	2,3	0,96
Agroturizam ne doprinosi razvoju lokalne infrastrukture *Agrotourism does not contribute to the development of local infrastructure*	2,1	0,91	2,8	1,15	2,3	1,04
Agroturizam ne „čuva" ruralni prostor *Agrotourism does not "preserve" rural area*	2,1	1,04	2,3	1,16	2,2	1,1

Izvor: Anketa / *Source: Survey*

Iz navedenog se može zaključiti kako studenti i jednog i drugog sveučilišta nisu posve upoznati sa samim pojmom agroturizma. Iznimno je važno znati da je ruralni turizam oblik turizma koji okuplja sve aktivnosti u ruralnom području, dok je agroturizam uži pojam od ruralnog turizma, a vezan je za ambijent sela i okolice i sve njegove aktivnosti koje se tiču poljoprivrede, manifestacija, gastronomije, folklora, zanatstva i slično.

Veliki dio (75%) ispitanika je posjetilo agroturističko gospodarstvo u svojoj državi, a samo 31% ukupnih ispitanika agroturističko gospodarstvo izvan svoje države.

Razlozi zbog kojih nisu posjetili agroturističko gospodarstvo su različiti i mogu se svrstati u četiri odgovora kao što su *(1) „Ne doživljavam agroturizam bitnim u turističkom smislu, jer i sam živim na selu, tako da, ono što je za urbane stanovnike zanimljivost, za mene je uobičajeni način života.“; (2) „Nisam imao priliku, a ne znam ni gdje ima takvih gospodarstava.“; (3) „Nikad nisam čula za agroturistička gospodarstva.“ te (4) „Nisam zainteresiran za takve oblike turizma.“*

Primjetne su razlike između skupina ispitanika s obzirom na stav prema agroturizmu. Međutim, ispitanici značajnim procjenjuju doprinos agroturizma otvaranju novih radnih mjesta te razvoju ruralne ekonomije. Agroturizam obogaćuje ukupnu turističku ponudu države koja ga zbog toga treba i novčano poticati. Kao dopunska djelatnost, agroturizam povećava konkurentnost poljoprivrednih proizvođača te time i smanjenju depopulacije područja. Bitno je spomenuti da ispitanici ističu pozitivnu ulogu agroturizma u čuvanju prostora, sprečavanju onečišćenja te ulogu u razvoju lokalne infrastrukture.

Na kraju, oko 90% studenata Agronomskog fakulteta u Zagrebu odgovorilo je kako bi proveli odmor na agroturističkom gospodarstvu, a njih 67% se želi baviti agroturizmom u budućnosti. Slično je i kod studenata Sveučilišta Szent Istvana u Gödöllu gdje njih 76% želi provesti odmor na agroturističkom gospodarstvu, a 73% bi se u budućnosti bavilo agroturizmom.

ZAKLJUČAK

Agroturizam kao oblik turizma je sastavni dio lokalne zajednice i on utječe na očuvanje ruralnog prostora. Rezultati istraživanja nisu pokazali bitnije razlike između stavova studenata Agronomskog fakulteta u Zagrebu te Sveučilišta te studenata Szent Istvana u Gödöllu, Mađarska.

Većina ispitanih kao glavnu karakteristiku ruralnog prostora navodi proces depopulacije (82%).

Ruralni prostor je dobar za odvijanje turističke djelatnosti (93%) i poljoprivredna djelatnost je komplementarna s turizmom (70%). Najveći dio ispitanika je čuo za pojam agroturizma (82%) te nešto više za pojam ruralnog turizma (92%). Veći dio ispitanih definira ruralni turizam kao „oblik turizma na seoskim područjima“ (52%) i značajni dio tvrdi da nisu upoznati s temeljnim razlikama ruralnog turizma i agroturizma (32%). Većina ispitanih je posjetila agroturističko gospodarstvo u svojoj državi (75%). Kao najčešći razlog neposjećenosti agroturističkom gospodarstvu su naveli nedostatak informacija i vremena. Većina ispitanih navodi da agroturizam omogućava razvoj ruralne ekonomije, povećava vrijednost postojeće poljoprivredne proizvodnje, doprinosi zadržavanju ljudi u ruralnom prostoru i obogaćuje ukupnu turističku djelatnost države te omogućuje stvaranje novih radnih mjesta. Također, njih 42% se u potpunosti slaže kako bi agroturizam trebalo poticati novčanim potporama od strane države te da se kroz agroturizam povećava konkurentnost poljoprivrednog gospodarstva i da poljoprivrednici lakše plasiraju svoje proizvode i usluge kroz agroturizam. Agroturistička djelatnost je veoma prihvaćena kod mladih, stoga je potrebno uložiti više sredstava u sam napredak agroturizma kao poslovne djelatnosti, čime bi došlo do većeg razvitka, a na kraju i bržeg napretka.

NAPOMENA

Rad je izvod iz diplomskog rada studentice Kristine Batelić, mag. ing. agr., studentice diplomskog studija Agrobiznis i ruralni razvitak na Agronomskom fakultetu u Zagrebu.

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ATTITUDES OF STUDENTS ON THE ROLE OF AGROTOURISM IN PRESERVING RURAL SPACE

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ABSTRACT

The rural area of Europe is experiencing significant changes, with the most prominent depopulation process. As a consequence, there are changes in the structure of economic activities where many traditional professions disappear. Significant changes have also occurred in agriculture, which has long been the main activity of the rural area. In the context of the many ways of revitalizing the rural area, the role of agrotourism is important, especially in increasing the income of farmers, which enables the retention of the population. The aim of the paper is to determine the attitudes of students of graduate studies at Szent Istvan University of Gödöllő in Hungary and the Faculty of Agriculture in Zagreb on the role of agrotourism in the preservation of rural area. The survey included 98 students and 33 students in Gödöllő and 65 students in Zagreb. The survey was conducted during the April 2017. The research is based on the assumption that students perceive agrotourism as an opportunity to preserve the rural area and that there is no statistically significant difference between the attitudes of the two groups of respondents. Most respondents stated that agritourism allows the development of rural economy, increases the value of existing agricultural production, contributes to the retention of people in the rural area, enriches the overall tourist activity of the state and enables the creation of new jobs. Also, 42% of them fully agree that agrotourism should be stimulated by state subsidies and, in the same percentage. They agree with the statement that agrotourism enhances the competitiveness of the agricultural economy and that farmers sell easier their products and services through agrotourism.

Keywords: *agrotourism, revitalization of rural areas, student's opinion*

47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Prethodno priopćenje
Preliminary communication

WATER MILLS IN BASILICATA REGION – A HERTIAGE TO BE PRESERVED

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ABSTRACT

Basilicata region is traditionally an agricultural territory which can be seen from the diffused presence of rural buildings and water mills, used in the past above all for grinding of the cereals. These factories were built primarily in the hilly and mountainous areas near to broad streams and springs. Unfortunately, today the greatest part of the mills is overgrown by uncultivated vegetation and represent ruins without the hydraulic and grinding systems. Only a small number of these mills is still working. A lot of factories, however, preserved, at least partially, the brickworks and/or the hydraulic and grinding systems; therefore, they could be recovered and used for didactic-demonstrative aims, in a context of rural tourism, and/or to produce good quality material for typical pasta and biscuits, in order to keep alive a historical-cultural tradition of the Basilicata.

The aim of this paper was to present the state of the art of some existing agricultural water mills and to give future perspectives and ideas how to reconstruct them and revitalize them. The paper shows their historical characterization and a first classification based on their state of conservation, both structural and plant.

Keywords: *water mill, rural construction, preservation, tourist-cultural routes.*

INTRODUCTION

The mountain and hilly rural territories of the Basilicata region (South Italy), typically covered by cereal cultivation, were characterized by a widespread presence of water mills. Most of them served for the processing of wheat into flour. Their recovery, in the context of environmental and historical protection would require research and legislators study. In fact, the water mills can be considered an environmental asset because they were an instrument for organizing and managing water and, so, the territory.

