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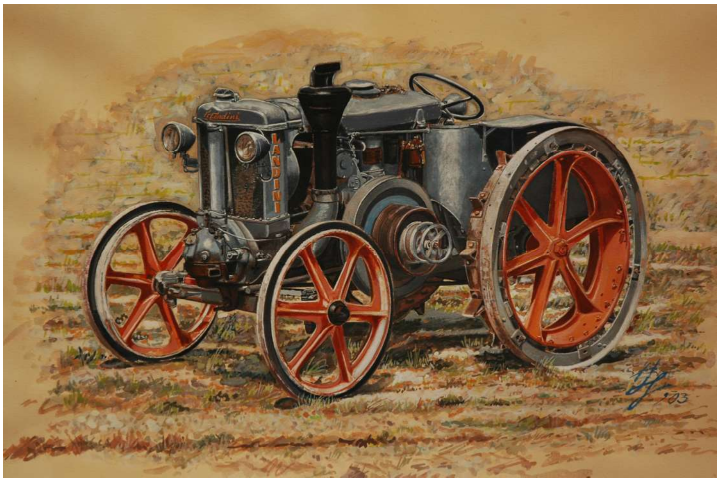

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ZAVOD ZA MEHANIZACIJU POLJOPRIVREDE
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AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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PRIČA O TRAKTORU S NASLOVNICE

SUPERLANDINI

Traktore Landini možemo uvrstiti u legende europske traktorske tehnike. Landinijevi traktori s užarenom glavom pojavili su se samo nekoliko godina nakon prvog traktora na svijetu s užarenom glavom - Lanzovog Bulldoga. Giovanni Landini, po osnivanju poduzeća 1884. godine u Fabrici (Italija), započinje proizvodnju različitih poljoprivrednih uređaja i strojeva poput vršalica, uređaja za podrumarstvo, lokomobila itd. Landini je uvidio da budućnost pripada motorima s unutarnjim sagorijevanjem, a ne parnim strojevima te se krajem devetnaestog stoljeća posvećuje razvoju stacionarnog motora s užarenom glavom. Svoj novi motor predstavio je na svjetskoj izložbi u Parizu 1900. godine (prvi stacionarni motor s užarenom glavom konstruiran je 1896. godine u tvornici Richards Hornsby and Sons u V. Britaniji). Landini je stacionarni motor doradio i tržištu ponudio seriju motora snage od 10 – 35 KS. Motor je također montirao na podvozje s kotačima tako da ga je bilo moguće premještati pa je postao primjenjiv u poljoprivredi za pogon različitih strojeva kao što su vršalice, slamoreznice, crpke za vodu. Godine 1925. jedan od Landinijevih sinova konstruirao je traktor s motorom s užarenom glavom snage 30 KS koji se pokazao prikladnim za različite poslove u poljoprivredi. Giovanni Landini na žalost nije doživio da svoj motor vidi ugrađen u traktor, umro je u listopadu 1924.

Pored Landinija značajni traktori s tim motorom su bili Lanz, Orsi, HSCS, Bubba, Ursus, S.F.Vierzon, Bolinder, Marshall itd. Izraz "motor s užarenom glavom" označava poseban sustav sagorijevanja mješavine goriva i zraka u vanjskoj komori. To je u stvari diesel motor koji radi u dva takta, a od četverotaktnog diesel motora se razlikuje po manjem stupnju kompresije koji iznosi 1:5 do 1:12. Zagrijavanje zraka pri takvoj kompresiji nije dovoljno za samozapaljenje. Gorivo se zato ubrizgava u posebnu komoru sa stlačenim zrakom (koja je zbog svog oblika i prethodnog zagrijavanja dobila ime "užarena glava"). Užarena glava je dobro vidljiva na prednjem dijelu traktora i daje mu karakterističan izgled.

Oko 1928. godine, nakon testiranja prototipova, Landini započinje serijsku proizvodnju traktora s užarenom glavom. Traktor na slici je model SUPERLANDINI čija je proizvodnja započela 1934. godine i s manjim preinakama se proizvodio čak do 1953! Najveća snaga motora koji je imao samo jedan ležeće postavljeni cilindar zapremine 12.200 cm^3 iznosila je 48 KS pri 620 min^{-1}. Hlađenje motora je bilo tekućinom, termosifonsko, a podmazivanje pod tlakom. Traktor je bio opremljen mjenjačem s tri stupnja prijenosa za vožnju naprijed i jednim unatrag i postizao je najveću brzinu kretanja od 6,2 km/h. Masa traktora iznosila je 3.500 kg. Bio je opremljen s električnim svjetlima, za proizvodnju struje služio je dinamo, koji je dobivao pogon preko remena od velikog bočno postavljenog zamašnjaka motora. Pored primjene u poljoprivredi traktor je primjenu našao i u industriji za pogon raznih stacionarnih strojeva, te kao vučno vozilo. SUPERLANDINI je kasnije opremljen i pneumaticima. Tvornica je imala u programu i druge izvedbe traktora s užarenom glavom, te su najsnažniji bili u ponudi i kao polugusjeničari. Godine 1957. započeli su s proizvodnjom novog, manjeg tipa traktora opremljenog Perkinsonovim diesel motorom i razdoblje motora s užarenom glavom je u Landiniju završilo. Landini traktori s užarenom glavom su zbog svoje robustnosti, izdržljivosti, jednostavnosti i malih troškova održavanja bili u upotrebi do početka 80-tih godina prošlog stoljeća.

Tekst: Viktor Jejčič   Slika: Dušan Jejčič

SADRŽAJ – CONTENTS

34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 37:631.147:631.17](536)(931)
Pregledni rad
Review paper

A COMPARISON OF STUDENTS' INSIGHTS AND ATTITUDES TOWARDS AGRICULTURAL ENGINEERING EDUCATION: EVIDENCE FROM NEW ZEALAND AND THE SULTANATE OF OMAN

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SUMMARY

Like other academic disciplines, agricultural engineering (AE) is faced with the challenges of recruiting and retaining sufficient undergraduate majors to ensure its survival. Combinations of historical problems that are related to the poor image of agriculture (and AE) have been exacerbated by the emergence of new knowledge frontiers and economic drivers anchored around information technology and biology. Consequently, there is a lively global dialogue on the future of AE education, including name change. The author has witnessed the repositioning the AE departments at Massey University in New Zealand and Sultan Qaboos University in Oman. At both institutions, a combination of written questionnaires and focused group study was used to assess students' perceptions and attitudes towards AE education, curriculum content and their career prospects. In this article, I compare and discuss the results and feedback obtained from students from both institutions. Based on these findings, suggestions are made to ensure greater stakeholder participation and contribution in the ongoing global dialogue on the transformation and future of AE education and profession. The comparative synthesis reported in this article underlines the vital importance of careful consideration of the local (institutional and national) conditions under which agricultural engineering education and profession are situated before embarking on program reform and transformation and student recruitment and retention.

[Ψ] The author is Director, Agricultural Experiment Station, and Associate Professor of Agricultural Engineering.

Key words: *agricultural engineering, biological engineering, biosystems engineering, recruitment and retention, engineering education*

INTRODUCTION

There is an ongoing global dialogue on the evolution and transformation of agricultural engineering education and profession in the new Century. During the past century, the discipline of agricultural engineering evolved from the application of engineering principles and technology to improve on-farm productivity and extended into new horizons dealing with environmental issues and post-production quality and safety of biological materials (Opara, 2004a,b). In response to external and internal pressures such as reduction of research funds from traditional sources and decline in undergraduate enrolments, many agricultural engineering departments and programs have restructured their curricula and changed the names of their programmes. In Europe and some other parts of the world, the ongoing transformation has resulted in change of name and focus towards 'Biosystems Engineering' (Briassoulis et al., 2001), while in North America (particularly the USA), the new emphasis has been towards 'Biological Engineering' (Cuello, 2002; Opara and Cuello, 2006). The objective of our study was to compare students' attitudes towards the name and future of agricultural engineering in New Zealand (Southern Hemisphere) and Sultanate of Oman (Arabian Gulf). Based on the findings, recommendations are made to improve stakeholder involvement in the ongoing dialogue on the future of agricultural education.

MATERIALS AND METHODS

During the 2001 final semester, we used a combination of focused group discussion and self-administered questionnaire to explore final year AE students' perceptions of several aspects of agricultural engineering program at Massey University (MU), New Zealand. Five students (out of six enrolled) participated in both the group discussion and questionnaire survey.

A similar study was carried out at the end of the 2003 Fall Semester at Sultan Qaboos University (SQU) in Oman among agricultural engineering students (comprised mainly of their final year). A total of 18 students participated in the group discussion and completed the questionnaire. In previous articles, we reported our findings from each separate study (Opara et al., 2006a,b; Opara et al., 2004a,b; Opara, 2003a,b). In the present article, we present a comparative synthesis of the responses from agricultural engineering students at universities to provide an international perspective.

RESULTS AND DISCUSSION

Selection of Agricultural Engineering Major

There is a major contrast in admission policy and procedure for degree major selection between the two universities. There are seven main universities in New Zealand and students can apply directly to any number of universities to enroll into specific degree majors like Agricultural Engineering. On the other hand, the Sultanate of Oman has only one national university (Sultan Qaboos University), which until very recently, was the only university in the country. At the end of high school education, students apply for admission into the university and indicate their choice of colleges in a ranked order. After the final selection of students is made based on high school grades and subjects taken, students who gain admission into the university are then allocated to one of the seven colleges, starting by allocating the top students to their preferred colleges. Our study showed that nearly all the students did not include the College of Agricultural and Marine Sciences (CAMS) as one of their preferred colleges when they applied for admission into the university. However, after they had been allocated to the college, about 72% of the students in the agricultural engineering major indicated that they selected it as their preferred major (among ten degree majors offered in the college).

While New Zealand students made the decision in their last year at high school to pursue a degree major in AE, the Omani students were not aware about the degree major until their first year at the university. Most New Zealand students came from a rural farming background and were particularly interested in 'farm machinery'. On the other hand, the Omani students were not interested in agriculture or farm related course; however, the word 'engineering' was the main factor that attracted them to apply to enroll in the AE degree major.

Preferred Host College for AE Major

Historically, the AE degree major has been offered through a range of colleges or faculties, including Agriculture, Engineering, Science, and Technology. Following the merger of the Faculties of Science, Technology, Veterinary Science, and Agricultural and Horticultural Sciences into the College of Science at MU in the later 1990s, the undergraduate degree major in AE was discontinued in 2002. Prior to this the AE major was offered in the Faculty of Agricultural and Horticultural Sciences, while at SQU it is offered in the College of Agricultural and Marine Sciences. At Sultan Qaboos University, the Department of Bioresource and Agricultural Engineering as merged with the Department of Soil and Water Science in 2004 into a new Department of Soils, Water, & Agricultural Engineering. At the same time, the name of the degree major was changed from Bioresource and Agricultural Engineering (BAE) to Agricultural Engineering.

When we asked the students to indicate their preferred host college/faculty for the degree major in AE, all the students at MU chose to retain the status quo and would like to see greater focus on agriculture and horticulture in the program rather than technology/engineering. In contrast, 75% of students are SQU preferred the AE to focus more on 'engineering' rather than 'agriculture and marine'. Furthermore, 64% would prefer the AE degree to be located in the College of Engineering (CoE) instead of CAMS.

Preferred Discipline/Major Name and Title of Degree Awarded

One of the most contentious issues in the ongoing dialogue about the future of AE education is the choice of a name that embodies both the tradition and projects the future of the profession. Students at both institutions expressed a strong preference for 'Agricultural Engineering' as the discipline name, with the addition of the word 'technology' as the next most preferred name. Thus, while the students at MU were satisfied with the name of their

Major (AE), students at SQU were dissatisfied with the inclusion of the word ‘Bioresource’ in theirs (BAE). Indeed, many of them questioned the meaning and relevance of the word ‘Bioresource’ in the name of their Major. Overall, students at both universities disliked the inclusion of the word ‘Biology’ or its variants in the name of their major or discipline.

There was a high preference among students from both institutions for a degree title that incorporated the word ‘engineering’ alone or in combination with ‘technology’ (BAgrTech and BEng for MU students, and BEngTech and BEng for SQU students, respectively). Similarly, students are both institutions would consider themselves as engineers (and titled) after graduation and would prefer the title ‘engineer’ instead of agriculturist, scientist, or technologist. Thus, students at both institutions were dissatisfied with titles of degree that they were awarded (BApplSc at MU and BSc at SQU, respectively).

Duration of Degree Program

The standard duration of the AE undergraduate degree program at MU was 3 years (and 4 years for Honours), while the average duration at SQU is 4 years. The majority of students preferred the status quo and the students at MU also expressed a willingness to pursue a revised standard 4 year program. We found that these preferences contradict the students’ high interest in ‘engineering’ both their degree title and name of major/discipline given that accredited engineering programs generally require more academic credit hours (and duration) to complete. Our experience at both institutions suggest that these students have low aptitude for mathematics, basic courses in science and engineering, and therefore would likely struggle to complete successfully a fully accredited AE degree program.

Employment Prospects and Career Choices

There was a very marked difference in students’ preference for employment after graduation. New Zealand students assessed their job prospects to be high (4.2/5.0) and students generally consider completing two majors (or at least a minor) to enhance their employment prospects. All students plan to pursue a career in the private sector, while 60% specifically indicated ‘consultancy’ in the agriculture/rural sector. On the other hand, most Omani students considered their employment prospects to be bleak and 89% indicated that they prefer to seek employment in the public (government) sector while 44% expressed interest to work in the private sector. Starting own business such as consultancy was the least preferred employment option among Omani students. Preference for public sector employment reduced to about 57% when calculated based on the total response by students. It should be pointed out that available records indicate that about 84% of AE graduates from SQU are currently employed in government ministries and parastatals. Considering the prestige that is accorded to government jobs and the favourable financial and fringe benefits, it appears that ongoing private sector diversification and labour market reforms are necessary to reduce the over-dependence of Omani graduates on government jobs.

Attitudes Towards Academic Program Content

Students at both institutions expressed considerable apprehension and dislike of courses in the basic physical and biological sciences (maths/physics, biology/chemistry) and also considered these courses to be less important than courses in engineering/technology and agriculture/horticulture. Students also questioned the relevance of some courses to their AE major. The suggestion to omit such courses was mostly related to students' perception of inadequate course administration, especially when the courses were taken from outside colleges/faculties. It should also be pointed out that some students had a very narrow view about what the types and range of courses that are required for successful education of future agricultural engineers. For instance, some students at SQU who have a bias towards the Soil and Water Engineering focal area in agricultural engineering strongly felt they do not need the compulsory course in 'Statics' and 'Dynamics', which are offered by the College of Engineering. However, students from both universities recommended the inclusion of more courses in 'design' of agricultural engineering systems, 'practical' use of agricultural machinery, and use of 'real' client-based projects in design course. The majority of students at SQU requested for the inclusion of more courses in computer programming and the use of professional software.

Critical Skills for Success in the Marketplace

Students at both institutions expressed moderate to high confidence that the contents of their degree programs would equip them with the necessary skills to meet the requirements of the job market. There was however, a slight difference among the two groups of students on the skills they considered to be most critical for success. Both students noted the importance skills in 'machinery' and 'communication' for AE graduates; however, students at MU placed greater emphasis on the importance of 'soft' skills (using word like 'creativity', 'lateral thinking', 'ability to work unsupervised', 'communication'), while SQU students placed greater importance on 'technical' skills (using words like 'computer', 'research', 'languages'). Interestingly, students from both groups demanded for inclusion of more practical farm operations with agricultural machinery, particularly the use of tractors.

Improving the Image and Appeal of Agricultural Engineering

In comparison with other engineering disciplines, students at both universities overwhelmingly perceived the public image and understanding of the role of agricultural engineering to be very poor or poor. Persistent poor image of AE among students and the general public was more attributed to its association with agriculture than engineering (74% & 26%) at SQU than MU (62% & 38%). To improve the image of AE and enhance its appeal among potential students, targeted 'advertising' of the discipline was specifically recommended by each group of students. The objective of such campaigns by AE professional societies and academic institutions would focus on providing informing and promoting AE among the general public and potential students. One student at MU recommended the implementation of a programme which he captioned "Meet Your Local Agricultural Engineer", while another student at SQU recommended launching special extension and community outreach programs where agricultural engineering organise "How-to-Do" events that demonstrate solutions to practical problems facing society. SQU students also recommended continuous interaction and partnership with the private sector through supervised internship programs and implementing industry-oriented student design projects.