In order to keep alive a historical-cultural tradition of the Basilicata region, the ancient water mills that are still conserved, or could reacquire, their functionality should be re-evaluated as energy production machine and / or machine for the production of high quality flours for producing typical fresh pasta and biscuits of this territory or to be used for the didactic-demonstrative purposes in a context of rural tourism. In particular, in reference to the high quality of the products, it would be interesting to improve not only the quality of the flours even but also of the final products. In the perspective of cereal-based functional food development, Di Silvestro et al. (2014) compared stone watermill and stone mill, which differed in the heat generated during grinding (respectively 30 and 60 °C), in order to verify the effects of the temperatures on the phytochemicals present in the grain.

Cartographic studies and inspections *in situ* have allowed the identification of some mills which have been characterized from an historical point of view and classified according to their state of conservation, both structural and plant.

The art of grinding has a very ancient past: originally the kernels were crushed with rudimentary tools like the stones. Subsequently the mortar, the stone roller and the revolving millstone moved by men or animals were used.

Between the ninth and tenth centuries a. C., the need to find a source of energy, different from muscular human or animal one, and the awareness that the regularity of the rotation movement is generated by the thrust of water, led to the technical development of hydraulic machines, included the water mills.

The spreading of the mills was slowly and not even in all the regions due to the many reasons such as the possibility of having available both a flow of water and a substantial investment of money and, above all the costs of the first plant.

Since their building was advantageous, only when the quantity of processed product was such as to amortize in reasonable time the expenses incurred, the monopoly of the water mills remained for a long time in the hands of religious bodies and some families of the upper bourgeoisie.

Since there was the need of a constant operation of the millstones over time, the water mills were built where the water courses were less affected by the o water level in the water courses.

Water was conveyed into a narrow artificial channel (*gora*, in Italian) and then on to a wheel with blades (*hydraulic wheel*) linked to a shaft (*axis*) in order to cause a continuous rotary movement. A shutter was opened or closed to regulate the water flow and, consequently, to control the speed of the wheel. In the oldest water mills (like the Greek ones) the axis was vertical with respect to the water current direction and the whole wheel was immersed in the water. Subsequently, the hydraulic wheels were constrained to a horizontal axis so to be able to be fed from the bottom, by exploiting the water current, or from the top. This second way was more complex but more efficient because the wheels were moved by current and the weight of the water in fall.

In the Basilicata region, it is possible to find different buildings once destined to the cereal grinding (De Rosa et al., 1998; Oliveto, 1997; Rescio, 2001); the most of them belonged to religious bodies and/or to the upper bourgeoisie, similarly to the national territory, as evidenced by historical notes. In 1004 the priest *Savino* donated the mill of the *De Fugardi* land, placed in *Montemilone*, to the abbot of the *Monastery of Morbano.* In 1053 *Unfredo* (*comes et dux Abulie et Calabrie*) offered the *Racidisio Mill* to the *Trinity of Venosa*; in 1546 *Donna Altabella Petitti di Saponara* sold a part of the mill, complete with the hydraulic and milling system, located in the countryside of *Moliterno*, to *Parisano* of *Moliterno*.

The structure and functioning of the water mills, built in the XIV and XV centuries, were unchanged until their final abandonment, after the Second World War, when the hydraulic energy was replaced progressively by other sources, as steam and electricity. In this contest, it is interesting to hypnotize that the water mills, apart from milling purposes use, can be consider for the reconstruction also as a renewable hydraulic energy sources (Sanchez-Jimenez, 2018).

MATERIALS AND METHODS

Bibliographic and cartographic studies as well as field surveys have been conducted to obtain indications about the diffusion of water mills on the whole territory of the Basilicata region with the aim to hypothesize the recovery of those structures considered valid from the historical-cultural point of view (even if ruins) or the re-use those still productive (needing improvements).

The first phase of the bibliographic research enabled locating of, about, one hundred water mills diffused on the territory, of which their different state of conservation was known. In order to do a new upgraded census of the water mills, comparing the literature conditions and data with the current ones, the second phase of the research (surveys in situ) started by analysis of some water mills, located in province of Potenza. In particular, six water mills were chosen randomly, in the north of the Basilicata Region, an area already known for its natural (the waterfalls of San Fele, the volcanic lakes of Monticchio) and historical (castles of Frederick II of Sweden, Orazio's house, one of the greatest poets of the ancient age) attractions and the food and wine routes. In this way, the upgrade of the list of the water mills started and if some of them were considered interesting, they could be insert very easily into existing touristic routes.

During the inspections *in situ*, the researchers compiled sheets to note several information grouped into four thematic levels concerning:

- The location of the building by geo-referencing;
- The typological and functional aspects and general conservation of the water mills;
- The analysis of the structural elements, the materials employed, the plants and their state of conservation;
- Historical analysis and photographic study.

The data summarized in the sheets, with the bibliographic and cartographic ones, will be the basis for the subsequent phase of "proposition of recovery and / or reuse interventions", compatible with the conservation status and with the history of the surveyed watermills.

RESULTS AND DISCUSSION

The Basilicata region is characterised by a territory traditionally suited to agricultural activity, also evidenced by the widespread presence of rural buildings used for the production and service activities of the primary sector. Water mills are located mainly in the hilly and mountainous areas (Fig. 1), near rivers and springs.

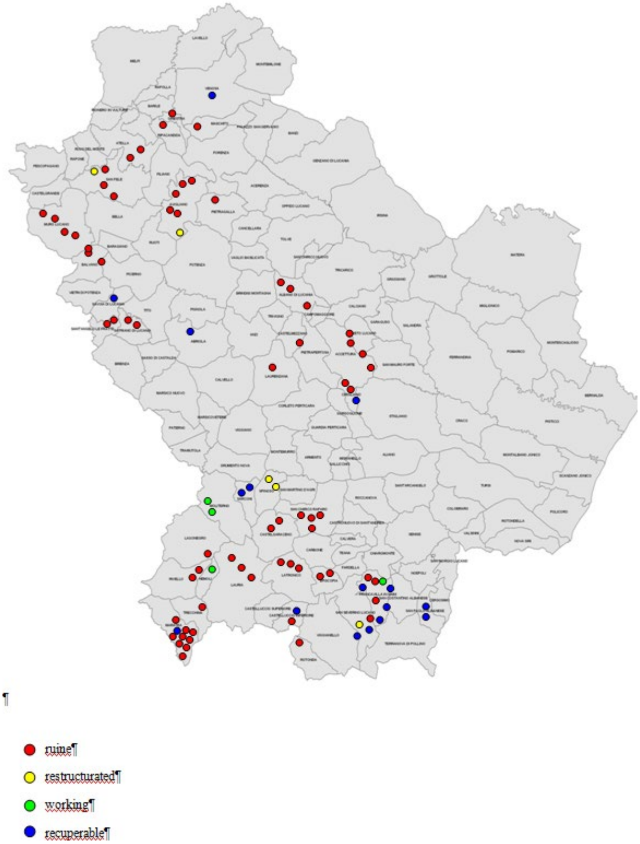


Figure 1 Some water mills on territory of Basilicata region

A first phase of the bibliographic research enabled locating of, about, one hundred water mills diffused on the territory, of which their different state of conservation is known. Six water mills were chosen randomly, for the surveys in situ, all located in province of Potenza.

Cartographic and bibliographic studies, together with the inspections in situ, allowed defining the prevailing typology of the water mill in Basilicata region: almost all were medieval period. They represented the evolution of the technological scheme of the "Greek-Arab mill", made by essential elements, as gripping, transport, energy production and milling systems.

From a building point of view, water mills were equal to the other rural constructions, characterized by elementary plans (rectangular or square) and simple structures with load-bearing walls (exposed or plastered). Generally, they were not operated directly by water of rivers or streams but were powered by derivation channels allowing the regulation of the water flow. The milling system was very simple:

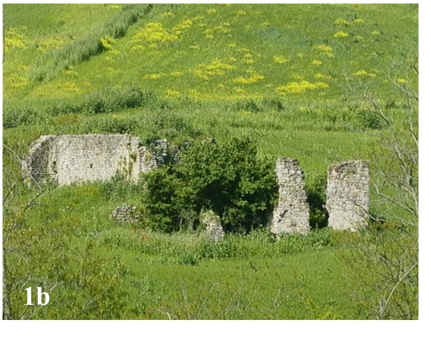
- a horizontal wheel, placed in a basement room characterized by arched ceiling, alimented by a wood little canal (inclined between 35 - 60 degrees) that carried water directly on a side of the wheel;
- an axis (tree of transmission) to transmit the movement to the milling stone;
- milling stones, two ring stones, one fixed and one mobile, having height 10-20 centimetres and diameter of 80-120 centimetres. The fixed stone was placed on a base into the space on the hydraulic wheel; it had a central hole across tree of transmission of the same wheel. The second mobile stone had a hole, shaped in the lower part, suitable both for its insert of the transmission tree and for the passage of the cereals to mill.

Analyzing the results of the carried research, it was possible to highlight the presence of buildings with different levels of susceptibility to recovery – re-use. There are three structures in ruins (one of which should be preserved due to its historical importance), one potentially recoverable plant (operating facility) and two renovated buildings, as shown in table 1.

Table 1 First water mills that were analysed

State of conservation	Name	Municipal territory
Ruin	Mill Plastino	Ginestra
	Old mill	Ripacandida
	Mill of Muro	Muro Lucano
Recuperable	Mill Latorre	Venosa
Restructured	Mill Lorenzo	San Fele
	Old mill	Avigliano

The ruins were without the hydraulic and milling systems. It was possible to see only remains of walls, sometimes covered with uncultivated vegetation. The ruins of these three water mills had a low historical value. Their examination has been useful for learning the building techniques and materials used, once time. In this sense, it was possible to observe walls of good realization made with square blocks and stones of several dimension well embedded, linked by mortar. The photos 1a and 1b show what remains of the Mill Plastino, one of the three mills of which there are only partially the perimeter walls.



Photos 1a, 1b Mill Plastino (land of Ginestra) - ruins

Mill Latorre, located in the land of Venosa, has been classified as “recoverable”. It has milling and hydraulic systems (Photo 2a) in a fairly good state, but it is not suitable for producing and therefore it's abandoned twenty years ago. This one needs some structural interventions (Photo 2b) and an external accommodation by cutting of spontaneous grass and plant (Photo 2c). Thanks to its collocation (countryside of Venosa is typical land of wine production), it can be recovered and inserted in already existing food and wine routes, as cultural point and /or selling one of cereal products (pasta and biscuits), even without recovering of its functionality.

Photos 2a, 2b, 2c Mill Latorre (land of Venosa) - recuperable

With reference to the water mills already restructured, two different situations were found; sometimes the interventions have not been very invasive, respecting both the history and the original function of the building (old mill into the land of *Avigliano*). Other water mills have been subjected to strongly invasive restructuration with distortion of the original functional and architectural features (*Mill Lorenzo*, land of *San Fele*). More in detail, the old water mill in Lavangone land (countryside of Avigliano) has worked until the early nineties, producing barley, oat and corn flours. Its original structure, dates back to 1840, but it has been subjected by renovation works, completed between 1998 and 1999. Respecting the original architectural and functional character of the building, works concerned only the main body. The water supply systems and the basement, housing the water gears, have not been restructured. Currently, the entry of the basement as well as walkways, are covered by spontaneous grass, bushes and brambles.

In the countryside of San Fele, there is the mill Lorenzo. At the end of the XX century, it was characterized by a high structural degradation due to the abandonment for the cessation of activity and to the stresses induced by the 1980 earthquake.

Successively, it was subjected to reconstruction interventions (law 219/81) that have profoundly altered the original architectural character of the building. It has not been possible to enter inside the mill, but by interviews with local people, it emerged that the original structure was in masonry with exposed stones and it had a wooden upper floor. It can be seen from photo 3a, that the exterior facades have been plastered and painted white. Besides, people also told that bricks had replaced the wood during the reconstruction of the upper floor. No functional recovery of the hydraulic and milling systems has been foreseen as witnessed by the abandonment of the millstones which, set aside outside the structure, are now covered by spontaneous vegetation (Photo 3b).

Photos 3a, 3b Mill Lorenzo (land of San Fele) – mill badly restructured

CONCLUSION

On the whole territory of Basilicata region, there is a significant number of water mills. Most of them are reduced to ruins while only a small number is still working.

First results of the analysis showed that some water mills preserve the masonry works and / or the milling and hydraulic systems, at least partially. These could be recovered for a didactic-demonstrative and / or productive reuse.

According the Authors, their recovery would have a positive impact on the territory, preserving historical-cultural traditions and enhancing the landscape.

The research will continue both to complete the census of the water mills present on the whole territory of the Basilicata region and to developed procedures, based on economic-technical criteria, in order to assess their susceptibility to recovery-reuse.

Recovered water mills, or eventual ruins interesting from a historical point of view, could be integrated in existing tourist-cultural routes or in new ones.

NOTE: The contribution to programming and executing this research must be equally shared between the Authors

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

VALORISATION OF HISTORICAL FARM BUILDINGS FOR PROTECTING THE RURAL LANDSCAPE

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SUMMARY

Rural buildings play a central role on the environmental characteristics of the rural land, because they accompanied in the centuries the development of agricultural activities; the farmer-man built them also considering the specific characteristics of the economic, social, climatic and cultural rural context. They are important elements of the rural landscape which, in addition to having a considerable architectural value, constitute a witness of the economic and productive organization of a specific territory. Mostly in some southern European countries - as in the Basilicata region (Southern Italy) – these rural structures have been built based on the agricultural needs and land characteristics. Considering the land abandonment occurred during the last centuries, also historical farm buildings, in most cases, have been abandoned, since people living there moved to more comfortable residences within urban settlements, causing a loss of the historical-cultural heritage of the rural landscape. In this context, it would be fruitful to improve the knowledge about the specific characteristic of farm buildings considering also their geographic location, in order to include each one of them into a geo-database and, through the use of new advanced tools, to connect the valorisation of these rural buildings within the relevant landscape. The use of advanced technological tools may considerably support the protection of landscapes with high cultural and naturalistic value. In recent years, open data and geographic technologies are allowing the implementation of multidisciplinary information, which may reveal crucial for a sound management of the rural landscape, including also an important focus on rural buildings. In this paper, the potential of a Geographic Information Systems (GIS) have been explored, with the aim to improve the cataloguing system of the Basilicata region's farm buildings, traditionally known as: "masserie". After the realization of a specific geo-database incorporating different datasets, specific tools have been used to provide some particular analyses that can be used both for the management and valorisation of farm buildings, even for touristic purposes. In addition, by *integrating some typical aspects of the landscape studies, an innovative approach has been implemented, so as to preserve not only each individual building, but even the entire rural landscape context in which these important witnesses of the rural history are included.*

Keywords: *Historical farm building, Geographical Information System, Rural landscape, Sustainable development.*

INTRODUCTION

Farm buildings, designed over the centuries in order to fulfil their primary agricultural role, now constitute a widespread heritage that in some cases possesses an irreplaceable architectural value, playing a central role for the sustainability of the rural environment as well. Conceived to host biological production, the farm building constitutes indeed a unique example in the wide epistemological sector of building construction (Picuno, 2012). The birth, growth and development of living vegetal or animal organisms contained ***inside*** these volumes raise architectural and technical issues that are radically different if compared to those of other building sectors. Aimed at producing optimal environmental conditions for plants and animals, while at the same time protecting the hygiene and health of workers involved in the daily operations for the care of living organisms at different stages of their development, the rural building constitutes therefore a unique and unrepeatable technological model (Fuentes, 2010; Fuentes et al., 2010; Picuno et al., 2015).

The originality of what happens inside the farm building corresponds to what happens *outside*. The role that the buildings have historically played is strictly connected with the surrounding context, due to the need of the farmer to live in close contact with agricultural land and animal husbandry (Cañas et al., 2009; Hernandez et al., 2004; Jeong et al., 2012; Lista et al., 2013/a; Lista et al., 2013/b). While the organization of human beings involved in the activities of the industrial or tertiary sector allowed aggregation in urban centres, the need to live in constant contact with the agricultural production developed a synergetic function of close proximity to the extra-urban land. This aspect led to the spread in rural areas of many examples of buildings that served for farming, storage and processing of agricultural products constituting, at the same time, housing for the farmer and his family. This form of settlement has been, and still is, a unique way by which humans have populated, in harmony with the natural elements, the agricultural land, joining the primary production needed for human nutrition with the control and care of rural land. So, the activities made by the Man have often strongly influenced the agricultural environment and the visual perception of its landscape (Statuto et al., 2014/a; Statuto et al., 2014/b; Statuto et al., 2015; Tortora et al., 2015).