CONCLUSIONS

In this article, we have synthesized the results from published studies on students' perceptions and towards attitudes agricultural engineering education to provide a comparative global perspective to the ongoing dialogue on the future of agricultural engineering education and discipline. The following conclusions may be drawn from the synthesis:

1. The results demonstrated low appeal of AE among students in both countries as evidenced by the low number of students registered in the major at Massey University which led to the closure of the major, and the fact that the large majority of students enrolled in the major at SQU did not select the college (and major) when they applied for university admission.
2. There was a difference in students' preference of host college or faculty for the degree major in AE: New Zealand students preferred the College/Faculty of Agriculture (or related College name) while Omani students overwhelmingly preferred the College of Engineering.
3. Both student groups preferred the name of the discipline or major to be Agricultural Engineering, and showed a strong resentment towards names that included Biology or its variants (Bio-).
4. Degree titles that included 'Engineering' and/or 'Technology' were highly preferred among students than those which included 'Agriculture' or 'Applied Science'. Students
5. New Zealand students perceived a favourable employment prospect after graduation and the majority chose to pursue careers in the private sector (mainly rural consulting); in contrast, the majority of Omani students prefer employment in the public sector, although their prospects have become very low in recent times due to very limited new employment opportunities in that sector.
6. Both student groups reported dislike and aptitude for mathematical sciences and demanded the inclusion of more 'practical' courses that are 'hands-on' and field-based such as machinery operation and industry-oriented design projects or capstone.
7. Regarding the skills which they considered to be vital for success in the job market, students at MU identified several 'soft' skills while SQU students placed more emphasis on 'hard' technical skills and English language.
8. Students considered the association with agriculture (rather than engineering) to be a major contributor to the poor image and public profile of agricultural engineering.
9. The differences found among students from Oman and New Zealand clearly suggest that efforts to improve the low public image and profile of agricultural engineering and to enhance student recruitment and retention must consider the local context through stakeholder analysis and input.

ACKNOWLEDGEMENT

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 620.95:633.2:661.9
Prethodno priopćenje
Preliminary communication

OBNOVLJIVI IZVORI ENERGIJE (OVE), BILJKA KAO ENERGIJA I BILJKA KAO HRANA

RAJKO BERNIK, ALEŠ ZVER

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Katedre za poljoprivrednu tehniku, Jamnikarjeva 101,1000 Ljubljana, Slovenija

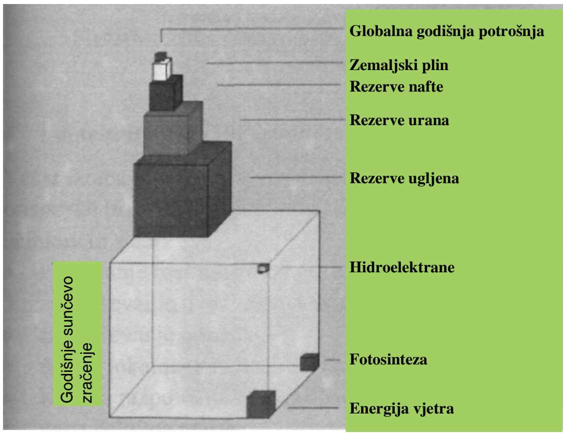
SAŽETAK

Potrebe stanovništva po energiji su sve veće, a po drugoj strani kopne zalihe fosilnih goriva. Prijeti nam nestašica energije. Djelomično rješenje problema je iskorištavanje obnovljivih izvora energije (OVE), među koje spada također i dobivanje bioplina iz biomase. U Evropi se susrećemo s viškovima hrane i napuštanjem ponekih poljoprivrednih zemljišta. U našem istraživanju smo vrednovali biljku kao energiju i biljku kao hranu. Urod postignut na pokusnom polju smo kemijski analizirali. Na temelju analiza biljaka smo teorijski izračunali količinu proizvedenog bioplina, prinos metaboličke energije (ME) i neto energiju laktacije (NEL) iz tih biljaka. U istraživanju smo kao krmno bilje uključili sudansku travu, kao drugo ne-krmno bilje pa faceliju i japanski dvornik.

Ključne riječi: *energija, obnovljivi izvori energije, bioplin, biljke, prehrana životinja, krma, sudanska trava, japanski dvornik, facelija.*

UVOD

Slika 1 prikazuje svjetsku godišnju potrošnju energije, zalihe fosilnih goriva i godišnje količine obnovljivih izvora energije u obliku volumenskih likova kocki. Tako je stvar razumljivija i onima koji se s energijom neposredno ne bave. Kocka koja predstavlja cjelokupnu potrošnju je na vrhu, doduše je mala, pojavljuje se pa svake godine. Kocke koje predstavljaju zemaljski plin, naftu, uran i ugljen značajno su veće, ali jednokratne. Te kocke se svaku godinu smanjuju za opseg energije, koju potrošimo, zato govorimo o još raspoloživim zalihama. Ocjena raspoloživih zaliha nafte trebala bi biti dovoljna samo za narednih 50 godina uz sadašnji opseg upotrebe, za ugljen pa negdje do 200 godina.



Slika 1 Godišnja potrošnja energije, zalihe fosilnih goriva i godišnje količine obnovljivih izvora energije (Nemec, 2005)

MATERIJALI I METODE

Pokus smo postavili na pokusnom polju (slika 2) Biotehničkog fakulteta u Ljubljani.

Slika 2 Pokusno polje (foto: Zver, 2005)

Priprema zemljišta za sjetvu

Na parceli, na kojoj je bio u 2004. godini predkultura krumpir, smo s biljkama izveli usporedni pokus. U jesen je bilo obavljeno jesensko duboko oranje do dubine približno 30 cm. Zemljište smo neposredno pred sjetvom obradili predsjetvenikom do sitno grudaste strukture, pogodne za sjetvu, tako da smo obezbjedili čim ravnomjernije uvjete za klijanje. Zemljište je za sve biljke bilo jednako obrađeno. Opredijelili smo veličinu parcele na 20 m^2, jer nam takva površina omogućava zadovoljavajući broj uzoraka.

Analiza tla je bila obavljena po AL-metodi. Dobivene vrijednosti hranljivih tvari su izražene u mg/100 g tla i njih svrstavamo u skupine koje smo označili slovima A, B, C, D i E. To su stupnjevi ili razine opskrbljenosti tla s hranljivim tvarima.

Ako uspoređujemo rezultate naše analize tla su fosforom dobro opskrbljena , s kalijem pa srednje opskrbljena. Fosfora je bilo 14,1 mg/100 g u tlu, što ga razvrstava u razred C; kalija pa je bilo 13,1 mg/100 g tla, što znači razred B.

Tla pred sjetvom i odmah po sjetvi, nismo gnojili, jer su analize pokazale da su tla primjereno opskrbljena. Biljke smo med vegetacijom, u sredini lipnja (neposredno pred kišom) dodatno gnojili s mineralnim gnojivom KAN (27 % N), količina dodatnog N/ha je iznosila 67,5 kg. Dodatno gnojenje smo obavili ručno.

Klima

Temperaturu zraka i tla, te količinu padavina smo mjerili na meteorološkoj stanici, koja stoji na pokusnom polju Biotehničkog fakulteta. Iz tablice 1 su vidljivi hidrometeorološki podaci za mjesece svibanj, lipanj i srpanj 2005. godine.

Tablica 1 Hidrometeorološki podaci, izmjereni na meteorološkoj stanici Biotehničkog fakulteta (Žust, 2003)

Dekada u 2005 g.	Maks. temp.	Min. temp.	Prosj. temp.	∑ sunčanih sati	∑ padavina
I svibanj	20,3	6,5	13,45	67,9	39,8
II svibanj	17,7	10,8	14,23	73,8	56,4
III svibanj	24,9	17,9	21,13	128,6	0,6
I lipanj	21	11,5	16,16	76,6	25,7
II lipanj	22,8	15,6	18,97	74,2	31,8
III lipanj	25,9	21,4	23,05	102,1	9,9
I srpanj	21,6	14,2	18,26	56,6	129,7
II srpanj	25,3	17,4	21,34	89,8	20,2
½ III srpnja, (prvih 5 dana)	21,7	18,5	19,82	32,1	9

Sjetva

Sjetvu sudanske trave, u pokusu, smo obavili 4. svibnja 2005. Sjeme smo posijali ručno, poprijeko i pomiješali u zemlju s grabljama. Zbog prethodnog obrađivanja s predsjetvenikom, koji je imao zadnji strojni element valjak, na parcelama su ostali jarci dubine 2 cm. Pri zatrpavanju sjemena u zemlju je većina, prije ravnomjerno posijanog sjemena, završila u tim jarcima, zato je usjev po klijanju izgledao kao da bi bio posijan na razmaku, po redovima. Meteorolozi su prognozirali veoma sušnu godinu, zato smo se odlučili i posijali usjev gušće, od preporuka u literaturi. Japanski dvornik na parcelama nismo sijali, jer ga ima dovoljno u okolici.

Upotrebljene biljke

Pri planiranju pokusa smo se odlučili, da u pokus uključimo biljku koju u literaturi pronađemo, kao biljku pogodnu za proizvodnju bioplina, kao i biljke koje u literaturi nisu spomenute kao potencialne za pridobivanje bioplina. Od biljaka smo izabrali:

- sudansku travu *(Sorghum sudanense),* sorte 'Zora',

Druge (ne-krmne) biljke, uključene u poskus, iako njihovu primjenu u proizvodnji bioplina u literaturi nismo pronašli, su:

- facelija *(Phacelia tanacetifolia Benth.),*
- japanski dvornik *(Reynoutria japonica*).

Berba

Slučajno smo izabrali 2m^2 na svakoj parceli. Urod smo ručno pokosili, pospremili ga u vreće iz jute i izmjerili. Vreće su bile predhodno izmjerene i označene.

Od pojedinog uroda smo izmjerili još 2000 g svježeg uzorka i dali ga u vreće iz jute. Označene uzorke smo 14 dana sušili u sušionici. Posušenim uzorcima smo izmjerili težinu, zatim smo samljeli s mlinom, koji je imao sito s rupama promjera 2 mm. Samljevene uzorke smo spremili u plastične vreće. Svaki uzorak smo čuvali za moguće daljnje analize. Nekoliko uzoraka smo još upotrijebili za precizno određivanje suhe tvari (SS), koju smo odredili tako, da smo uzorak izmjerene težine sušili na 105^0 C, dok nismo dobili konstantnu masu.

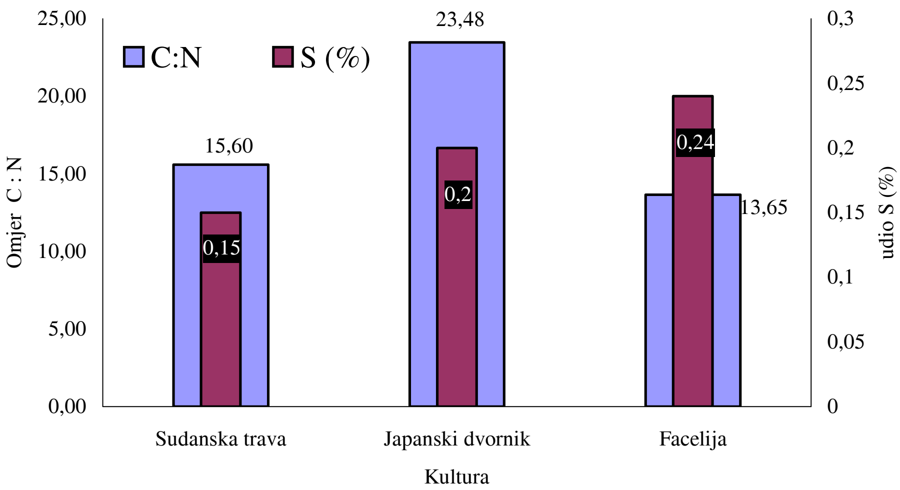
Određivanje C, N, S

Kemijsku analizu za određivanje C, N i S smo obavili na Šumarskom institutu Slovenije na Odijelu za šumsku ekologiju, po metodi za određivanje:

C: ISO 10694 **N:** ISO 13878 **S:** ISO 15178

U svim primjerima određivanja se radilo o spaljivanju pri 1350 ^{0}C i analizi plinova sagorijevanja – analizi elemenata.

Slika 3 prikazuje udjele pojedinih elemenata u izabranim kulturama. Kao temelj za maksimalnu proizvodnju bioplina smo uzimali u obzir omjer C : N, koji je između 25-30 : 1, navodi Polprasert (1986). Kao što možemo vidjeti, nijedna kultura nije postigla optimalan omjer među elementima, najviše pa se tome približio japanski dvornik. Uzrok za takav omjer je činjenica da su biljke bile još mlade. Sumpor je nepoželjni faktor u tehnologiji bioplinova, jer na strojne elemente djeluje korozivno (Đulbić, 1986). Naviše sumpora je bilo pri faceliji zatim pri japanskom dvorniku, najmanje pa pri sudanski travi. Pri uskom omjeru C : N možemo zaključiti da je veći udio bjelančevina ili nebjelančevinastog dušika u biljkama.



Slika 3 Omjer C : N i udio sumpora (S)

Prinosi i vrednovanje biljaka

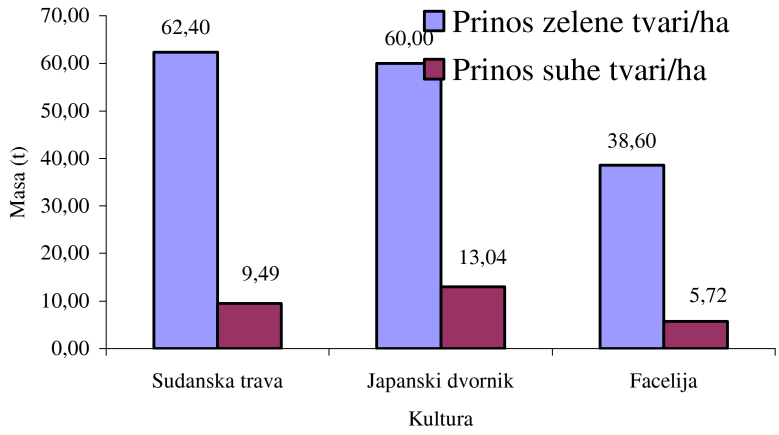
Na osnovi prinosa na pokusnim parcelama smo izabrane kulture vrednovali kao sirovine za proizvodnju bioplina i kao krmu. U nastavku vrednovanja smo bioplin i proizvode stočarstva (mlijeko i meso) izrazili u novčanoj vrijednosti.

Određivanje udjela suhe tvari (% SS) i suhe tvari (SS) iz svježih biljaka

Sadržaj vode se među biljkama razlikuje, zato smo svakoj biljki utvrdili udio suhe tvari, da bi nakon toga lakše međusobno uspoređivali. Prinose nam prizakuje slika 4.

$$\%SS = \frac{masa\_SS(g)}{masa\_svježe\_tvari\_(g)} \times 100 \quad [\%] \qquad (1)$$

$$masa\_SS/ha = \frac{\%SS * urod/ha}{100\%} \quad [g] \qquad (2)$$



Slika 4 Količine prinosa svježe biljne mase i SS na hektar

Pretvorba biljne suhe tvari u bioplin

Jedan od ciljeva našeg istraživanja je utvrđivanje količine proizvedenog bioplina iz pojedinih biljaka. Različiti autori navode različite količine proizvedenog bioplina iz istih biljnih vrsta. Našim biljkama smo izračunali udio SS i analizirali smo na sastojak C, N i S. Tako smo pridobili dovoljno podataka, da smo mogli usporediti biljke iz našeg istraživanja i biljke drugih istraživača, koji su iz biljaka pridobili bioplin. Na osnovu tih usporedbi smo našim biljkama odredili faktor pretvorbe biljne suhe tvari u bioplin (tablica 2). Za biljke koje smo nismo primjetili u literaturi, pa smo sami teoretski odredili količinu bioplina proizvedenog iz kilograma suhe tvari.