The recent expansion of rural tourism currently registered in Europe (Ana, 2017) makes it necessary to monitor rural buildings, both to preserve them as historical and cultural heritage and to redevelop in the perspective of sustainable tourism planning. Besides the importance from a tourism point of view, there is also a growing interest focused onto the ecological effects of the rural buildings on landscape, then on the importance of applying a sustainable rural development strategy to improve the protection of habitats and ecosystem services (McKenzie et al., 2011; McCann et al., 2017). In fact, as reported by Haller & Bender (2018), there is a strong link between biodiversity and conservation/restoration of grassland, which necessarily passes through the conservation of the rural building heritage. This is especially true for some Natura2000 priority habitats such as the semi-natural dry grasslands *code 6210*

(Calaciura and Spinelli, 2008). The monitoring of the rural buildings and of surrounding landscape, considering the multidisciplinary and the strong spatial component of the information, requires therefore a suitable approach, which is now possible when based on new geographic technologies (Cano et al., 2013, Palmisano et al., 2016; Jeong et al., 2013).

In the present study, the potential of a Geographic Information System (GIS) applied to the monitoring, conservation and enhancement of the rural heritage of one southern Italian region, *i.e.*: the Basilicata region, has been explored. After the creation of a preliminary geo-database of rural buildings and spatial data related to the rural landscape, two methodologies have been implemented: the first one, was aimed to evaluate the role and impact of the rural buildings in the conservation of semi-natural environments of the surrounding context; the second one, has been focused on the assessment of the safeguarding of the visual quality of the rural landscape.

MATERIALS AND METHODS

The study area, consisting of the total land of the Basilicata region (Southern Italy), covers a total surface of almost 10,000 km^2 and 90% of the whole territory being mountain (Fig. 1). It has a population of about 600,000 units distributed into the two provinces of Matera and Potenza. The territory has a strong agricultural vocation; indeed almost 50% of the regional area is cultivated, the main agricultural activities having an influence on the structure and the biotic components of the landscape are *arable land* and *pasture*, which occupy 29% and 13% of the territory respectively. The other main component of the landscape of the Basilicata region is constituted by *forests*, which cover 35.6% of its territory.

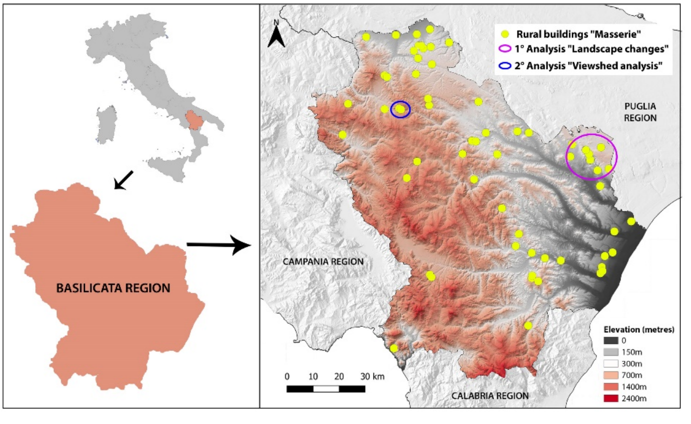

Figure 1 Study area, rural buildings at regional level and areas of analysis

One of the most important elements of the Basilicata's landscape, expression of a type of agriculture that is not particularly intensive, is constituted by the old rural buildings. These have a considerable architectural and cultural value and they are a testimony of the historical economic and productive organization of this territory (Grano, 2014; Picuno, 2012).

The first fundamental operation conducted has been the collection and standardization of the various datasets, so as to be able to realize a Geographical Information System (GIS) model able to include and link all the information related to the rural buildings. Thanks to an available open dataset of the Basilicata Region, it has been possible to collect the position of the main rural buildings (so-called: "*masserie*"), having a cultural interest and protected by specific regulations. In according with Cano et al., (2013), this is the starting point for the cataloguing process. Thanks to the potential of GIS tools, it has been possible to connect different datasets coming from both field survey (measuring, photographic report, field databases) and spatial analysis work (studies on land use and surrounding landscape, socio-economic analysis, viewshed analysis, index creation) so as to create a single GIS-based model of rural buildings. This database model can be exploited for several purposes: planning and management; protection and conservation of the surrounding rural landscape (Jeong et al., 2016); valorisation of the existing rural buildings; strategic decision on the localization of new farm buildings; *etc*. The creation of a geo-database has been the preliminary and fundamental operation for implementing and monitoring concrete valorisation actions (Cillis and Statuto, 2018).

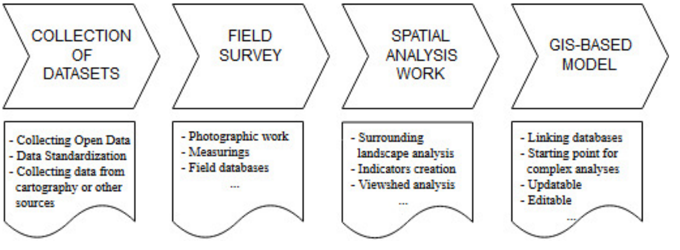

Figure 2 Flowchart of the GIS-based model implementation

In this study, to explore the GIS tools potential to be applied to the rural building and landscape management, a specific framework has been implemented (figure 2). To examine in depth the potential in the use of GIS tools for the management of rural buildings and the surrounding rural landscape, two types of analysis have been implemented, so as to contribute to the valorisation of historical farm buildings, in the framework of the protection of the rural landscape. All operations were performed with the open source QGIS software and all used dataset are free and open.

After the creation of the geo-database, the first analysis performed has been finalized to set each single rural building to understand, as proposed by McKenzie et al. (2011), if it can have an important ecological role on the surrounding environment and habitats. To do this, spatial analyses have been carried out regarding changes in land use in the surrounding area of each rural building, so as to highlight any transition that can have negative repercussions on some important habitats for the biodiversity such as, for example, the loss in grasslands (Eriksson and Cousins, 2014; Hallen and Bender, 2018). To this aim, it has been decided to carry out this spatial analysis only on some rural buildings which are located in the neighbouring or even within a protected natural area, due to the critical ecological role that these buildings could have for the protection of some natural habitats. On the basis of the analysis of the information levels that compose the GIS-based model realized in the first phase, the analysis has been restricted to the Regional-Natural Archaeological Park of the Rupestrian Churches of Matera (EUAP0419), which has been selected because it is the area of the Basilicata region around which it is concentrated the higher number of rural buildings.

Considering a 1-km-radius buffer zone around each rural building (309,02 ha), the land cover changes during 1990-2000, 2000-2006 and 2006-2012 have been detected. To enable a more detailed analysis, proposing at the same time a methodology that can be replicated to the entire rural heritage as well, a specific rural building has been identified, for which the dynamics of change between the different land use classes have been analyzed. The datasets used are those provided by the free Network of the National Environmental Information System (SinaNET – ISPRA).

The second analysis involved an inter-visibility assessment of rural buildings (Hernández et al., 2004). These buildings, as well as being an important safeguard for the ecological protection of the rural landscape, have also an important historical and cultural value, for which there is a need to preserve simultaneously the farm building and the surrounding rural landscape. Through the *"Viewshed Analysis"* QGIS plugin, it is possible to calculate the visible surface from a given observation point to a digital elevation model. With this type of analysis, it is possible to evaluate the visual quality of the landscape (La Rosa, 2011), then exploit it for planning purposes, such as the identification of some negative visual impact assessment that new constructions and land use transformations can have on the surrounding landscape. The plugin, based on a raster of the digital model of the surface (with a resolution of 5 meters, and freely available on the cartographic portal of the Basilicata region) and the position of the viewpoint on panoramic roads close to rural buildings, returns a cumulative integer raster grid in which each cell stores the number of visible viewpoints. To limit the survey region, an area of influence of 1-km-radius around the building has been considered even in this second application. This methodology can be useful for tourism purposes as well to enhance points of panoramic view from which to appreciate the rural landscape as a whole.

RESULTS AND DISCUSSION

From the first spatial analysis (Table 1) it emerged that in the first period (1990 - 2000) there have been no important changes in terms of surface. In fact, only around the "*Masseria Monacelle*" there has been a change in land use of about 24 ha (8% of the buffer area). The following period (2000 - 2006) is that one in which the greatest changes have occurred. In each one of the buffer areas of each farm, a percentage of change has been recorded, with even 50% of changes in the case of "*Masseria San Francesco*". In the last period (2006 - 2012) a reduction in the area subject to change has been registered, with a maximum value of 28% (in the case of "*Masseria Monacelle*"). This methodology, which in this study has been applied at a small scale, can reveal useful to identify how the landscape around the farms has been transformed, mainly identifying those farms playing an important ecological role within the rural landscape.

Moreover, with the construction of a geo-database including rural buildings, it is possible to carry out some geospatial surveys, from simple mapping to geo-statistical surveys and cross tabulation (McKenzie et al., 2011; Statuto et al., 2018). For example, it is possible to identify the rural building around which there have been more land use dynamics, to be linked to an area with high naturalistic value. A preliminary analysis is shown in table 2, in the case of "*Masseria San Francesco*". Here, after having identified the rural building showing the highest level of variations, the relevant changes in land use classes, which could have characteristics related to semi-natural grassland habitats, have been assessed (Figure 3).

It can be noted that an increase, in the period 2000-2006, of natural grasslands (50 ha) that potentially (excluding 2 ha that in the period 2006-2012 were converted into cultivated areas), could turn into habitats of interest (*code 6210*) and then be monitored accordingly.

Table 1 Surfaces (in percentage and hectares) that changed with respect to the buffer analysis in the three analysis periods

Name of the Rural Building	Changes 1990-2000		Changes 2000-2006		Changes 2006-2012	
	ha	%	ha	%	ha	%
Masseria Parco dei Monaci	0.00	0.00	24.78	8.05	0.00	0.00
Masseria Malvezzi	0.00	0.00	37.01	11.98	26.70	8.64
Masseria Monacelle	24.80	8.03	42.72	13.82	87.18	28.21
Masseria S. Francesco	0.42	0.14	154.27	49.92	3.00	0.97
Masseria Selva Malvezzi	0.00	0.00	24.98	8.08	39.89	12.91
Masseria Torre Spagnola	0.00	0.00	35.44	11.47	23.09	7.47

Table 2 Changes in land use classes (in hectares) for the three-time period of analysis in the area close to "*Masseria San Francesco*"

Changes in land use classes	Masseria San Francesco		
	1990 - 2000	2000 - 2006	2006 - 2012
Annual crops with permanent crops to Non-irrigated arable land	18.37		
Non-irrigated arable land to Complex cultivation patterns		11.87	
Industrial or commercial units to Complex cultivation patterns		0.42	
Olive groves to Natural grasslands		52.45	
Annual crops with permanent crops to Complex cultivation patterns		27.06	
Complex cultivation patterns to Discontinuous urban fabric		20.26	
Annual crops with permanent crops to Olive groves		31.29	
Natural grasslands to Complex cultivation patterns			2.76
Complex cultivation patterns to Olive groves			0.24

The second application which has been here performed, has concerned a viewshed analysis related only to two neighboring rural buildings: *"Masseria Serra dell'Olmo"* and *"Borgo Rurale Piano del Conte"*. These two historical rural buildings have been chosen since they are located close to an area with an high landscape value, at the same time affected by some re-development actions. This operation has been done starting from the information collected in the geodatabase: geolocalization of the rural buildings; digitalization of panoramic roads; and implementation of the digital surface model (DSM) of elevation.

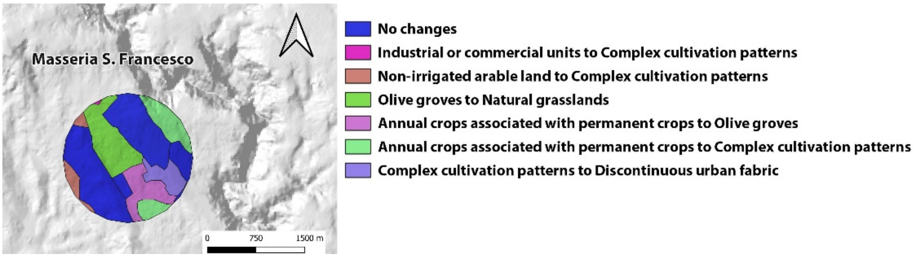

Figure 3 Land use changes in case of the "*Masseria San Francesco"* (year 2000-2006)

From the mapping of the cells visible from the panoramic roads (Figure 4), it is possible to calculate the percentage of visible surface in the reference area buffers (470.17 ha). Specifically, from the results of the analysis reported in Table 3, it is noted that almost 30% of the area is not visible from the roads (percentage less than 1.5%) and that about 72 ha are visible from 25-50% of the study area. Moreover, when considering the area close to the rural buildings in relation to the planning needs (as an example, a buffer 100-meters-radius and about 3 ha was taken), it is possible to make an even more detailed analysis. Table 4 shows indeed that almost 80% of the area surrounding the rural building "*Masseria Serra dell'Olmo*" is visible from 10 to 50% of the scenic roads. Instead, for the other considered farm (*Borgo Rurale Piano del Conte*), most of the surrounding area is not visible from the panoramic roads. In this way, it is possible to contextualise the rural building within the landscape, then evaluating its potential in terms of increase/decrease of the visual quality of the rural landscape and therefore, during the relevant planning activities, regulate any constructions or changes in land use that could affect its aesthetic value.

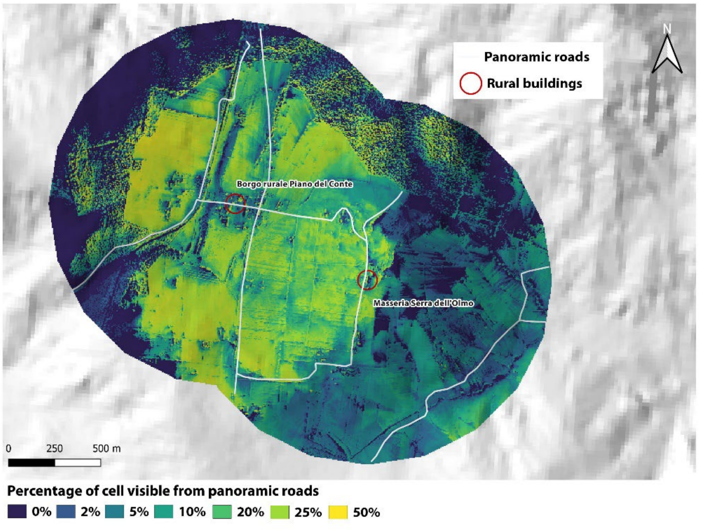

Figure 4 Viewshed analysis performed in the buffer area of rural buildings "*Masseria Serra dell'Olmo*" and "*Borgo Rurale Piano del Conte*".

Table 3 Surface modification inside 1-km-buffer (in hectares and %) of different percentage class of cell visible from panoramic roads.

Percentage of cell visible from panoramic roads (%)	Surface ha	Surface %
< 1.5	140.47	29.88
1.5 - 5	62.49	13.29
5 - 10	72.03	15.32
10 - 20	77.72	16.53
20 - 25	45.11	9.59
25 - 50	72.35	15.39
Total	470.17	100

Table 4 Surface variation inside the 100 metres buffer (in hectares and %) of different percentage class of cell visible from panoramic roads for "*Masseria Serra dell'Olmo*" e "*Borgo Rurale Piano del Conte*".

Percentage of cell visible from panoramic roads (%)	Masseria Serra dell' Olmo Surface		Borgo Rurale Piano del Conte Surface	
	ha	%	ha	%
< 1.5	0.22	7.12	0.51	16.59
1.5 - 5	0.17	5.42	0.72	23.14
5 - 10	0.30	9.71	0.77	24.84
10 - 20	1.35	43.69	0.79	25.65
20 - 25	0.66	21.20	0.15	4.69
25 - 50	0.40	12.86	0.16	5.10
Total	3.09	100.00	3.09	100.00

CONCLUSIONS

Farm buildings play a central role for improving the sustainable growth of agriculture, even through new alternative ways for living the extra-urban land, as the rural tourism. The role of rural building is indeed fundamental for enabling practices aimed to reduce resources consumption, combat environmental degradation and create better living environments, preserving at the same time architectural and historical assets that constitute a living witness of the building heritage left by our forefathers, who marked the rural territories, influencing and steering the spontaneous development of nature, while leading to production that enabled to get food.