Tablica 2 Količina proizvedenog bioplina iz kg SS prema različitim autorima i upotrebljeni faktor za preračunavanje iz naših biljaka

Sirovina	Količina bioplina/kg SS	
	Postignute dobivene količine bioplina po drugim autorima (m^3/kgSS)	Količine bioplina u našim izračunima (m^3/kgSS)
Kukuruz	0,3-0,4 Medved in Novak (2000), 0,41 Beck (1997), Dulbić (1986)	0,4
Ljulj	0,28-0,55 Medved (2000), 0,41 Beck (1997)	0,4
Lucerna		0,45
Sudanska trava		0,45
Facelija		0,4
Crna djetelina	0,43-0,52 Đulbić (1986)	0,45
Japanski dvornik		0,35
TDM-djetelinsko travna smjesa	0,28-0,55 Medved (2000), 0,41 Beck (1997)	0,45

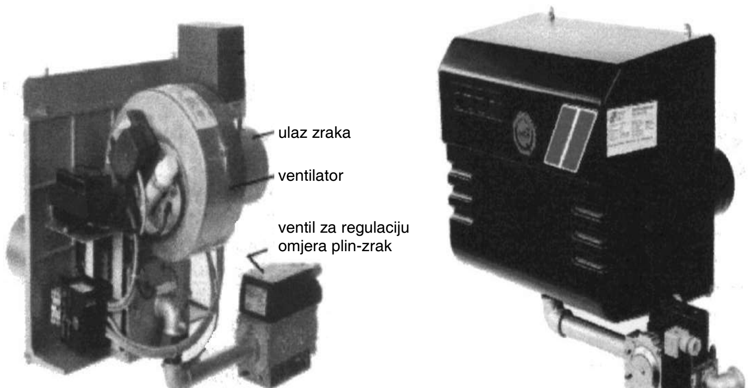
Količinu bioplina smo izračunali po jednadžbama:

$$V_{bioplina} / kgSS = masa\_SS \times faktor\_pretvorbe \text{ [m}^3\text{]} \quad (3)$$

$$V_{bioplina} / ha = Q_{bioplina / kgSS} \times masa_{SS} / ha \text{ [m}^3\text{]} \quad (4)$$

Pretvorba bioplina u električnu i toplinsku energiju

Za model motora za iskorištavanje (loženje) bioplina smo izabrali Otto motor s unutrašnjim sagorijevanjem (Fiat Totem Standard, 15 kW) koji je generator s visokim ukupnim i posebno toplinskim iskorištenjem. Za pokretanje i regulaciju upotrebljava električnu struju iz mreže. Pogonski motor je 900 cm^3 Fiat 100 GL, koji je opremljen s asinhronim trofaznim generatorom. U zatvorenom primarnom hidrauličkom strujnom krugu kruži 2-3 m^3/h tekućine za hlađenje (glikol), koja izmjenjuje toplinu u četiri izmjenjivača topline. Fiat Totem je najpouzdaniji i najprovjereniji među malim motorima za proizvodnju električne energije i topline, što potvrđuje činjenica, da poneki djeluju više od 30.000 sati (Piccinini i suradnici, citat po Hercegu, 2004)



Slika 5 Bioplinski izgarač

U izračunavanjima nismo uzimali u obzir gubitke pri prijenosu i akumulaciji zahvaćene otpadne topline motora. Iskorištenost, upotrebljena u jednadžbama, je izračunana na osnovi podataka o ulaznoj moći u motor i proizvedenoj električnoj i toplinskoj moći. Bioplin smo teoretski pretvarali u električnu i toplinsku energiju s motorom Fiat Totem.

$$Q_V = H_i \times V_B \times \eta_t \text{ [kWh/ha] [zahvaćena toplina tekućine za hlađenje motora]} \quad (5)$$

$$Q_e = H_i \times V_B \times \eta_e \text{ [kWh/ha] [proizvedena električna energija]} \quad (6)$$

$H_i = 22{,}1\ldots MJ/m^3$ za bioplin sa 65 % sadržajem CH_4 (Mrhar i suradnici, 1990). [ogrijevna vrijednost bioplina]

$\eta_t = 0{,}70$ (Piccinini i suradnici, 1996 cit. po Hercegu, 2004) [toplinsko iskorištenje motora Fiat Totem]

$\eta_e = 0{,}27$ (Piccinini i suradnici, 1996 cit. po Hercegu, 2004) [električno iskorištenje motora Fiat Totem]

$V_{bioplina}$ = teoretska količina bioplina dobivena iz pokusnih biljaka na jednom hektaru [m^3]

Pretvorba biljne SS (suhe tvari) u NEL (neto energiju za laktaciju) i u ME (metaboličku energiju)

$$NEL/ha = SS/ha * faktorNEL \quad \text{[MJ NEL]} \tag{7}$$

$$ME/ha = SS/ha * faktorME \quad \text{[MJ ME]} \tag{8}$$

Pretvorba NEL (neto energije za laktaciju) u mlijeko i ME (metaboličke energije) u meso

Za potrebe održavanja te dobivanja mesa i mlijeka je potrebna energija. Pri sastavljanju obroka ili kod preračunavanja se pri tovnim govedima upotrebljava ME (metabolička energija), izražena u MJ, pri kravama pa NEL (neto energija za laktaciju), izražena u MJ. Najprije moramo uzeti u obzir energiju koju životinja treba za život (energija za održavanje) i tek nakon toga energiju koja će se pretvoriti u mlijeko ili meso. U tablici 3 su preračunane vrijednosti za podmirivanje potrebe po prehrani. Energija za održavanje se za krave muzare izračuna po slijedećoj formuli:

$$\text{MJ NEL/dan} = (\text{masa životinje})^{0,75} \times 0{,}293\text{MJ} \quad \text{(DLG, 1997)} \tag{9}$$

MLIJEKO: Za dobivanje jednog litra mlijeka s 4 % mliječne masnoće životinja potroši 3,17 MJ NEL. U našem primjeru smo pretpostavili da imamo krave lisaste pasmine, teške 650 kg, koje za potrebe održavanja trebaju 37,7 MJ NEL na dan.

$$\text{Količina mlijeka}_{\text{4 \% m. m.}}\text{/ha} = \frac{MJ\_NEL/ha}{3{,}17} \tag{10}$$

MESO: Potrebe po održavanju tovljenih bikova lisaste pasmine se izračunaju po sljedećoj formuli:

$$\text{MJ ME/dan} = (\text{masa životinje})^{0,75} \times 0{,}53 \quad \text{(DLG, 1997)} \tag{11}$$

Tablica 3 Potrebe po održavanju za različite mase životinja (DLG, 1997)

Masa životinje (kg)	Potrebe po održavanju (MJ NEL/dan)
450	28,6
500	31,0
550	33,3
600	35,5
650	37,7

U našem primjeru smo predpostavili da imamo bikove lisaste pasmine, koji imaju prirast 1.300 g/dan, za potrebe po održavanju i potrebe prirasta potroše 95,2 MJ ME na dan.

$$\text{Prirast bikova/ha} = \frac{MJ\_ME/ha}{95,2} \tag{12}$$

Prirast bikova na hektar smo izračunali uz pretpostavku, da je dnevni prirast bikova 1.300 grama. Za lakše vrednovanje prirasta, smo na osnovu pretpostavljenog udjela mesnatosti (56% mesnatost), priraste izrazili u mesu.

Meso = (prirast bikova × faktor mesnatosti (56 %))/100 % …(13)

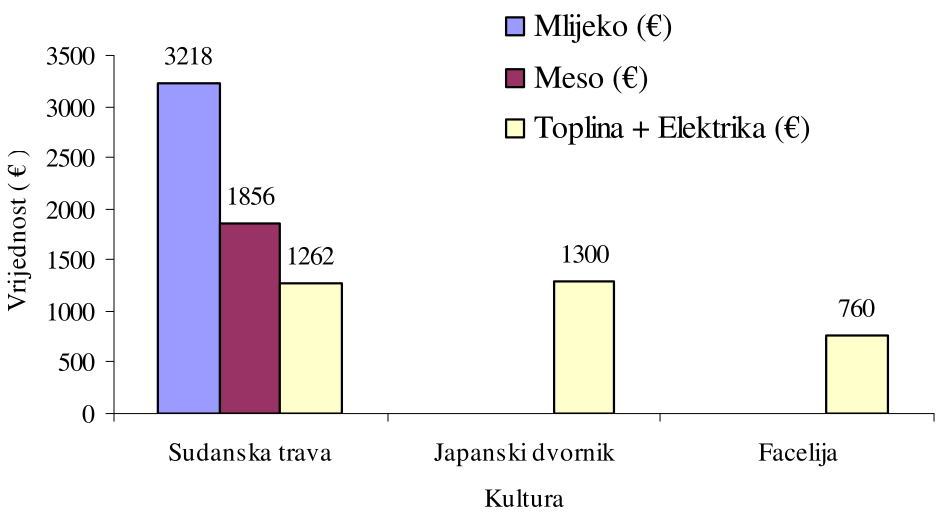
NEL i ME energiju smo analiziranim biljkama odredili s pomoću DLG ključa.

Cjenik mlijeka i mesa

Za lakše vrednovanje smo sve produkte izrazili u istoj mjernoj jedinici i to u novcu. Zbog lakšeg računanja smo vrijednosti zaokružili. Cijene mesa i mlijeka su prikazane u tablici 4. Jednogodišnja cijena (SIT/kWh) topline je 12,37 SIT (0,05154 €) i električne energije16,05 SIT (0,06875 €)(Nemac, 2003).

Tablica 4 Cijene mlijeka i mesa (Otkupne cijene za stoku, 2005)

	SIT (€) / kg
Otkupna cijena mlijeka s 4% mliječne masnoće i 3,04 mliječnih bjelančevina	64,00 (0,26667)
Otkupna cijena mesa bikova starih do 24 mjeseca	660,00 (2,75)



Slika 6 Vrednovanje različitih produkata, pridobivenih iz biljaka na jednom hektaru

ZAKLJUČAK

Na pokusnoj parceli smo dobar prinos postigli s sudanskom travom 9,5 t suhe tvari na hektar. Od drugih ne-krmnih biljaka smo postigli dobar prinos s japanskim dvornikom. Facelija se po količini prinosa nije pokazala kao potencijalna energetska biljka. Japanski dvornik se je pokazao kao veoma dobra biljka za proizvodnju bioplina.

S kemijskom analizom biljaka na C, N i S smo utvrdili njihov kemijski sastav. Rezultati analiza su pokazali, da biljke, osim japanskog dvornika, u toj fazi zrelosti samo nisu primjerne za proizvodnju bioplina, jer nemaju pravog omjera C : N. Dobre bi bile kao dodatak smjesi za proizvodnju bioplina, s vidika omjera C : N i sadržaja sumpora. Sadržaj sumpora pri nijednoj od biljaka nije bio previsok.

Vrednovanje proizvoda u proizvodnji bioplina i stočarstvu je pokazalo, da je zasada, kvalitetne krmne biljke prikladnije upotrebljavati za krmu, nego za proizvodnju energije.

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RENEWABLE ENERGY SOURCES (RES), PLANTS AS ENERGY AND PLANTS AS FOOD

ABSTRACT

The population demand for energy is increasing day by day; fossil fuel supply, on the other hand, is on the verge of running out. Consequently, we could be facing a lack of energy. Partial solution to the problem is the exploitation of renewable energy sources (RES), including acquiring biogas from biomass. In Europe, we are confronted by food excess and abandonment of some cultivated lands. In investigation, we have rated plants as energy and plants as food. On the basis of chemical analysis we have calculated the amount of produced biogas and product of metabol energy and also net energy of lactation. The plants used in our research are Sudan grass, Phacelia and Japanese knotweed

Key words: *renewable energy, biogass, plants, animal nutrition, feed, Sudan grass, Phacelia, Japanese knotweed*

34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.372:658.8](497.4)
Stručni rad
Expert paper

PROPISI ZA PRODAJU I KORIŠTENJE TRAKTORA NAKON PRISTUPA SLOVENIJE EU

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SAŽETAK

Pristupom Slovenije EU 1.5.2004. godine počeli su se primjenjivati propisi o provjeravanju sukladnosti - homologaciji traktora. Jedan od osnovnih elemenata EU je zajedničko tržište i iz toga proizlazi i harmonizacija propisa. U radu su prikazani postupci primjene direktiva za homologaciju traktora u EU i njihova implementacija u nacionalne propise Slovenije. Prikazani su postupci primjene propisa odnosno postupci homologacije traktora kupljenih iz EU, uvezenih iz trećih država i pojedinačno uvezenih. Propisi o upotrebi traktora, naročito u cestovnom prometu samo su djelomice dio propisa EU, veći dio su nacionalni propisi. Prikazana je njihov važnost za traktore.

***Ključne riječi**: propisi, traktori, provjeravanje sukladnosti, homologacija, EU, sigurnost cestovnog prometa*

UVOD

Svrha provjeravanja sukladnosti vozila je osigurati da u upotrebo dođu samo takva motorna i vučna vozila, koja zadovoljavaju važeće homologacijske propise za vozila. Postupak se provodi prije puštanja vozila u promet, znači prije njegove registracije. Rezultat provjere sukladnosti vozila sa propisima je potvrda o sukladnosti vozila, koja je osnova i uvjet za njegovu registraciju. Taj postupak obuhvaća cestovna vozila, poljoprivredne i šumarske traktore.

METODE

Na osnovi važećih propisa za vozila i cestovni promet pripremili smo pregled sustava provjeravanja sukladnosti vozila – traktora (homologacija) i upotrebu u cestovnom prometu.

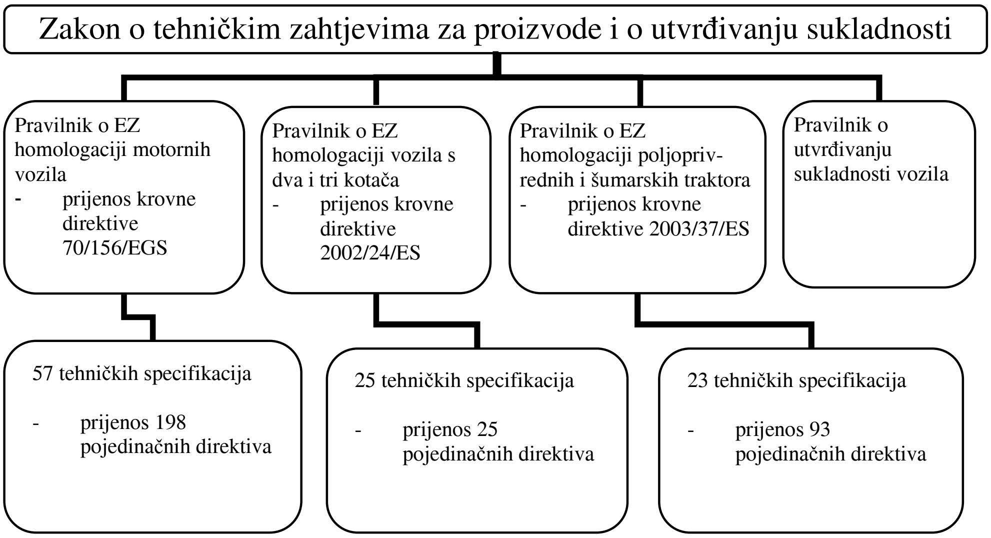
REZULTATI SA DISKUSIJOM

Sustav provjeravanja sukladnosti vozila u Republici Sloveniji

Sukladnost cestovnih vozila počela se u Sloveniji provjeravati 1993. godine, da bi se spriječio nekontrolirani uvoz neodgovarajućih vozila. Novi zakon o vanjskoj trgovini nije više sprečavao uvoz polovnih vozila, što je bilo karakteristično za propise SFRJ. Kod tehničkih propisa je Slovenija naslijedila potpis SFRJ u »Sporazumu o zajedničkim uvjetima za homologaciju dijelova i opreme vozila i međusobnom priznavanju homologacija«, Ženeva 1958. Tako je bilo moguće u tehničke propise prenijeti međunarodne homologacijske pravilnike ECE, koji slijede iz citiranog sporazuma. Ti propisi odnose se samo na cestovna vozila i ne obuhvaćaju traktore, zato se propisi (»Odredba o homologaciji vozila« u više verzija) do 2004. godine nisu odnosili na poljoprivredne i šumarske traktore i za njih nije bio propisan postupak provjeravanja sukladnosti (homologacija).

Harmonizacija sa propisima EU počela je 1998. godine tzv. postupkom screeninga (provjeravanje usklađenosti SI propisa sa EU propisima). Sa kraljevinom Švedskom bio je potpisan twinnig ugovor (»Internal Market: Horizontal Framework Legislation and Instituional Infrastructure«), dio kojeg je i sektor vozila. Rezultat je sadašnja organizacija državnih organa u razmatranom sektoru i potpuna usklađenost SI propisa sa EU propisima (Acquis communitaire). Nadležni državni organ od 2001. godine je Ministarstvo prometa, Direkcija Republike Slovenije za ceste, Sektor vozila. U 2004. godini sa Ministarstva poljoprivrede na njega preneseni su i traktori. U EU vozila reguliraju tri krovne direktive, koji određuju postupke homologacije pojedinih kategorija vozila, tehničke propise za pojedine sustave i sastavne dijelove vozila te određuju pojedinačne direktive, koje su vezane na krovne direktive. Na osnovi »Zakona o tehničkim zahtjevima za proizvod i o utvrđivanju sukladnosti« krovne direktive prenesene su u SI pravni sustav u vidu tri »Pravilnika o EZ homologaciji«, pojedinačne direktive pa u vidu više tehničkih specifikacija. Za regulaciju čitavog sustava (postupci) bio je objavljen i nacionalni propis »Pravilnik o utvrđivanju sukladnosti vozila«, koji regulira i postupke za vozila, koji nisu dio EU homologacije, za polovna vozila i drugo (slika 1).

U ožujku 1974. godine primijenjena je krovna direktiva za homologaciju poljoprivrednih i šumarskih traktora: direktiva savjeta 74/150/EGS, koja je bila više puta mijenjana odnosno dopunjavana (tabela 1). Postupak homologacije traktora kao cjeline u upotrebi je od 1990. godine, kada su primijenjene još zadnje pojedinačne direktive o tehničkim zahtjevima. Glavni cilj krovne direktive je sagraditi sustav u kome može proizvođač prodavati homologirane traktore na zajedničkom tržištu bez ponovnih ili dopunskih testiranja u pojedinim zemljama europske zajednice odnosno unije. Sve do 1989. godine proizvođači su morali za vozila u svakoj državi EZ dobiti nacionalnu homologaciju, koja se bazirala na direktivama EZ ali na nacionalnom sustavu homologacije.



Slika 1 Primjena EU propisa o homologaciji vozila u pravnom sustavu SI

Europske direktive za poljoprivredne i šumarske traktore i njihova primjena u SI

Tabela 1 Krovna direktiva za traktore

Krovna direktiva	Direktive, koje mijenjaju krovnu direktivu							
74/150	79/694	82/890	88/297	97/54	2000/2	2000/25[a]	2001/3	2003/37

[a] To je u principu samostalna direktiva, ali djelomično mijenja i krovnu direktivu.

Na osnovi krovne direktive u SI je bio primijenjen »Pravilnik o EZ-homologaciji poljoprivrednih i šumarskih traktora (Uradni list RS, št. 125/03)« (vidi točku 3.1 i sliku 1). Na osnovi tog pravilnika pojedinačne direktive prenesene su u 23 tehničke specifikacije (tabela 2). U Uradnom listu RS objavljeni su samo naslovi tih specifikacija (tabela 3), a njihov sadržaj javno je dostupan na **www.drsc.si** odnosno na **www.dc.gov.si** na slovenskom jeziku.

Poljoprivredni i šumarski traktori po klasifikaciji vozila spadaju u kategoriju T (traktori s kotačima) i kategoriju C (gusjeničari). U kategorije T1 do T4 spadaju traktori sa konstrukcijski određenom najvećom brzinom kretanja do 40 km/h. U kategoriju T5 spadaju traktori sa konstrukcijski određenom najvećom brzinom kretanja većom od 40 km/h. Isto vrijedi za kategorije C1 do C5. EU homologacija (za sada) obuhvaća potkategorije traktora 1 do 4, a kategorija 5 razmatra se u nacionalnom sustavu.

Tabela 2 Tehničke specifikacije u SI za traktore na osnovi direktiva EU

SI	EU						
Tehnička specifikacija	Osnovna direktiva	Direktive, koje mijenjaju osnovnu direktivu					
TSV 401.00	74/151	82/890	88/410	97/54	98/38		
TSV 402.00	74/152	82/890	88/412	97/54	98/89		
TSV 403.00	74/346	82/890	97/54	98/40			
TSV 404.00	74/347	79/1073	82/890	97/54			
TSV 405.00	75/321	82/890	88/411	97/54	98/39		
TSV 406.00	75/322	82/890	97/54	2000/2	2001/3		
TSV 407.00	76/432	82/890	96/63	97/54			
TSV 408.00	76/763	82/890	97/54	1999/86			
TSV 409.00	77/311	82/890	97/54	96/627[b]	2000/63[b]		
TSV 410.00	77/536	87/354	89/680	1999/55			
TSV 411.00	77/537	82/890	97/54				
TSV 412.00	78/764	82/890	83/190	87/354	88/465	97/54	1999/57
TSV 413.00	78/933	82/890	97/54	1999/56			
TSV 414.00	79/532	82/890	97/54				
TSV 415.00	79/533	82/890	97/54	1999/58			
TSV 416.00	79/622	82/953	87/354	88/413	1999/40		
TSV 417.00	80/720	82/890	88/414	97/54			
TSV 418.00	86/297	97/54					
TSV 419.00	86/298	89/682	2000/19				
TSV 420.00	86/415	97/54					
TSV 421.00	87/402	89/681	2000/22				
TSV 422.00	89/173	97/54	2000/1				
TSV 423.00	2000/25						

[b] To nije direktiva nego odluka (decision).

Tabela 3 Naslovi tehničkih specifikacija za traktor u SI

TSV – 401 (00)	o največji dovoljeni masi v obremenjenem stanju, prostoru za namestitev zadnjih registrskih tablic in pritrditvi tablic, posodah za tekoče gorivo, dodatnih utežeh, zvočni opozorilni napravi in dopustni ravni hrupa ter izpušnem sistemu kmetijskih in gozdarskih traktorjev (direktiva 74/151)
TSV – 402 (00)	o največji konstrukcijsko določeni hitrosti in prostoru za tovor kmetijskih ali gozdarskih traktorjev (direktiva 74/152)
TSV – 403 (00)	o vzvratnih ogledalih kmetijskih ali gozdarskih traktorjev (direktiva 74/346)
TSV – 404 (00)	o vidnem polju in brisalcih vetrobranskega stekla za kmetijske ali gozdarske traktorje (direktiva 74/347)
TSV – 405 (00)	o krmilju kolesnih kmetijskih ali gozdarskih traktorjev (direktiva 75/321)
TSV – 406 (00)	o preprečevanju radijskih motenj, ki jih povzročajo kmetijska in gozdarska vozila (elektromagnetna združljivost) (direktiva 75/322)
TSV – 407 (00)	o zaviranju kmetijskih in gozdarskih kolesnih traktorjev (direktiva 76/432)
TSV – 408 (00)	o potniških sedežih za kmetijske in gozdarske traktorje (direktiva 76/763)
TSV – 409 (00)	o ravni hrupa, ki ga zaznajo vozniki kmetijskih ali gozdarskih traktorjev (direktiva 77/311)
TSV – 410 (00)	o zaščitni konstrukciji pri prevrnitvi kolesnih kmetijskih ali gozdarskih traktorjev (direktiva 77/536)
TSV – 411 (00)	o ukrepih proti emisiji onesnaževal iz dizel motorjev kmetijskih in gozdarskih traktorjev (dimljenje) (direktiva 77/537)
TSV – 412 (00)	o vozniških sedežih na kolesnih kmetijskih in gozdarskih traktorjih (direktiva 78/764)
TSV – 413 (00)	o vgradnji svetlobnih in svetlobno signalnih naprav na kmetijske in gozdarske traktorje (direktiva 78/933)
TSV – 414 (00)	o svetlobni opremi za kmetijska in gozdarska vozila (direktiva 79/532)
TSV – 415 (00)	o napravi za vleko traktorja in vzvratni prestavi kmetijskih ali gozdarskih traktorjev (direktiva 79/533)
TSV – 416(00)	o zaščitni konstrukciji pri prevrnitvi kmetijskih ali gozdarskih traktorjev (statični preskus) (direktiva 79/622)
TSV – 417 (00)	o delovnem prostoru, dostopu do vozniškega prostora ter vratih in oknih kmetijskih in gozdarskih traktorjev (direktiva 80/720)
TSV – 418 (00)	o priključnih gredeh kmetijskih in gozdarskih traktorjev ter njihovi zaščiti (direktiva 86/297)
TSV – 419 (00)	o zadaj nameščenih zaščitnih konstrukcijah pri prevrnitvi za ozkokolotečne kmetijske ali gozdarske traktorje (direktiva 86/298)
TSV – 420 (00)	o vgradnji, legi, delovanju in označevanju upravljal kmetijskih ali gozdarskih traktorjev (direktiva 86/415)
TSV – 421 (00)	o zaščitni konstrukciji pri prevrnitvi, ki je vgrajena pred vozniškim sedežem ozkokolotečnih kmetijskih in gozdarskih traktorjev (direktiva 87/402)

	Tabela 3 – Nastavak
TSV – 422 (00)	Del I (Zaradi enostavnejše uporabe je ta tehnična specifikacija razdeljena na 6 delov od katerih vsak vsebuje samo eno zaključeno celoto.) o merah in vlečenih masah, regulatorju vrtilne frekvence in zaščiti pogonskih sklopov, zasteklitvi, mehanskih priključnih napravah, ploščici proizvajalca in upravljanju zavor vlečenega vozila (direktiva 89/173) (Ta del vsebuje zahteve za mere in vlečene mase.)
TSV – 422 (00)	Del II (Ta del vsebuje zahteve za regulator vrtilne frekvence in zaščito pogonskih sklopov, štrlečih delov in koles.) (direktiva 89/173)
TSV – 422 (00)	Del III (Ta del vsebuje zahteve o zasteklitvi.)
TSV – 422 (00)	Del IV (Ta del vsebuje zahteve za mehanske priključne naprave.) (direktiva 89/173)
TSV – 422 (00)	Del V (Ta del vsebuje zahteve za ploščico proizvajalca.) (direktiva 89/173)
TSV – 422 (00)	Del VI (Ta del vsebuje zahteve za upravljanje zavor vlečenega vozila.) (direktiva 89/173)
TSV – 423 (01)	o ukrepih proti emisijam plinastih in trdih onesnaževal iz motorjev za pogon kmetijskih in gozdarskih traktorjev, razveljavlja TSV – 423 (00)

Postupci utvrđivanja sukladnosti vozila (homologacija)

Postupak se provodi pred puštanje vozila u promet (upotrebu), znači prije njegove registracije. Rezultat provjere sukladnosti vozila sa propisima je potvrda o sukladnosti vozila, koja je osnova i uvjet za registraciju. Postupak u principu ovisi o tome, ima li vozilo EU homologaciju.

Vozila sa EU homologacijom

Proizvođač ili njegov ovlašteni zastupnik homologacijskom organu (Direkcija za ceste) predočava dokumentaciju o EU homologaciji. Nakon završenog postupka svakom prodanom vozilu može se izdati potvrda o sukladnosti za vozilo homologiranog tipa (potvrda tip SA).

Postupak nacionalne (SI) homologacije

Taj postupak je u principu namijenjen za serijski proizvedena vozila u SI, ali i za uvozna. Proizvođač/zastupnik mora vozilo sa homologacijskom dokumentacijom dovesti stručnoj ustanovi, koja provjeri stanje i izradi tehnički izvještaj, kojeg provjeri homologacijski organ. Ako su rezultati sukladni propisima, izdaje se certifikat o SI homologaciji. Na toj osnovi vozilu se može izdati potvrda o sukladnosti za vozilo homologiranog tipa (potvrda tip SA).

Postupak priznavanja strane nacionalne homologacije

Proizvođač ili njegov ovlašteni zastupnik kod homologacijskog organa priloži kopiju strane nacionalne homologacije. Ako je ta sukladna sa propisima, izdaje se potvrda o sukladnosti i certifikat o SI homologaciji. Na toj osnovi vozilu se može izdati potvrda o sukladnosti za vozilo homologiranog tipa (potvrda tip SA).

Pojedinačno odobrenje unikatnih vozila ili malih serija

Stručna organizacija provjeri vozilo i dokumentaciju i u slučaju sukladnosti sa propisima izdaje potvrdu o sukladnosti za pojedino vozilo (potvrda tip SB).

Pojedinačno odobrenje novog vozila bez EU homologacije

Taj postupak u praksi primjenjuje se za sve autobuse, sva teretna i vučena vozila te za traktore kategorije T5 (konstrukcijska brzina kretanja iznad 40 km/h). Stranka u postupku (obično vlasnik vozila) stručnoj ustanovi mora predložiti svu dokumentaciju koja se odnosi na homologaciju pojedinih dijelova, nacionalnu potvrdu iz države porijekla, potvrdu tehničkih službi i slično. Na osnovi provjere vozila i dokumentacije izdaje se potvrda o sukladnosti tipa SB.

Pojedinačno odobrenje prerađenog vozila

Prerada je svaka promjena na već homologiranom vozilu, koja tom vozilu mijenja njegove karakteristike. Poslije prerade potreban je pregled stručne ustanove, koja provjeri sukladnost prerade sa propisima i upiše promjenu u već postojeću potvrdu.

Pojedinačno odobrenje pri uvozu/kupovini u EU novog vozila sa EU homologacijom

Kupac koji je sam kupio novo vozilo u državi EU mora stručnoj ustanovi priložiti EU homologaciju (COC – Certificate of Conformity) i vozilo na pregled. Poslije vizualnog pregleda vozila na eventualne prerade i sukladnost vozila sa podacima u dokumentaciji (identifikacija) izdaje se potvrda o sukladnosti tipa SB. Taj postupak koriste obično i zastupnici, koji prodaju toliko malo vozila, da se im ne isplati postupak za tipsku homologaciju (točka 3.3.1).

Pojedinačno odobrenje kod uvoza/kupovine polovnog vozila u EU (»sa EU homologacijom«)

Vrijedi za polovna (rabljena) vozila, koja su ranije bila registrirana u EU (za nove članice prvi put registrirana nakon 1.5.2004.), nezavisno od toga, da li imaju EU homologaciju ili ne. Vlasnik mora stručnoj ustanovi priložiti dokumente o vozilu koji su bili važeći do njegove odjave u državi porijekla (COC, registracijski dokument, prometna dozvola). Obavlja se identifikacija vozila, vizualni pregled o sukladnosti sa Pravilnikom o opremi vozila i po potrebi tehnički pregled ako postoji sumnja u tehničku ispravnosti te se izdaje potvrda o sukladnosti SB.

U tu grupu pripada i odobrenje kod uvoza polovnih vozila iz država koje nisu članice EU i vozila registriranih u novim članicama EU prije 1.4.2005. Za ta vozila se traži dokumentacija koja dokazuje sukladnost sa direktivama EU. Praktično, to znači da vozilo ima EU homologaciju, što znači da uvoz tih vozila nije moguć.

Drugi propisi za vozila

Za cestovna vozila pa tako i za traktore u Sloveniji vrijede i drugi propisi koji se temelje na propisima EU ili međunarodnim propisima UN/ECE, ali su u osnovi nacionalni propisi. Ovdje ćemo nabrojiti samo pojedine najvažnije (originalni naslovi):

- Pravilnik o napravah in opremi vozil v cestnem prometu
- Pravilnik o merah in masah vozil v cestnem prometu

- Pravilnik o kompletu za prvo pomoč

Pored tih vrijedi još 11 propisa za vozila koji imaju značaj za manje grupe pojedinih vozila. Njihova zajednička svrha je da su u cestovnom prometu samo takva vozila s kojima je vožnja sigurna i ne dovode u rizik vozača i druge sudionike u prometu. Za traktore i druga poljoprivredna vozila vrijedi jedna iznimka kod dimenzija vozila na tzv. »poljoprivrednom transportu« (npr. među parcelama, među gospodarstvom i parcelama). Tada najveća širina vozila može biti 3,06 m (umjesto uobičajenih 2,55 m) bez dozvole za izvanredni prijevoz.

Propisi za upotrebu traktora – Zakon o sigurnosti cestovnog prometa

Taj se zakon u prvom redu odnosi na vozače i određuje pravila vožnje u cestovnom prometu i samo u iznimnim slučajevima odnosi se na vozila u užem smislu. To je osnovna razlika na propise o vozilima o kojima smo raspravljali u prethodnim točkama. U principu za vozače traktora i drugih poljoprivrednih vozila vrijede jednaki propisi kao za vozače drugih vozila, ako nije u zakonu drukčije određeno. Pojedine iznimke za traktore posljedica su specifičnosti tih vozila. Zakonodavac je njima pokušao omogućiti normalnu vožnju tih vozila u cestovnom prometu, a istovremeno postići da ta vozila ne ugrožavaju druge sudionike u prometu.