In this study, an approach based on geographic technologies has been proposed, in order to implement new methodologies useful for the enhancement and conservation of agricultural built heritage and rural landscape. The implementation of a GIS for cataloguing historical rural buildings with geo-referenced information and subsequently using them as a basis for more complex spatial analysis, has allowed the assessment of the role and impact of these buildings within the surrounding context. This approach would reveal a suitable tool for future possible application in rural landscape analysis, planning and management.

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47. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

Izvorni znanstveni rad
Original scientific paper

VINSKE CESTE KAO TURISTIČKA PONUDA RURALNOG PROSTORA: STAVOVI STANOVNIKA GRADA ZAGREBA

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SAŽETAK

Vinske ceste su značajan oblik turističke ponude suvremenog doba i posebno su razvijene u okolici većih gradova. One su bitan segment turističke ponude i dodatnog dohotka stanovnika ruralnog prostora. U istraživanju se pošlo od pretpostavke da kod odluke o odlasku u posjet vinskoj cesti nema značajnih razlika s obzirom na dob i spol ispitanika, ali da postoji razlika s obzirom na dohodak kućanstva anketiranih. Anketno istraživanje je provedeno na uzorku od 167 punodobnih ispitanika u 2018. godini. U radu je korišten Hi-kvadrat test nezavisnosti i neparametrijski testovi za utvrđivanje povezanosti sociodemografskih obilježja ispitanika i učestalosti, odnosno motiva posjeta vinskim cestama. Različiti su motivi za posjete vinskim cestama. Prema rezultatima istraživanja stanovnici grada Zagreba posjećuju vinske ceste najviše zbog kušanja vina (39,3%) zatim turističkih sadržaja (16,8%) te prigodnih događaja (15,9%). Relativno su zadovoljni ponudom (57,9%) i smatraju da vinske ceste trebaju bolju promociju. Istraživanje je pokazalo da osobe sa završenom višom ili visokom školom posjećuju vinske ceste češće nego ispitanici sa završenom srednjom školom. Na učestalost posjeta značajan je utjecaj visine dohotka kućanstva. Ispitanici vinsku cestu u ruralnom području percipiraju kao čuvara prostora, visoko ocjenjuju njenu ulogu u poticanju razvitka ruralne ekonomije te povećanju konkurentnosti poljoprivrednih gospodarstava. Vinske ceste su kanal prodaje lokalnih poljoprivrednih i drugih proizvoda te potiču novo zapošljavanje.

Ključne riječi: *vinske ceste, ruralni prostor, grad Zagreb, turisti, dohodak*

UVOD

Vinski turizam pojam je novijeg doba, ali se o njemu raspravlja u akademskim krugovima. Definicija tog tipa turizma koja se najčešće izdvaja je Hallova (1996.) prema kojoj se vinski turizam odnosi na posjete vinogradima, vinarijama, vinskim festivalima i izložbama vina u kojem su kušanje vina i/ili doživljavanje posebnosti vinorodnog područja glavni motivacijski čimbenici posjetitelja. Gotovo da i ne postoji regija Hrvatske koja nema vinske ceste. Najrazvijenije vinske ceste su u Istri, zatim Slavoniji i Zagorju. Vinska cesta je poseban oblik prodaje poljoprivrednih, turističkih i ugostiteljskih proizvoda jednog vinorodnog područja na kojemu poljoprivredna gospodarstva i drugi djeluju udruženi pod nazivom vinske ceste. Vinske ceste pružaju usluge kušanja vina iz vlastite proizvodnje, usluge hrane i pripremanja iste, usluge smještaja i usluge koje unapređuju turističku ponudu.

Vinska cesta uključuje i prirodnu ljepotu koju karakterizira posebni krajolik kroz koji prolazi cesta. Na cesti se nalaze kulturne i prirodne znamenitosti koje njeguju tradiciju i posebnosti vinorodnog područja. Di Gregorio i Licari (2006) naglašavaju simbiozu lokalnih specifičnosti, prirodne osnove i kulturne baštine te ponudu vinskih cesta i vina koji zajedno potiču socio – ekonomski i prostorni razvoj vinorodnog područja.

Svaka vinska cesta mora ispuniti uvjete vinske ceste. Ona mora prolaziti vinorodnim područjem na prostoru najmanje jednog vinogorja gdje postoji ponuda i proizvodnja vina i drugih proizvoda od grožđa i vina. Na cestovnoj udaljenosti mora biti najmanje 5 poljoprivrednih gospodarstava unutar 10 km koja nude usluge kušanja i barem jedno od njih da je kontroliranog podrijetla.

Najmanje dva gospodarstva moraju imati usluge hrane, pogotovo seljačkih specijaliteta. Za vinske ceste je bitno da je okoliš očuvan i prirodno lijep, cestovna mreža mora biti dostupna i povezana s prometnicama višeg ranga, nužne su odgovarajuće oznake i informativni materijal o vinskoj cesti dostupan posjetiteljima. Moguće je i povezivanje manjih lokalnih vinskih cesta u regionalne što doprinosi prepoznatljivosti brenda (Drvenkar i Banožić, 2010).

Na vinskoj cesti moraju se označiti atrakcije i ugostiteljska ponuda. Od atrakcija zanimljivi su kulturni spomenici, galerije, muzeji, vidikovci i manifestacije. Dodatna ponuda koja može obogatiti turističku ponudu na vinskim cestama je planinarenje, biciklizam, jahanje, hodanje, zmajarenje, ribolov, lov, berba i drugi oblici. Razvoj vinskog turizma doprinosi pozicioniranju i prepoznatljivosti određenog turističkog područja i stvara konkurentsku prednost (Razović, 2015), a vinska cesta doprinosi promociji područja (Weston, 2003). Izravan utjecaj vinskog turizma na ekonomski razvoj prostora očituje se kroz povećanu prodaju i potrošnju proizvoda i usluga (Šlezak, 2010) odnosno razvoj i drugih djelatnosti u području. Prema Šlezaku (2010) utjecaj ovog oblika turizma vidljiv je i kroz povećanu brige za zaštitom prostora, unaprijeđenije prometne i komunalne infrastrukture sve do socio – ekonomske i demografske preobrazbe prostora u kojem se on odvija.

Cilj rada je utvrditi učestalost i motiv posjeta stanovnika grada Zagreba vinskim cestama te njihove stavove o vinskoj cesti kao dijelu turističke ponude ruralnog prostora.

MATERIJAL I METODE

U radu su korišteni primarni i sekundarni izvori podataka. Provedeno je anketno istraživanje sa 167 punodobnih ispitanika na području Grada Zagreba pri čemu je i 107 posjetilo vinsku cestu (poduzorak). Sudjelovanje u istraživanju je bilo anonimno. Istraživanje je provedeno putem Google obrazaca, online. Za mjerenje stavova (stupanj suglasnosti s navedenim izjavama) korištena je Likertova ljestvica (Marušić i Prebežac, 2004). Za obradu podataka korišten je statistički paket SPSS 21. Kao sekundarni izvori podataka korišteni su podatci Državnog zavoda za statistiku (DZS), Agencije za plaćanja u poljoprivredi, ribarstvu i ruralnom razvoju, ARKOD, znanstvena i stručna literatura, te relevantni internetski izvori.

REZULTATI I RASPRAVA

Ukupno je anketirano 167 osoba prosječne dobi 40, 9 godina. Prevladava mlađa skupina u dobi od 19 do 29 godina (107; 64,1%).

Prosječan prihod kućanstva je viši od prosjeka Hrvatske pri čemu su podjednako zastupljena kućanstva s prihodima od 6.001 do 10.000 kn (64; 38,3%) i ona s više od 10.000 kn (64; 38,3%). Gotovo tri četvrtine ispitanika ima višu ili visoku stručnu spremu (122; 73,1%) te četvrtina srednju (44; 26,3%).

Ispitanici su odgovarali na pitanje o učestalosti kozumiranja vina. Trećina (34,1%) konzumira vino jednom mjesečno, 24,6% jednom tjedno, 14,8% dva do tri puta tjedno, 5,4% četiri do pet puta tjedno dok ih 10,8% vino konzumira svaki dan. Ostali ispitanici (10,3%) uopće ne konzumiraju vino.