Tu ćemo navesti samo najčešća posebna rešenja za poljoprivredna vozila u cestovnom prometu:

- registracija: zahtijeva se za traktore i prikolice, najveće dozvoljene mase iznad 5 tona ili konstrukcijske brzine vožnje iznad 30 km/h;
- spora vožnja: ako vozilo vozi sporije od dozvoljene brzine na dionici puta i iza njega se stvori kolona, mora na prvom mogućem mjestu propustiti kolonu;
- ograničenja brzine za traktore: 60 km/h ako ima amortizaciju obje osovine i kočnice na sva 4 kotača; 50 km/h ako ima amortizaciju najmanje prednje osovine i kočnice na sva 4 kotača; 40 km/h ako ima kočnice na sva 4 kotača; 30 km/h za sve ostale traktore;
- prijevoz osoba osim vozača na traktoru: samo na sjedištu za suvozača; djeca do 12 godina samo ako je ugrađeno posebno sjedalo za djecu;
- prijevoz osoba na prikolici: do 5 osoba u teretnom prostoru; moraju sjediti u sanduku (ne na teretu);
- prepreka na cesti je i zemlja ili gnoj; odmah potrebno počistiti (velik problem u jesen);
- žuto rotacijsko svjetlo: obavezno je za traktore sa priključkom koji je širi od traktora;
- vozačka dozvola kategorije F: obavezan je ispit iz sigurnosti u radu sa traktorom i poljoprivrednim strojevima (pored teoretskog i praktičkog vozačkog ispita); minimalna starost 15 godina, ali je do navršenih 18 godina dozvoljeno voziti traktore sa najvećom brzinom 40 km/h;
- registracijske tablice su istog osnovnog oblika i boje kao za ostala vozila;

- tehnički pregledi: prvi put tri godine poslije prve registracije i potom svake dvije godine do sedam godina starosti traktora (vrijedi i za prikolice i većinu drugih vozila).
- registracija traktora bez računa: moguća je za traktore proizvedene prije 1977. godine i bila je moguća jednu godinu poslije zadnje dopune zakona (do 13.8.2005.). U jednoj godini tako je bilo registriranih oko 8.000 traktora.
- Zaključak

U Sloveniji od 1.5.2004., nakon pristupa u EU, vrijede propisi za provjeru sukladnosti (homologacija) i za poljoprivredne i šumarske traktore. Tako se mogu prodavati (registrirati) traktori koji ispunjavaju sve propise i imaju potvrdu u sukladnosti. Nakon 1.4.2004. sa slovenskog tržišta su nestali svi istočnoeuropski proizvođači traktora osim češkog Zetora (sa oko 5% udjela na tržištu u 2005.), jer nisu uspjeli ispuniti propise o homologaciji ili nisu to ni pokušavali.

Domaći proizvođač (Agromehanika) ispunio je zahtjeve, isto tako i Limb, novi domaći proizvođač (do sada 3 registrirana traktora). Isto tako su se sa ispunjenim zahtjevima ove godine na tržištu pojavili Farmtrac (Poljska) i Kioti (Južna Korea), sa 7 odnosno 5 traktora od 1139 novih traktora koji su bili u Sloveniji registrirani u prvih 11 mjeseci 2005. godine (2004. godini 1078 novih traktora).

Sa tim propisima na tržište Slovenije će dolaziti samo novi traktori koji su sigurni za upotrebu i ispunjavaju sve zahtjeve za očuvanje prirodne okoline. Ali problem predstavlja veliki broj (više od 10.000) sa današnjeg gledišta neodgovarajućih traktora u upotrebi kupljenih prije deset i više godina, koji će biti u upotrebi još puno godina. Njihova neusklađenost i loše ponašanje vozača rezultira velikim brojem udesa sa smrtnim slučajevima (25 u 2004. godini).

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REGULATIONS OF TRACTORS TRADING AND USING SINCE SLOVENIA JOINED EU

SUMMARY

Date of Republic of Slovenia joining to Europen Union has marked the beginning of compulsory tractors homologation procedure. Since common market is one of the basic joining elements of the EU, regulations harmonisation is neccessary. The paper shows procedures of EU tractor homologation recommendation practice and implementation into Slovenian official regulations. Some details of tractor homologation procedure are shown for case of importing tractor bought in EU countries, importing tractor from third countries and personal single tractor importing. Traffic regulations regarding tractor using have just been described, since their greater part is involved into national regulations.

***Key words**: Regulations, tractors, homologation checking, conformity, European Union, traffic safety*

34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Prethodno priopćenje
Preliminary communication

THE RESEARCH ON A BOSCH INJECTION PUMP WITH BIODIESEL FUEL

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SUMMARY

The paper presents some experimental results concerning the use of a Biodiesel type fuel.

The fuel was produced starting from waste cooking oil, collected from a local branch of the McDonalds' restaurants.

The injection equipment of a Diesel engine (in line type PES 5MW 55/320/RS 120403 BOSCH injection pump, RO-KCA30S16 injectors with RO-DNOSD21 nozzles, opening at 13 MPa) was tested. The cyclic fuel delivery, pressure wave propagation time, average injection rate and maximum pressure during injection were significantly affected when pure Biodiesel was used as fuel. As a result, an overall earlier start of combustion (with 1.8…2^0 CA) is expected to occur when methylester is used in order to fuel the engine.

The use of the Biodiesel type fuel (BTF) affected the injection rate mainly at low pump speeds and large displacements of the control rod (higher values than the ones recorded for Diesel fuel).

The peak pressure during injection increased with 10…40 bar, depending upon pump speed and position of the control rod.

Key words: *Biodiesel, compression ignition engine, injection equipment, injection characteristics*

INTRODUCTION

Vegetable oils and animal fats are a renewable and potentially inexhaustible source of energy, with an energy content close to Diesel fuel. Due to their poor physical properties (high viscosity, high pour point), these fuels are unsuited to be used in Diesel engines.

These properties can be improved by transesterification; when using methyl alcohol, methyl esters are the final product.

According to Directive 2003/30 EC of the European Parliament and Council [14], the term **Biodiesel** is used for any methylester produced from vegetable or animal oil, of Diesel quality.

It is agreed that a proportion of 2…5% methylester in Diesel fuel does not involve any changes in the construction of the engine's fuelling system and this type of Biodiesel blends can be burned directly in unmodified Diesel engines [5].

Cooking oils, used for frying food, have a limited life in food production due to their contamination with material from food and due to fatty acids formation; waste cooking oil can be seen as a "near to waste" by-product of food production industry. As a result, the use of waste cooking oil instead of virgin oil in order to produce Biodiesel is an effective way to reduce the raw material cost and helps to solve the problem of waste oil disposal. These vegetable oils contain some degradation products of vegetable oils and foreign material. However, analyses of used vegetable oils claimed that the differences between used and unused fats are not very great and in most cases simple heating and removal by filtration of solid particles makes the oil appropriate for subsequent transesterification [6].

Injection characteristics have a significant effect over the engine working process. For the same injection timing, ignition delay and cyclic fuel delivery, an increased injection duration (or decreased average injection rate) leads to the decrease of the peak combustion pressure; the shape of the engine's working cycle diagram is also affected [2].

BIODIESEL CHARACTERSTICS AND INJECTION EQUIPMENT

The material used for the vegetable oil methylester (VOME) production was waste cooking oil collected from a local branch of the McDonalds' restaurants [7].

Table 1 Phisycal characteristics of the fuels

Item	Test method	Fuel			
		Diesel	Used cooking oil	B100*	B50*
Density at 15^{0}C [g/cm^3]	EN ISO 3675	0.8393	0.891	0.857	0.851
Viscosity at 40 ^{0}C [mm^2/s]	EN ISO 3104	4.9	34.0	5.7	5.2
Acid value [mg KOH/g]	ASTM D664	0.089	2.67	0.92	0.42
Ash content [%]	SR ISO 6245:1995	0.085	0.075	0.038	0.016
Flash point [^{0}C]	ASTM D93	69	115	110	82
Cu strip corrosion	EN ISO 2160	1b	2e	2a	1b
Surface tension [N/m]	-	0.0281	0.0336	0.0296	0.0290

*Note: B100 – pure methylester; B50 – 50% methylester+50%Diesel fuel

The main physical properties of the Biodiesel type fuel (BTF) are summarized in table 1. It is important to notice that the transesterification process has significantly decreased the viscosity from aprox. 34 mm^2/s for the waste cooking oil to 5.7 mm^2/s for the methylester (compared to 4.9 mm^2/s for Diesel fuel); the surface tension has dropped from 0.036 N/m to 0.0296 N/m.

The tested injected equipment consisted of:

- injection pump type PES 5MW 55/320/RS 120403 (BOSCH);
- RO-KCA30S16 injectors with RO-DNOSD21 nozzles, opening at 13 MPa.

The injection equipment was tested on a MIRKOZ (Hungary) test rig, using a BOSCH injection rate meter and an IAN 101 oscilloscope (fig. 1).

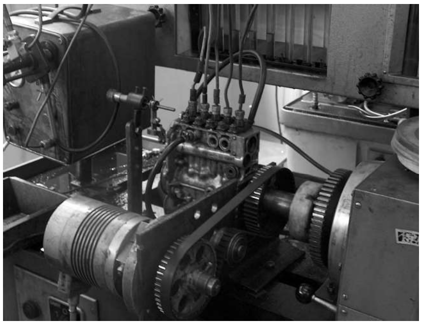

Fig. 1 View of the injection test rig

The tests were developed at different pump speeds (500, 700, 900, 1200 and 1500 rev/min) and displacements of the injection pump control rod (2, 4, 7, 10 and 12 mm away from stop position).

RESULTS AND DISCUSSION

The following injection characteristics were investigated:

- cyclic fuel delivery;
- injection duration;
- pressure wave propagation time;
- injection rate and average injection rate;
- peak injection pressure.

Cyclic fuel delivery

For the both fuels, the cyclic fuel delivery has increased with pump speed and control rod displacement (fig. 2). A comparative analysis shows that the use of methylester leads to higher values of the cyclic fuel delivery, especially al low and medium pump speeds (500…900 rpm), as presented in fig. 3. For the above mentioned speeds, the fuel delivery increased with up to 9…10 mm^3/cycle; at 1200…1500 rpm, the cyclic dose increased with max. 4…5 mm^3/cycle and only for displacements of the control rod up to 7 mm.

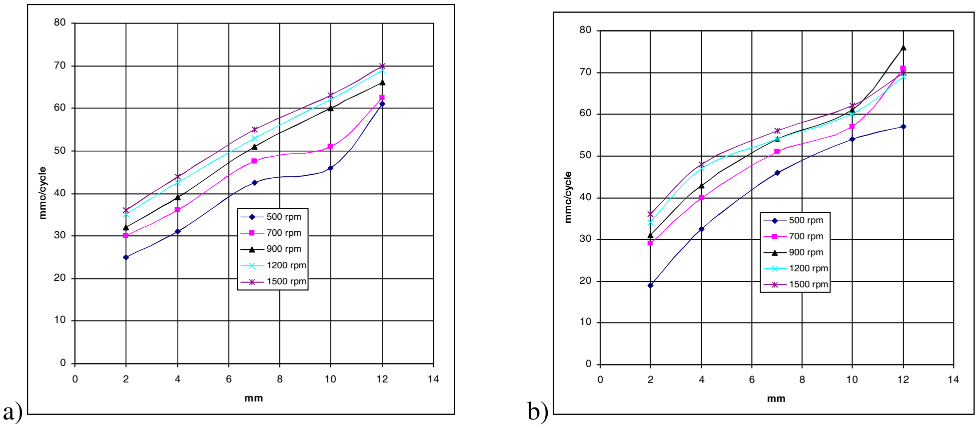

Fig. 2 Cyclic fuel delivery; a-Diesel fuel; b-BTF

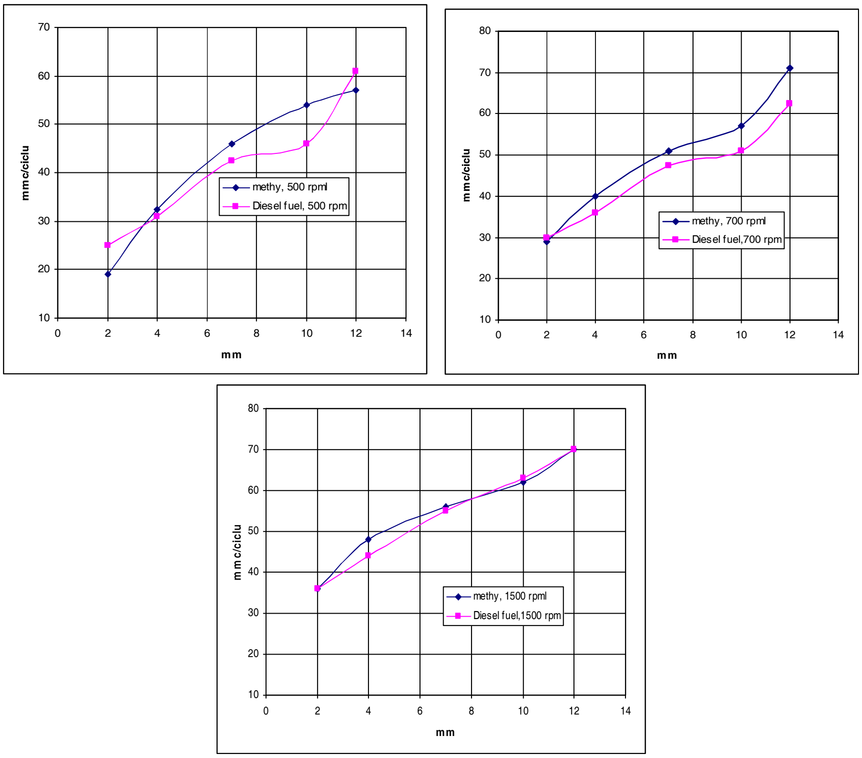

Fig. 3 Cyclic fuel delivery at different pump speeds

Injection duration

As shown in fig. 4, for the both fuels, the injection duration has increased with the pump speed and control rod displacement, due to the increase of the cyclic fuel delivery.

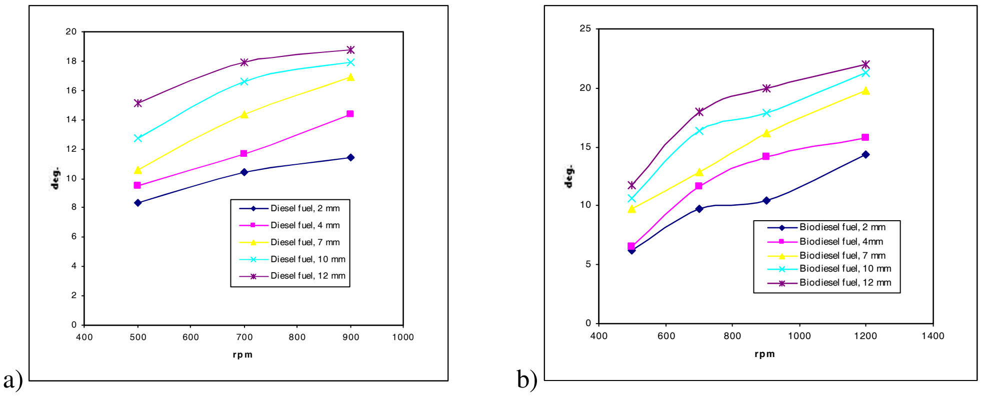

Fig. 4 Injection duration; a-Diesel fuel; b-BTF

At low pump speeds, the injection duration is higher for Diesel fuel than for methylester (fig. 5a); the differences are comprised between 1 and 3^0PA*. As the pump speed increases, the injection duration for Diesel fuel drops bellow the one for methylester (fig. 5b); for example, at 1200 rpm, the injection duration for methylester was increased with 1.4…4.5^0PA. This behaviour may be connected with the evolution of the average injection rate, as shown in the following section. In the meantime, at high pump speeds, the effect of the higher viscosity of BTF leads to an increased hydraulic resistance at fuel flow, thus increasing the injection duration.

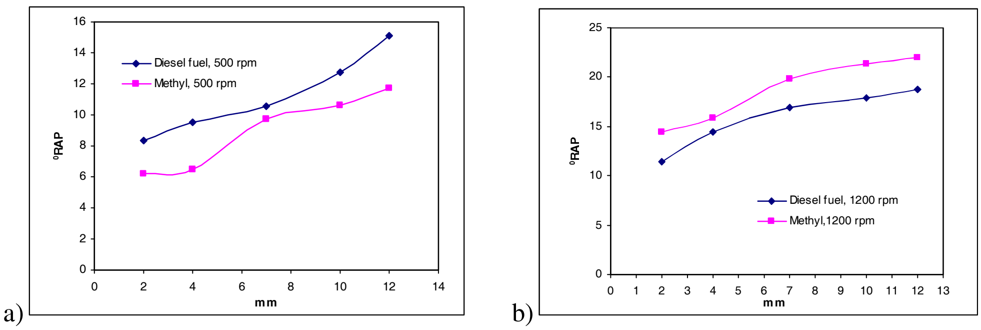

Fig. 5 Comparative analysis of injection duration

* PA - pump shaft rotation angle.

Average injection rate

The average injection rate was defined as the cyclic fuel delivery to injection duration ratio. Fig 6 shows that an increased pump speed has led to a lower injection rate (due to higher injection duration); in the meantime, a higher displacement of the control rod led to higher average injection rates (due to the increase of the cyclic fuel delivery).

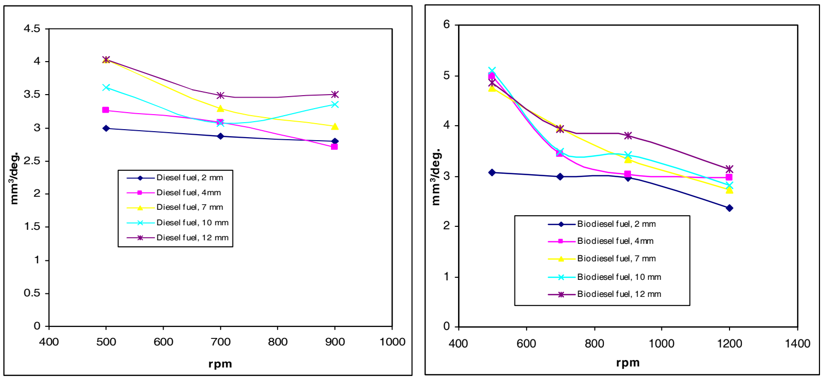

Fig. 6 Average injection rate*;* a-Diesel fuel; b-BTF

From fig. 7 we notice that high average injection rates are achieved for methylester especially at low pump speeds, which results in lower injection duration for BTF, as shown in fig. 5a. As the pump speed increases, the differences between Diesel fuel and BTF are diminished (when referring to the average injection rate) because the injection duration and the cyclic fuel delivery for BTF have a decreasing tendency. The average injection rate for Biodiesel exceeds the one for Diesel fuel by 10…50% at 500 rpm and only by 5…10% at 1200 rpm.

Pressure wave propagation time

The time the high pressure wave needs to reach the injector increases with the pump speed (fig. 8), while the effect of the control rod position is not very significant. The pressure wave propagation time has decreased when using Biodiesel (fig. 9); this finding, also reported by other authors [11, 12], seems to be the effect of the higher viscosity and isentropic bulk modulus.

The propagation time has decreased with $0.4…0.8^0$ PA when the BTF was used instead of Diesel fuel. It should be mentioned that a lower pressure wave propagation time is equivalent with an earlier start of injection (injection timing advanced by $0.8…1.6^0$ CA*) and may result in higher levels of NO_x emissions [2, 3, 9, 10]. As Biodiesel type fuels were reported to have a shorter ignition delay compared to Diesel fuel [1, 8], the cumulative effect of the lower propagation time and shorter ignition delay is expected to induce an overall advance of the start of combustion that could reach $1.8…2^0$ CA. As a result the NO_x

* CA -crankshaft rotation angle.

emissions will be significantly affected, unless adjustments of the injection timing are made.

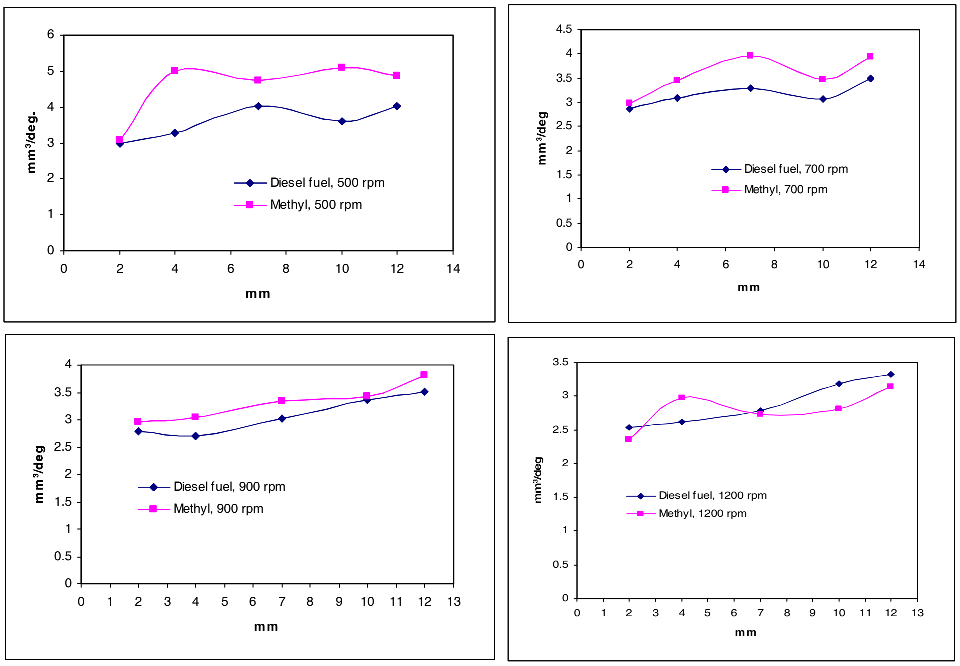

Fig. 7 Comparative analysis of average injection rate

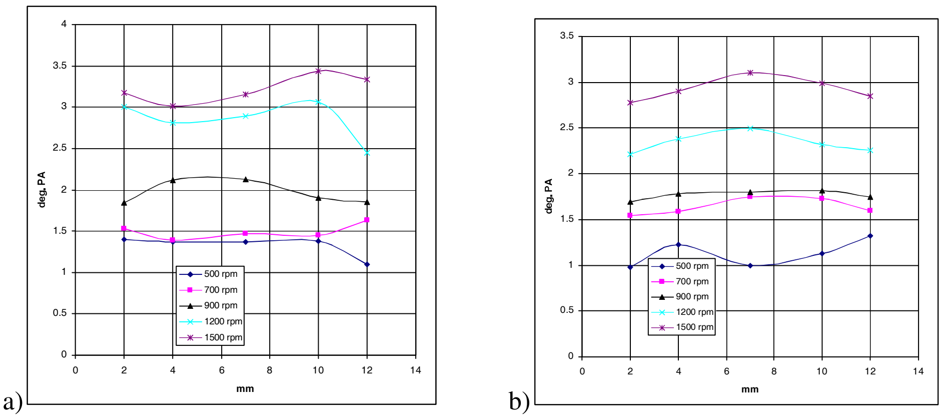

Fig. 8 Pressure wave propagation time; a-Diesel fuel; b-BTF

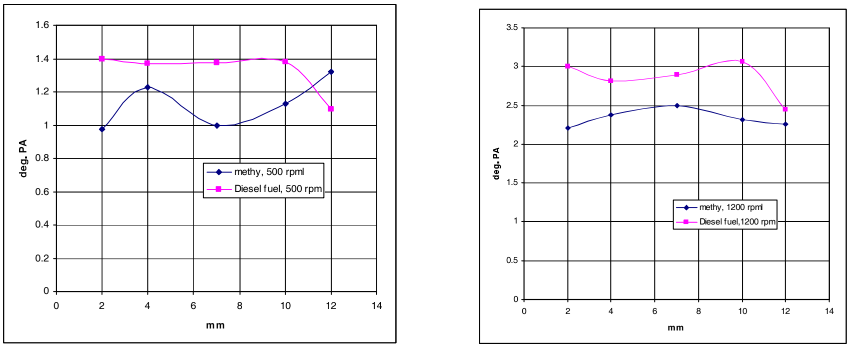

Fig. 9 Comparative results concerning the pressure wave propagation time

Injection rate

For the both fuels, the pump speed and the position of the control rod (fig. 10 and 11) affect the injection rate.

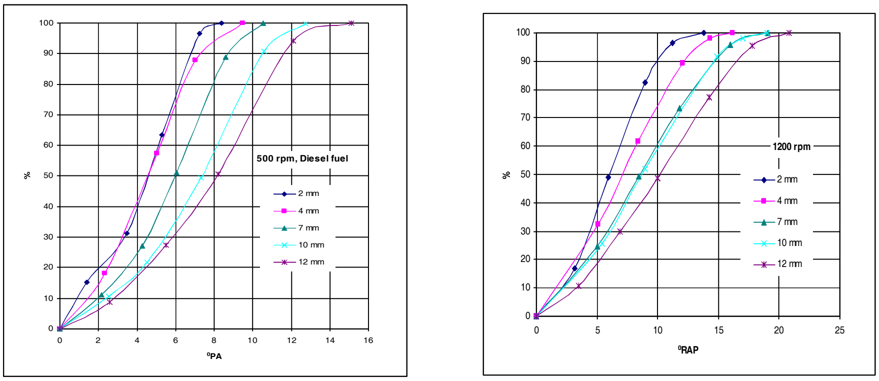

Fig. 10 Injection rate for Diesel fuel

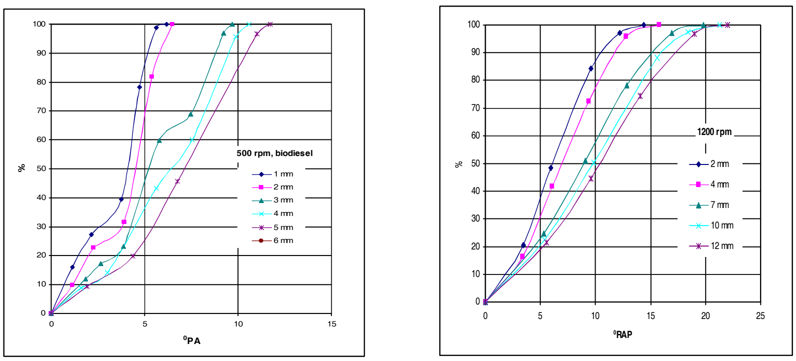

Fig. 11 Injection rate for methylester

A comparative analysis of the injection rate for Diesel fuel and methylester shows that significant changes of the injection rate are noted mainly for low pump speeds and large displacements of the control rod (fig. 12 and table 2), due to the increased cyclic fuel delivery (see also fig. 3). At higher speeds, the charts show no significant differences between the injection rates recorded for the tested fuels (fig. 13).

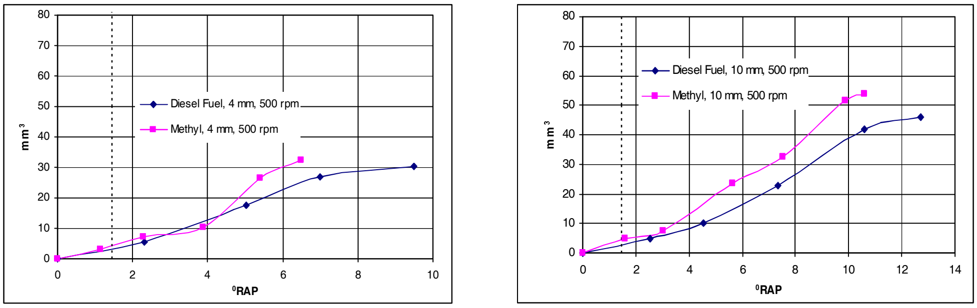

Fig. 12 Injection rate at 500 rpm

Table 2 Comparative analysis of injection rate (500 rpm)

Control rod position [mm]	Time elapsed since start of injection [^{0}PA]	Quantity of injected fuel [mm^3]	
		Diesel fuel	Biodiesel
4	6	22	30
10	6	15	27
10	10	39	52

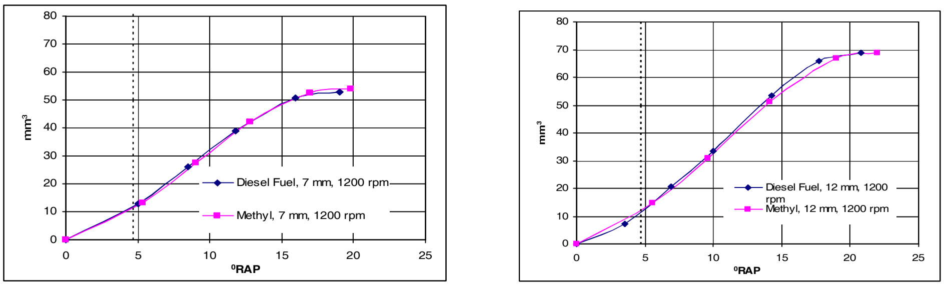

Fig. 13 Injection rate at 1200 rpm

Maximum injection pressure

Some of the results concerning the peak injection pressure are presented in fig. 14. It is obvious that the use of methylester leads to higher injection pressures, probably due to the higher viscosity of BTF. The pressure increased with 10…40 bar, depending upon pump speed and position of the control rod.

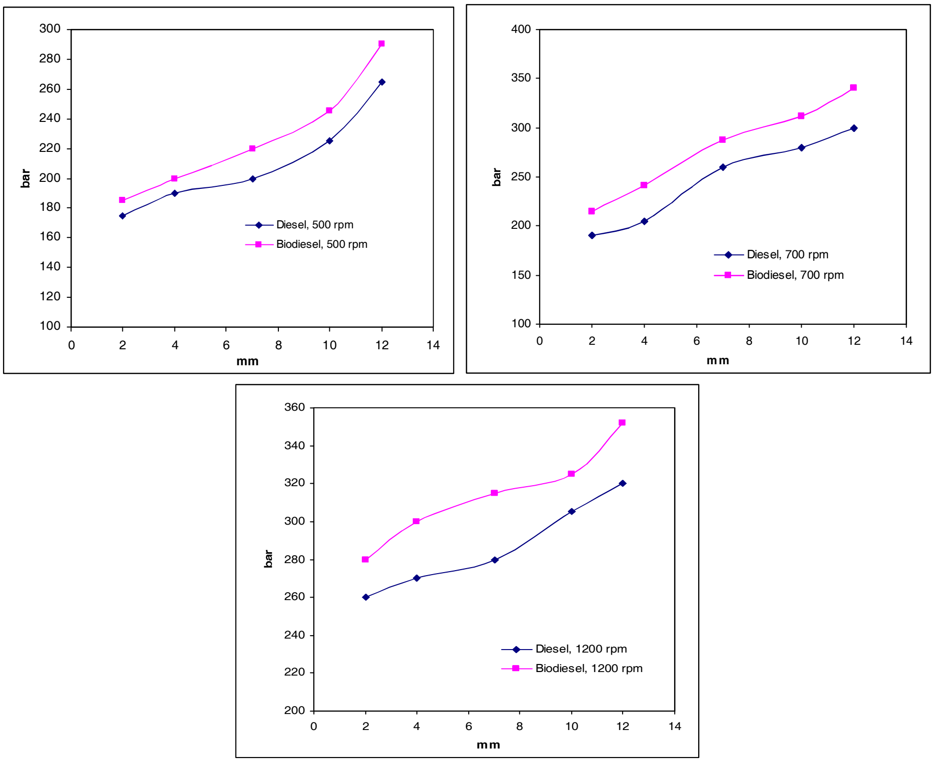

Fig. 14 Peak injection pressure

CONCLUSIONS

1. A Biodiesel type fuel was produced starting from waste vegetable oil, using the base catalyzed method.
2. The injection equipment of a Diesel engine was tested in order to study the effect of the Biodiesel fuel over the injection characteristics.
3. The cyclic fuel delivery, pressure wave propagation time, average injection rate and maximum pressure during injection were significantly affected when pure Biodiesel was used as fuel. As a result, an overall earlier start of combustion (with 1.8…2^0 CA) is expected to occur when methylester is used in order to fuel the engine.
4. The earlier start of combustion is expected to affect the engine's emissions, peak combustion pressure, pressure rise rate and output power (especially for the full load regime). The lower average injection rate at high pump speeds may affect the fuel spray quality and is only partially compensated by the increased peak injection pressure.

5. In order to counteract these negative effects, a higher injector opening pressure and adjustment of the injection timing should be taken into account when using pure Biodiesel in order to fuel the engine.
6. The use of the BTF affected the injection rate mainly at low pump speeds and large displacements of the control rod (higher values than the ones recorded for Diesel fuel).
7. Taking into account the results concerning the behavior of the injection equipment, we conclude that, from this point of view, it is possible to use B50 or B100 type fuels for fueling the Diesel engine, if proper adjustments of the injection timing are made.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

RESEARCH REGARDING ON BIOFUELS INFLUENCE OF USING AT COMPRESSION IGNITION ENGINE

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ABSTRACT

The paper present a part of researches carried out regarding the influences of using biofules in feeding compression ignition engine. In these way have been make experimental research on compression ignition engine, to determine technical status of this and performances for many moments of running.