Gotovo dvije trećine ispitanika je (107; 64,1%) barem jednom u životu posjetilo vinsku cestu. Preko polovice ih posjećuje vinske ceste jednom godišnje (58; 54,2%), trećina dva do tri puta godišnje (34; 31,8%), manje njih četiri do pet puta godišnje (4; 3,7%) te 6 i više puta godišnje (11; 10,3%).

Tablica 1 Razlozi za posjet vinskoj cesti
Table 1 Reasons to visit the wine road

	Frekvencija *Frequency*	Postotak *Percentage*
Kušanje vina *Wine tasting*	43	40,5
Prigodni događaji (teambuilding, berba grožđa, slavlja) *Occasional events (teambuilding, grape harvest, celebrations)*	14	13,2
Kulturne i povijesne znamenitosti *Cultural and historical sights*	19	17,9
Prirodne znamenitosti *Natural sights*	4	3,8
Turistički sadržaji (kulturne i tradicijske manifestacije) *Tourist facilities (cultural and traditional events)*	6	5,7
Kušanje ostalih proizvoda (sir, med, tradicijski proizvodi) *Tasting of other products (cheese, honey, traditional products)*	18	17,0
Sportski sadržaji *Sports facilities*	2	1,9
Ukupno *Total*	106	100,0

Izvor: Anketa / Source: Survey

Kao najčešći motiv posjete vinskoj cesti je upravo kušanje vina (43; 40,6%). Također su čest razlog posjeta kulturnim i povijesnima znamenitostima (19; 17,9%), kušanje ostalih proizvoda (18; 17%) te prigodni događaji (14; 13,2%). Manje je zastupljeno sudjelovanje u sportskim sadržajima (2; 1,9%), razgledavanje prirodnih znamenitosti (4; 3,8%) i uživanje turističkih sadržaja (6; 5,7%) rjeđe su navođeni.

Hi-kvadrat test pokazuje da ne postoji statistički značajna razlika između muškaraca i žena u učestalosti posjete vinskim cestama ($\chi 2$ (1) = 0,221; p = 0,638) odnosno ne može se zaključiti jesu li češći posjetioci muškarci ili žene. Također, ne postoji niti razlika kod motiva zbog kojih jednih i drugi posjećuju vinske ceste (χ^2 (6) = 2,147; p = 0,925).

Ispitanici sa završenom srednjom školom posjećuju vinske ceste statistički značajno rjeđe nego što je očekivano, a sudionici sa završenom višom ili visokom školom statistički značajno češće (χ^2 (1) = 4,980; p = 0,029). Postojeće odstupanje je male veličine efekta (Cramerov V = 0,173).

Hi-kvadrat test kojim je provjereno postojanje razlike među sudionicima različitih stupnjeva obrazovanja obzirom na glavni motiv posjeta vinskoj cesti nije utvrđena statistički značajna razlika (χ^2 (5) = 4,133; p = 0,542). Razlike koje su pronađene male su veličine efekta (Cramerov V = 0,199).

U slučaju kada se uspoređuju dvije skupine, korišten je Mann-Whitney test koji nije pronašao statistički značajnu razliku između muškaraca i žena po učestalosti posjete vinskih cesta (U = 1288, p = 0,449). Efekt postojeće razlike je zanemarive veličine (η^2 = 0,007).

Mann-Whitney U test nije detektirao niti statistički značajnu razliku između sudionika koji jesu odnosno nisu posjetili vinske ceste prema visini dohotka (U = 3047,5, p = 0,556). Efekt postojeće razlike je također zanemarive veličine (η^2 = 0,003).

Dob ispitanika je mjerena na omjernoj ljestvici, no Shapiro-Wilk test normalnosti proveden nad podskupinama nezavisne varijable proračunao je statistički značajna odstupanja od normalne distribucije ($p < 0,05$) kod obje podskupine. Uvid u grafičke prikaze distribucija također je otkrio distribuciju drugačiju od normalne. Zbog toga je proveden neparametrijski test Mann-Whitney U test koji nije pronašao statistički značajnu razliku između sudionika koji su završili srednju i višu ili visoku školu po učestalosti posjećivanja vinskih cesta (U = 870, p = 0,340. Efekt postojeće razlike je zanemarive veličine (η^2 = 0,009).

Kako bi se utvrdila povezanost učestalosti posjećivanja vinskih cesta s visinom dohotka i dobi, izračunati su Kendallovi Tau koeficijenti korelacije, koji mjere snagu povezanosti između dvije varijable mjerene na barem ordinalnoj ljestvici. Statistički značajna povezanost između učestalosti posjećivanja vinskih cesta i dobi nije pronađena (τ_b = -0,076; p = 0,330; n = 107). Pronađena je statistički značajna povezanost učestalosti posjećivanja vinskih cesta i visine dohotka kućanstva (τ_b = 0,211; p = 0,015; n = 107). Sudionici koji češće posjećuju vinske ceste imaju statistički značajno veći dohodak kućanstva.

Razlike u motivima za posjet vinskih cesta po dobi i visini dohotka utvrđen je primjenom Kruskal-Wallis H testa. Kruskal-Wallis H test nije zabilježio statistički značajne razlike među različitim motivima za posjet vinskim cestama (H (6) = 1,377; p = 0,971). Sukladno tome, post hoc testovi za utvrđivanje razlika među podskupinama nisu provedeni.

Kruskal-Wallis H test proveden s dobi kao zavisnom varijablom nije našao statistički značajne razlike među različitim motivima za posjet vinskim cestama (H (6) = 3.766; p =

0,708) te zbog toga post hoc testovi za utvrđivanje razlika među podskupinama nisu provedeni.

Ispitanici koji su posjetili vinsku cestu odgovarali su na pitanja o prihvatljivoj udaljenosti od mjesta stanovanja. Pitanje je glasilo „Koja vam je prihvatljiva udaljenost za posjet vinske ceste od mjesta življenja?“. Za najveći dio njih (38,3%) udaljenost od mjesta stanovanja nije važna, za četvrtinu (25,2%) ispitanika u poduzorku prihvatljiva je udaljenost do 60 minuta vožnje, dok je za manji dio ispitanika prihvatljiva udaljenost do 30 minuta (21,5%) a za najmanji dio 120 minuta vožnje (15%). Prema Šlezaku (2010) primjerice Međimurska vinska cesta u okvirima Hrvatske rubno položena, dovoljno je blizu Zagreba, najvećeg emitivnog centra vinskog turizma. Udaljenost od oko 120 kilometara, odnosno sat i pol vožnje od Zagreba, ovu cestu ipak čini dovoljno dostupnom.

Na pitanje „Tijekom kojeg godišnjeg doba najčešće posjećujete vinske ceste?“ ispitanici su odgovorili da to čine najčešće u jesen (41,1%) i proljeće (29,0%). Posjete ljeti su također značajno zastupljene (25,2%) dok zimi ispitanici najslabije posjećuju vinske ceste (4,7%).

Na pitanje „Da li ste zadovoljni ponudom posjećenih vinskih cesta?“ preko 84% ispitanika koji su posjetili vinske ceste su zadovoljni ponudom usluga i proizvoda koje se nude posjetiteljima, dok njih 12,15% nije niti zadovoljno niti nezadovoljno ponudom.

Uloga vinske ceste općenito je pozitivno percipirana. Izjave da vinska cesta čuva tradiciju područja (4,17), da vinske ceste trebaju bolju promociju (4,13) te da doprinose razvoju ruralne ekonomije (4,12) su izjave s najvišim srednjim ocjenama.

Na pitanje koji su se sadržaji posebno svidjeli ispitanicima prilikom posjeta vinskoj cesti isti su mogli izabrati između više ponuđenih odgovora. Od ukupnog broja ispitanika (107) njih 82 navelo je kao odgovor samo kušanje vina, zatim mogućnost kušanja ostalih proizvoda (57) te ponudu vina (51).