***Key words**: biofuel, Diesel engine, duty cicle, reliability.*

INTRODUCTION

Stipulate of Rudolf Diesel- father of compression ignition engine (early on 1900, when at World Exhibition from Paris he present a these type of engine working with peanuts oil), using of biofules from vegetable oil tend to occupy today a bigger weight.

Fact that oils make parts of oxygenate fuels, make like integral utilization or in mixture with diesel fuel to permit decreasing of pollution level, so these oils is biodegradable.

Alongside with advantage assure of newly fuel, must be take into account some negatively aspects.

In these way, pure vegetal oil contain a great amount of lipoids, fat free salt, phosphates, Stearns, ceros, etc., which make he viscosity greater than diesel fuel. This associate with a great boiling point make difficulties in running in good condition of engine and aid of forming sedimentation. In succession of great viscosity spraying will be defectively, result drops of fuel with relatively great diameter that will be vaporize with.

Difficulty, affects mixture forming. In condition of highly temperature a part of fuel molecules suffer a recombination and forming compose who amplify carbon sedimentation in combustion chamber, in injector nozzle holes, on the valves, etc.

It does know as, quality of spraying is determined from many parameters that are divided in:

a) functional parameters of injection system (pressure at injection begun, fuel velocity through nozzle hole ,revolution of injection pump);
b) environment status in take place injection (pressure in combustion chamber, temperature in combustion chamber, air density in combustion chamber);
c) physical property o fuels;
d) components of injection system (cam profile, type of injection pumps and injectors, numbers, shape, and dimensions of nozzle holes);
e) duty factors.

Taking into account all these aspects, became necessarily as in research who Automotive and Agricultural Machinery Department from Technical University of Cluj-Napoca, to carry out regarding biofuels, to analyze influence of using these type of fuels in compression ignition engine. These analyze is based on using biofuels at D 118 engine – factory made, without any constructional modification.

EXPERIMENTAL RESEARCH

Experimental research regarding on influence of using biofules on compression ignition engine to find out followings:

- evaluation of effects to using biofuels who are based on rape oil about engine reliability (wear- important component elements of a crank gear and to a timing gear- produce during testing);
- evaluation of effects to using biofuels who are based on rapeseed oil through the characteristics of lubricating oil;
- evaluation of effects to using biofuels who are based on rape oil about engine performances.

For evaluation of engine wearing have been utilize like diagnostics parameter wearing measured for the parts who are directly solicited behind development of burnings newly fuels in D 118 engine (pistons, rings, connecting rod, crankshaft, cylinder head, inlet and outlet valves); In this way, before start the test, we proceed at (fig.1):

a) dismantling of this engine in parts;
b) cleaning and degrease the parts choose for analyze;
c) measuring dimensions of the parts, in accordance with establish methodic ;
d) remounting the engines.

After 100 hours of running of the engines (feed with biofuels who are based on rape oil) on load, are replay the steps mentioned above and introduce a second step, a additional step, who analyze sedimentation on studying parts. The same steps have been make and after 200 and 300 hours of running.

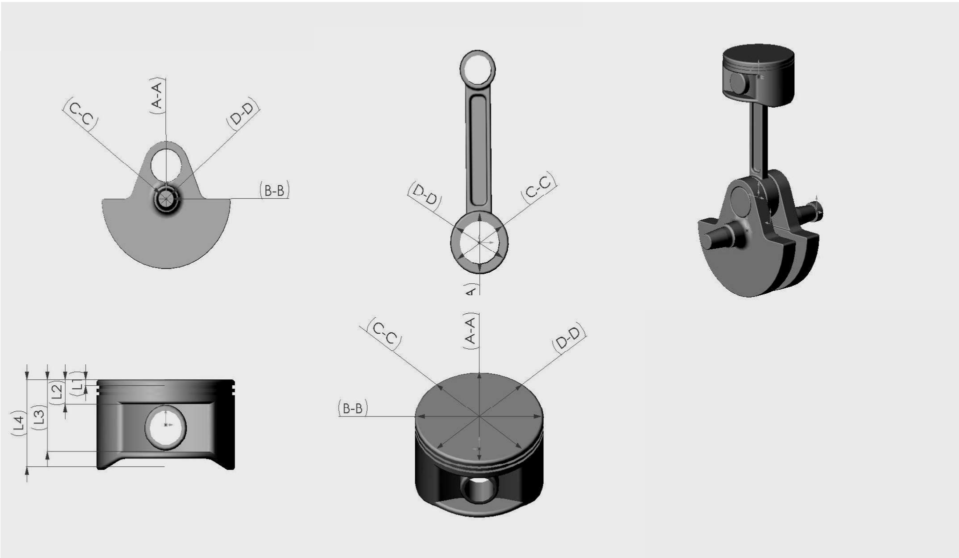

Fig. 1 Measuring method of the engine parts

In this way is found out sedimentation only on the parts that configure combustion chamber of engines. To another parts (connecting rod bearing, main bearing, piston pin, crankshaft) not have been observe any kind of sedimentation.

Sedimentation observed after 100 ours of idle running is presented in figures 2,3,4,5. After other 1000 hours of running of engines, in this time working way, is find out that sedimentation have been considerable reduced.

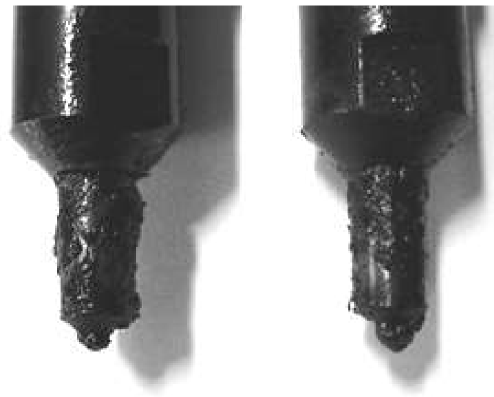

Fig. 2 Injectors sedimentation after running with biofuels who are based on rape oil

Fig. 3 Cylinderhead sedimentation after running with biofuels who are based on rape oil

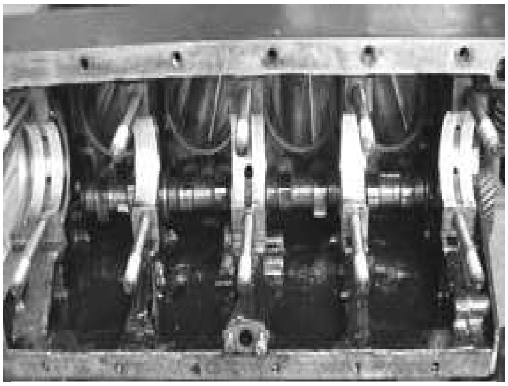

Fig.4 Bearings sedimentation after running with biofuels who are based on rape oil

Fig. 5 Piston sedimentation after running with biofuels who are based on rape oil

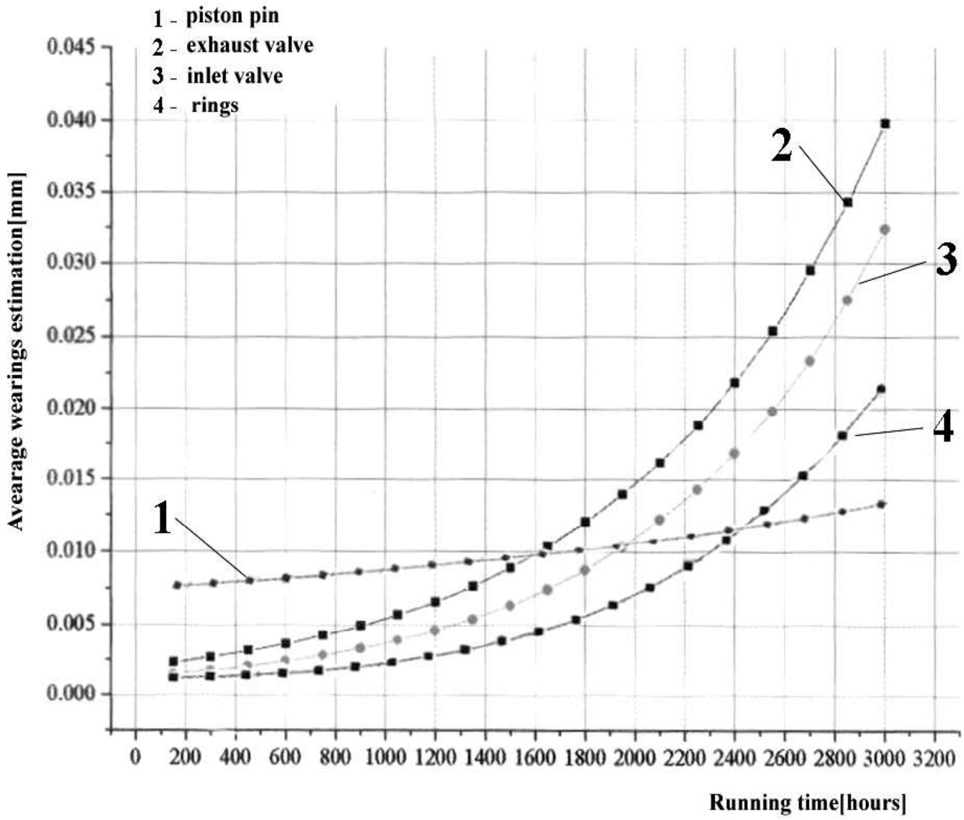

Fig.6 Wearing of some parts estimation

On the data obtained after measured the dimensions of parts, have been estimate average wearing of the part and determine probability of distribution regarding process of degradation at those (fig.6).

In order to estimate the dimensional changes occur of each pieces diagnosed, the exponential distribution law was used. According with this hypothesis, the density of time functioning distribution represents the significant parameter.

It is described by the equation:

$$f(t) = \lambda \cdot e^{-\lambda \cdot t} \tag{1}$$

where:

- λ represents the versus of mean dimension measured during the test of the diagnosed pieces
- t time of estimation.

Thus, on basis of a measurements and estimation, have been compare wirings of D 118 engine in case o running with befouls who are based on rape oil with normal wearing (admitted from manufacturer of engines). Must be mentioned fact that evaluation have been realize for the case of engine running without modifications.

In this way is find during testing not have been produce failings, and basis dimensions of the analyzed parts is in normal limits.

In case of piston, wearing who appears (prevision otherwise) is situated in a plane normal to axis of piston pin and appear due to secondary movement. From analyze curves of average wearing variation to find out that period of functioning to appearance extreme wearing is form 5000 hours.

Must be take into account the fact that good running of the engine is affect to totals wearing at piston and afferent cylinder sleeve. Is important to mention fact that wearing is uniform at 4 pistons, fact who indicate a normal running of an engine feed with newly fuel.

Rings suffer an increased process of degradation. Calculated estimation on the base of measurements indicates a normal running period of 3500 hours.

Cylinder sleeve suffer degradation almost from those of the piston, period on normal running is estimate lass to 5000 hours. Must be take into account the fact that good running of the engine is affect to totals wearing at piston and afferent cylinder sleeve.

Measuring the rod of inlet and exhaust valve conduce at estimation a differentiate wearing a these two valves, most affected is exhaust valve (here can observe an accentuate process of wearing. Anyway, function period of valves is in harmonies with admissible limits (app. 7000 hours).

Influences study about characteristics of lubricate oil have been realize taking and analyze samples of oil (from inferior crankcase of engine) from 50 in 50 hour of engine running with newly fuel. From analyzed report realized in laboratory, from each sample is see way of modification in time an oil characteristics, such how can see in table 1.

Table 1

Type of lubricate oil	Characteristics	STAS	Results		
			Fresh oil	After 100 hours running	After 200 hours running
M30S2	Inflammability, ^0C	5488-80	220	198	190
	Freezing point, ^0C	5489-80	-20	-15	-12
	Viscosity at 40 ^0C,cSt	39-80	80,44	78,12	66,8
	Viscosity at 40 ^0C,cSt	117-66	56,5	55,1	53
	Viscosity at 40 ^0C,cSt	8421-80	10,8	9,0	7,8
	Viscosity index	55-81	116	86	75
	Much.impurtities + water,%	7423-70	-	0,2	0,5

Influences analyze about engines performances were made from raise the regulator revolution characteristics at the engine in condition of using biofuels who are based on rape oil comparatively with using of classic fuels (diesel fuels).

Without these elements, during entire periods of evaluation of influences were analyzed variation of exhaust gases, variation of a cooling liquid temperature and variation of lubricating oil pressure, to find out that parameters corresponding to the normal running engine condition.

CONCLUSIONS

Effect of using fuel on rape oil based is harmonies, from point of view the durability, in standards impose to the engine manufacturer.

From point of view the reliability, not recorded failures on entire period of testing, fact who indicates harmonization in limits exploitation after a normal repartition laws a possible event, which can appear.

These experimental testing were make obvious also fact that the utilization of engines in load assure reduction nearly in total of a sedimentation.

Is possible to appreciate that newly fuel not bring penalization from point of view a analyze state parameters ,who have a effect similar with a diesel fuel on entire testing period. In addition, using fuels additives and some minimal constructive modifications in components of high pressure feedings system, maybe solve problem of sedimentation and increasing engines performance.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

EXPERIMENTAL RESEARCH REGARDING THE INFLUENCE OF THE BIOFUELS THROUGH THE CHEMICAL POLLUTION FOR THE D 118 DIESEL ENGINE

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ABSTRACT

In the paper are presented the results obtained in the laboratory regarding the Diesel engine chemical pollution fueled with biodiesel obtained from rapeseed oil. The results show significant changes regarding the pollutants participation in the exhaust gases. Also the engine parameters: power and specific fuel consumption were measured at the same time with the pollutants evaluation.

Key words: *engine, diesel, fuel, vegetable oil, performance.*

INTRODUCTION

The new vegetable fuels obtained from agriculture and organics materials assure significant advantages in the transportation field and for agriculture.

These fuels reduced the emission of the pollutants based on carbon monoxide, according with the engagement of European Union stipulated in the Kyoto agreement.

At the same time, the new vegetable fuels assure a more independence of the nationals transportation systems (at the moment more then 98% of fuel is obtain from mineral oil), by diversification of products and improving the safety of engines fueled processes (fig. 1).

A plus benefit consists in a new market for agricultural products of the farmers.

For the next years the European Union schedule is to increase the biofuels used in transportation especially regarding road transportation [4].

Based in European Community Directives, in all countries members will be promote in the next years actions for replace the mineral fuel with vegetable one in 5,75% proportion (until 2010). This will be happened after if until 1996 only 0,25% from fuel consumption was based on biofuel.

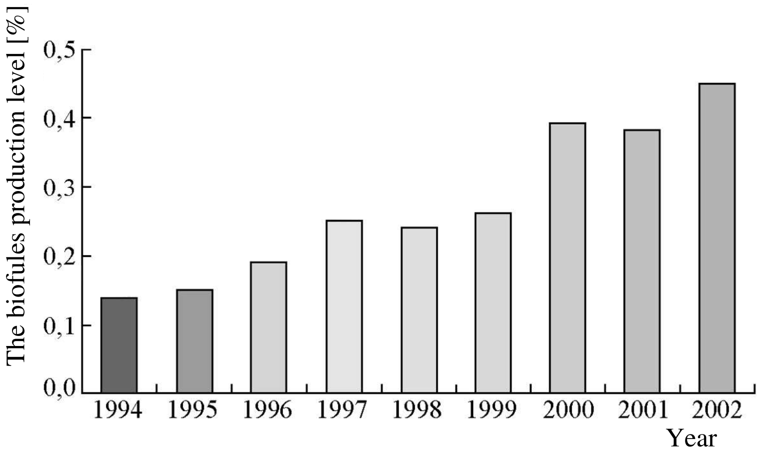


Fig. 1 The level of biofuels from the road transportation consumtion

Almost ¾ from biofuels was produced and used in France and Germany (2002), and at that moment it represent only 0,45% of the fuels used in transportation. In this countries the taxes policy encouraged the biofuels production and utilization.

This fact represents for the farmer and chemical industry a challenge in order to increase the biofuel production.