U otvorenom tipu pitanja ispitanici su mogli navesti što im se nije svidjelo prilikom posjeta vinskim cestama. Neki od izdvojenih odgovora su: „*Oglašavanje o događanjima izvan mjesta vinske ceste (negdje dalje, da ljudi koji nisu u blizini mogu saznati za to, a ne samo staviti plakate u mjestu gdje se to odvija)*“; „*Angažiranost i samopromocija vinara na vinskim cestama.*“; „*Infrastruktura, sadržaji za obitelji s djecom, dodatni sadržaji koji bi ispunili vrijeme za višednevni posjet, radno vrijeme ili dežurstva vinarija*“; „*Valorizacija kulturne materijalne i nematerijalne baštine i prikaz tradicijskih zanata i uključivanje turista u to*“; „Kvalitetniji pristup kod kušanja vina uz bolje čaše, komadić kruha, sira, nisu uvijek rashlađena“; „*Smještaj, samoberba, edukativne radionice*“; „*Kvalitetnija prezentacija sa više zanimljivosti, informacija i stečenih/prenesenih znanja, kušanje proizvoda koji "pašu" uz određenu sortu vina, autohtona glazba*“; „*Prezentacija kako se nekad radilo da bi se dobilo vino*“; „*Nikada nisam posjetio vinsku cestu a da je došlo do nekakvog nezadovoljstva ili da je nešto nedostajalo. Sve su posebne na svoj način.*“; „*poklon - paketi*“; „*Bolje radno vrijeme, dostupnost i ponuda hrane uz kušanje vina*“ itd.

Posljednje pitanje u upitniku bilo je otvoreno za komentare ispitanika ukoliko smatraju da je nešto izostavljeno kroz prethodna pitanja. Izdvajamo jedan odgovor: „*Jedini minus vinskih cesta ide cijenama vina, koja su tamo skuplja nego u vinarijama i dućanima, umjesto da bude obrnuto.*“

Tablica 2 Stavovi ispitanika o vinskoj cesti (1-u potpunosti se ne slažem; 2-ne slažem se; 3-niti se slažem niti se ne slažem; 4-slažem se; 5-u potpunosti se slažem)
Table 2 Respondents attitudes on wine road (1 - strongly disagree, 2 - disagree, 3 - neither agree or disagree, 4 - agree, 5 - strongly agree)

	N	Min	Max	SO* *AG*	SD *St. Dev.*
Vinska cesta čuva tradiciju područja *The wine road preserves the tradition of the area*	107	1	5	4,17	1,225
Vinska cesta doprinosi razvoju ruralne ekonomije *The wine road contributes to the development of the rural economy*	107	1	5	4,12	1,171
Vinska cesta potiče diverzifikaciju ruralne ekonomije *The wine road encourages the diversification of the rural economy*	107	1	5	4,07	1,135
Vinska cesta povećava konkurentnost poljoprivrednih proizvođača *The wine road increases the competitiveness of agric. producers*	107	1	5	4,07	1,118
Vinska cesta povećava vrijednost poljoprivredne proizvodnje *The wine road increases the value of agricultural production*	107	1	5	4,01	1,161
Razvoju vinskih cesta pomaže poslovno povezivanje poljoprivrednih proizvođača *Business association of agricultural producers helps to the development of wine roads*	107	1	5	4,00	1,099
Vinske ceste olakšavaju poljoprivrednicima prodaju proizvoda i usluga *Wine roads help farmers sell their products and services*	107	1	5	3,94	1,106
Vinska cesta obogaćuje ukupnu turističku ponudu države *The wine road enriches the total tourist offer of the state*	107	1	5	3,93	1,294
Vinska cesta omogućava stvaranje novih radnih mjesta *The wine road allows to create new jobs*	107	1	5	3,83	1,209
Vinske ceste doprinose zadržavanju ljudi *Wine roads contribute to retaining people*	107	1	5	3,81	1,297
Kroz vinske ceste se ekonomično iskorištavaju prirodni resursi *Natural resources are exploited economically through wine roads*	107	1	5	3,79	1,234
Hrvatska ima bogatu ponudu vinskih cesta *Croatia has a rich wine roads offer*	107	1	5	3,53	1,152
Mlađa populacija je više zainteresirana za vinske ceste od starije populacije *The younger population is more interested in wine roads than the older population*	107	1	5	3,03	1,224
Poljoprivrednici koji se uključuju u projekt vinske ceste ne trebaju dodatno (cjeloživotno) obrazovanje *Farmers involved in the wine road project do not need additional (lifelong) education*	107	1	5	2,63	1,307
Vinska cesta ne doprinosi razvoju lokalne infrastrukture *The wine road does not contribute to the development of local infrastructure*	107	1	5	2,46	1,362
Vinska cesta nepovoljno utječe na autohtonost područja *The wine road adversely affects the autochthonous area*	107	1	5	2,25	1,388
Vinska cesta zagađuje okoliš i narušava krajolik *The wine road pollutes the environment and distorts the landscape*	107	1	5	1,97	1,328

* Srednja ocjena / Average grade; Izvor: Kao za Tablicu 1. / Source: Same as for Tab. 1

ZAKLJUČAK

Prema rezultatima istraživanja stanovnici grada Zagreba posjećuju vinske ceste najviše zbog kušanja vina (39,3%) zatim turističkih sadržaja (16,8%) te prigodnih događaja (15,9%). Relativno su zadovoljni ponudom (57,9%) i smatraju da vinske ceste trebaju bolju promociju.

Više od polovine sudionika na pitanje o učestalosti posjeta vinskih cestama navelo ih je da posjećuju jednom godišnje (54,2%), otprilike trećina dva do tri puta godišnje (31,8% poduzorka). Manje su zastupljeni oni sudionici koji češće posjećuju vinske ceste, četiri do pet puta godišnje (3,7%) te 6 i više puta godišnje (10,3%).

Između muškaraca i žena ne postoji statistički značajna razlika s obzirom na odluku o posjećivanju vinske ceste. Isto se odnosi i na motiv posjete s obzirom na dob pri kojemu također nije nađena statistički značajna razlika. Prema obrazovanju utvrđena je statistički značajna razlika s obzirom na sudionike koji su završili višu ili visoku školu i onih sa srednjom školom. Sudionici sa završenom višom ili visokom školom učestalije posjećuju vinske ceste od onih sa završenom srednjom školom. Provjerena je i razlika između različitog stupnja obrazovanja i motiva za posjet vinskoj cesti te su rezultati pokazali da ne postoji statistički značajna razlika između te dvije varijable.

Statističkom analizom pronađena je statistički značajna povezanost učestalosti posjećivanja vinskih cesta i visine dohotka kućanstva. Sudionici koji češće posjećuju vinske ceste imaju statistički značajno veći dohodak kućanstva

Vinske ceste posjetitelji vide kao doprinos razvoju ruralne ekonomije, očuvanje tradicije, povećanje vrijednosti poljoprivredne proizvodnje, zadržavanje ljudi na ruralnom prostoru, obogaćivanje turističke ponude države, povećanje konkurentnosti, stvaranje novih radnih mjesta i povećanje znanja o vinu.

NAPOMENA

Rad je izvod iz diplomskog rada studentice Marine Petrić, mag. ing. agr., studentice diplomskog studija Agrobiznis i ruralni razvitak na Agronomskom fakultetu u Zagrebu

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WINE ROADS AS A TOURIST OFFER OF RURAL AREAS: ATTITUDES OF INHABITANTS OF ZAGREB CITY

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ABSTRACT

Wine roads are a significant form of tourist offer of the modern age and have been specifically developed around the big cities. They are an important segment of the tourist offer and additional income of residents of rural areas. The study is based on the assumption that in the decision to go to visit the wine road there is no significant differences according to age and sex of respondents, but there are differences regard to household's income. The survey was conducted on a sample of 167 adult respondents in 2018. Hi-square test independence and nonparametric tests were used to determine the relation between the socio-demographic characteristics of the respondents and frequency, or motives in visiting the wine roads. According to the survey results, respondents visit the wine roads mostly because of wine tasting (39.3%) followed by tourist contents (16.8%) and occasional events (15.9%). They are relatively satisfied with the offer (57.9%) and believe that wine roads need better promotion. The research has shown that respondents with higher or high school degree visit the wine roads more often than those who have completed secondary school. The level of household income has a significant impact on the frequency of visits the wine roads. Respondents perceived wine roads in a rural area as the "guardian" of these areas, highly evaluate its role in promoting the development of rural economy and increasing the competitiveness of farms. Wine roads are a channel for local agricultural and other products selling and encouraging new employment.

Keywords: *wine roads, rural area, Zagreb City, tourists, income*

Snaga održavanja

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