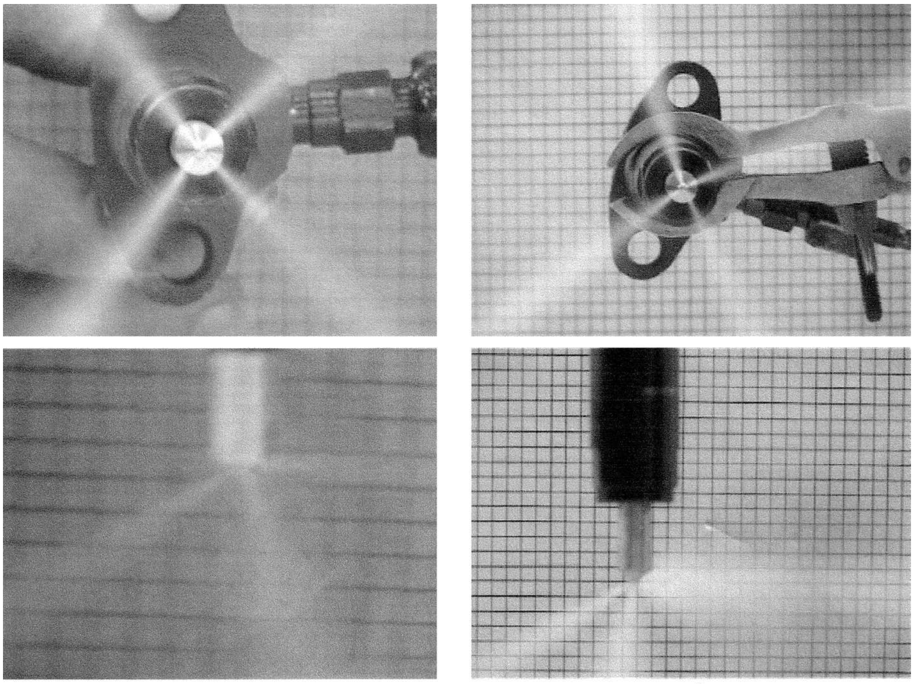
EXPERIMENTAL RESEARCH

In order to increase the engine energetic parameters and to reduce the pollution, the analyze of the injection pressure for biofuels from vegetable oil represent an important research step.

In this respect the experimental research carried out in the laboratory, was divided in two important ways:

- the analyze of the fuel nozzle in the injection process for six fuels obtained from vegetable oil (a mixture which consist in petrol and methyl ester from rapeseed oil: 10%, 20%, 30% 40% and 50%), tested at different injection pressure;
- the chemical pollution evaluation for the mentioned fuel mixtures.

The experimental research regarding the effect of the injection pressure for different mixtures was carried out using a laboratory stand of D 118 Diesel engine and a video camera. Significant video captures of spraying quality during the injection are presented in figure 2.



a. b.

Fig. 2 The injection video capture for D 188 Diesel engine injector – injection pressure 175 dan/cm^2; a) petrol; b) metylester

The test results analyze show the fact that for the injection pressure recommended by the factory (regarding D 118 Diesel engine), the fuel sprayed in optimum conditions is the petrol. In the case of the mixture of rapeseed methyl ester and petrol, the spraying cone is reduced.

In order to adjust the injection parameters the test made for the injector with an open higher pressure show significant changes regarding the spraying quality. In this case the cone of the area covered by the fuel increase finally was obtained a quality of the injection appropriate with the petrol injection.

The analyze of the injection pressure influence through the spraying cone angle for three fuels tested show significant particularly aspects: the fuels from vegetable oils due to the highest viscosity need a great injection pressure to assure the uniform distribution of the fuel in the combustion chamber. For obtain the same spraying cone as them resulted for petrol, in the case of methyl ester the injection pressure was 275 dan/cm^2. If the injection pressure is under this value, we observed that the cone is divided in two parts: central part with a higher density of fuels were was observed precipitations of large fuel molecules and the outside part composed by fine molecules covered by a mixture (air and exhaust gases). Due to different density the speed of molecules displacement in the combustion chamber is not the same. The result is a non uniform distribution of burning points in the volume of the combustion chamber.

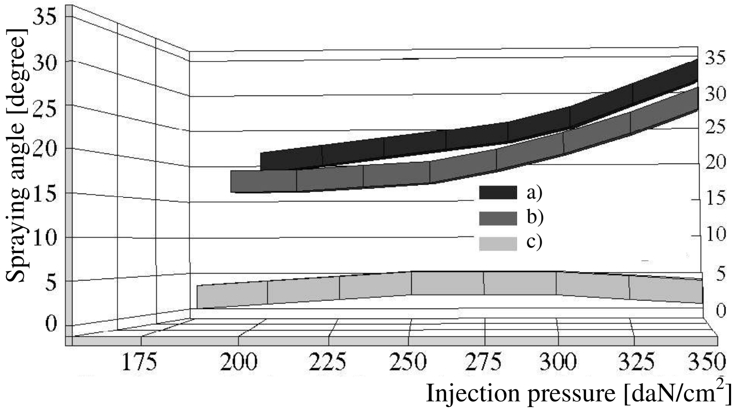


Fig. 3 The injection pressure influence through the spraying cone for three fuels: a) petrol, b) metylester, c) rapseedoil

The increasing of the injection parameters produced a pollutants reduction. That was happened due to the fact in this way was improving the burning conditions.

For evaluate the effect of injection condition through the pollutants emission a laboratory test was start. For measure the pollutants SMP 4000 diagnose station was used (fig. 4).

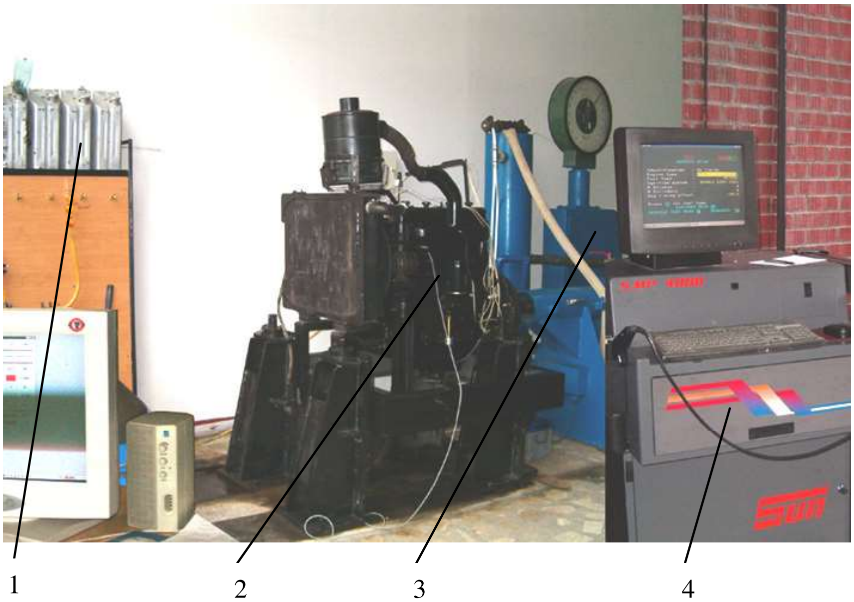


Fig. 4 The test stand: 1 – fuel tanks; 2 – D118 Diesel engine; 3 – dynamometer; 4 – SMP 4000 pollutants diagnose station

The measured pollutants are:

- CO carbon monoxide [%] in volume;
- CO_2 carbon dioxide [%] in volume;
- HC hydrocarbon [ppm]
- Smoke [1/m].

The test was carried out for two injection pressure: 175 and 275 daN/cm^2. Significant changes occur in the pollutant emission for the two pressures. As a results of better injection conditions, the pollutants emission decrease especially the smoke (fig. 5).

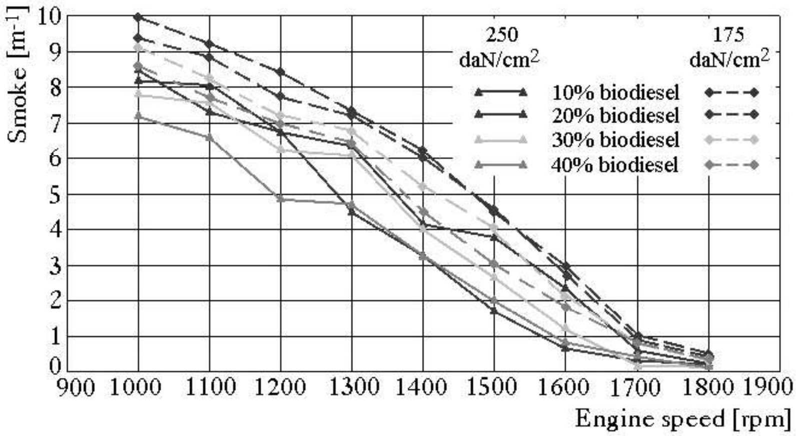


Fig. 5 The smoke emission for tested biofuels and depending by injection pressure

CONCLUSIONS

The research carried out offer some information's regarding the influences of the fuel from vegetable oil through the Diesel engine functioning conditions.

A concluded remark consists in the necessity to increase the injection pressure, and that depending by the biofuel type.

For the rapeseed oil used as a fuel for Diesel tractors, is need to reduce it viscosity and the modification of the injector spraying diameters.

The challenge for the future consists in:

- analyze of the cone forming process and an evaluation of the quantity of the average diameter of the fuel molecules;
- analyze of the injector spraying diameter through the injection quality;
- the analyze of the injection pomp and the possibilities to modify its characteristics in order to assure the functioning conditions for the engine fueled with vegetable oil.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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EXPERIMENTAL RESEARCH REGARDING THE NOISE AND VIBRATIONS FOR TRACTORS FUELED WITH BIODIESEL FROM RAPSEED OIL

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ABSTRACT

In the paper are presented the experimental results obtained in the laboratory for Romanian D118 Diesel engine from U 650 and U 800 tractors. The purpose of the research is to evaluate the influence of biodiesel from rapeseed oil through the noise emission and the engine vibration spectrum in 1/3 frequency band. Using N121 noise analyzer and a RFT frequency analyzer, the engine was tested in full and partial load conditions. The results were compared with the registered values for the Diesel oil fueled case.

Key words: *biofuel, noise, vibration, test*

OVERVIEW

The engines fueled by rapeseed oil represent a challenge for a lot of farmers who are able to increase their work efficiency in accordance with the future tendencies regarding the dramatic reduction of the petrol resources.

At this stage, several problems represent the research objectives focused on some particular aspects of the rapeseed oil fueled process.

The important research ways are:

- the energetic engine parameters (effective power and fuel consumption);
- the chemical pollution (smoke, CO, CO_2, HC and NOx)
- the noise of the engine fueled with rapeseed oil.

The environmental pollution problems are analyzed in accordance with the energetic parameters of the engine. In this respect, some research has begun in our university on two different directions:

- chemical pollution;
- noise produced by the engine in different functioning conditions.

A specifique part of the research carried out in the laboratory consists of noise and vibration evaluation for each biofuel tested. In this respect, the rapeseed oil mixtures with petrol which were tested are: 10%, 20%; 30%; 40% and 50%.

The experimental tests show that the mixture 40% rapeseed oil and petrol represents the most efficient fuel for Diesel engine which assures appropriate energetic parameters with pure petrol. To evaluate the effect of biofuels, the test results were compared with the engine functioning conditions fueled with petrol.

The noise produced by the engine of the tractors fueled with biodiesel from rapeseed oil shows due to the burning process some particular aspects, especially the exhaust gases mixture and their physical properties: gaseous density, temperature and the rate of the pollutants participation in the mixture.

TESTS METHODS AND EQUIPMENTS

To evaluate the tractors noise rate, the tests were carried out in accordance with 59 Regulation of CE – ONU, considering also the amendments 1/1990 and 2/1999: and the 74/151 Directive of EEC, considering the amendments: D 88/410 EC and D 98/38 EC.

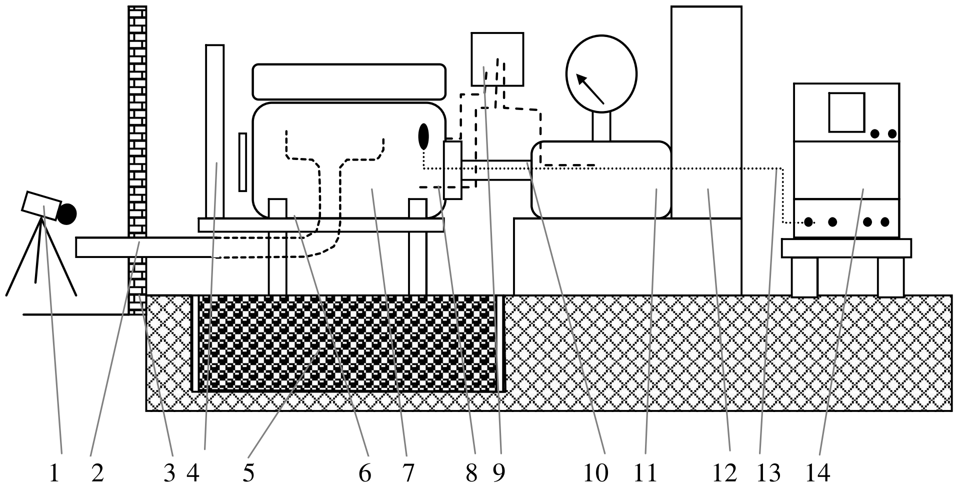

Fig 1 The laboratory test stand: 1 – microphone of N 121 noise analyzer; 2 – exhaust pipe; 3 – lab wall; 4 – cooling radiator; 5 - insulated stand pavement; 6 – stand enforcement; 7 – D 118 Diesel engine; 8 - transducer wires; 9 – RS 232 interface; 10 – torque axe; 11 – dynamometer; 12 – cooling tank; 13 piezoelectric wire transducer; 14 – vibration analyzer RFT with 1/3 octave spectrum

The tests carried out were detailed in the following procedures:

A. The engine test in laboratory conditions using the stand to evaluate the average noise produced by the exhaust system, the vibrations of the engine and the back pressure in the intake manifold;

B. The entire tractor noise test in accordance with CE regulation, for the same rapeseed oil mixtures.

The laboratory stand used for Diesel engine tests to evaluate the noise and the vibration is described in figure no.1 and 2.

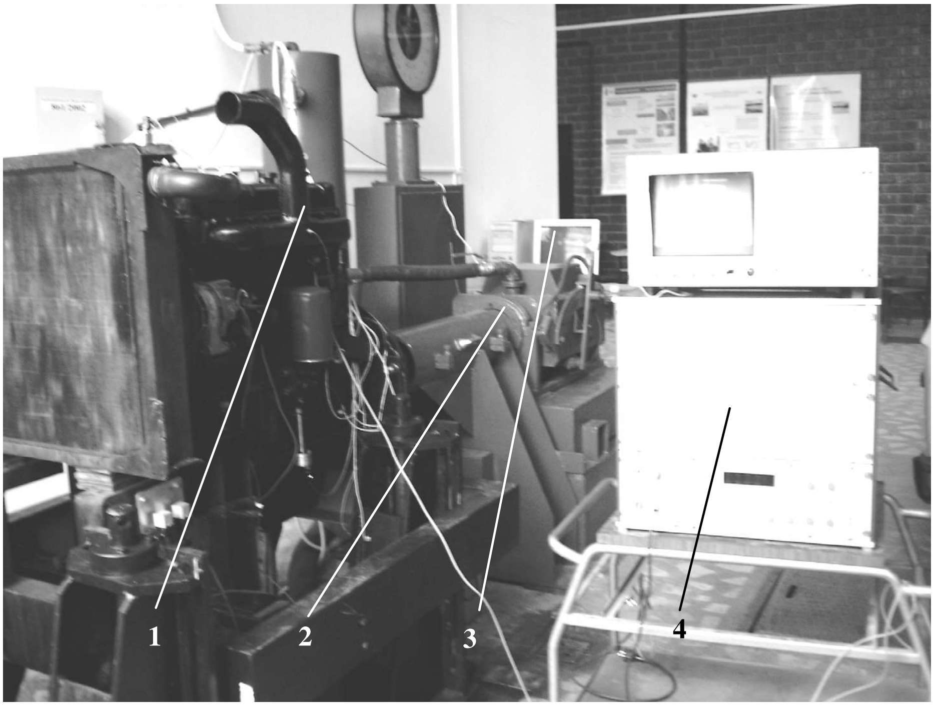

Fig. 2 The experimental laboratory stand illustration: 1 – D 118 Diesel engine; 2 – the stand hydro – dynamometer; 3 – Computer with collecting data system; 4 - RFT vibration analyzer.

The parameters needed to evaluate the engine energetic performances were collected on a RS 232 serial interface which communicates with a PC. In order to collect the noise and vibrations parameters two different equipments were used: the noise environmental analyzer NOR121 and RFT vibration measurement equipment on 1/3 octaves band width.

The noise and vibrations were collected at the same time with the energetic parameters in order to conclude the same functioning conditions.

The NOR 121 equipment made by Norsonic Company, corresponds to no.1 precision class, in accordance with the ISO references for environmental acoustic instruments (fig. 3).

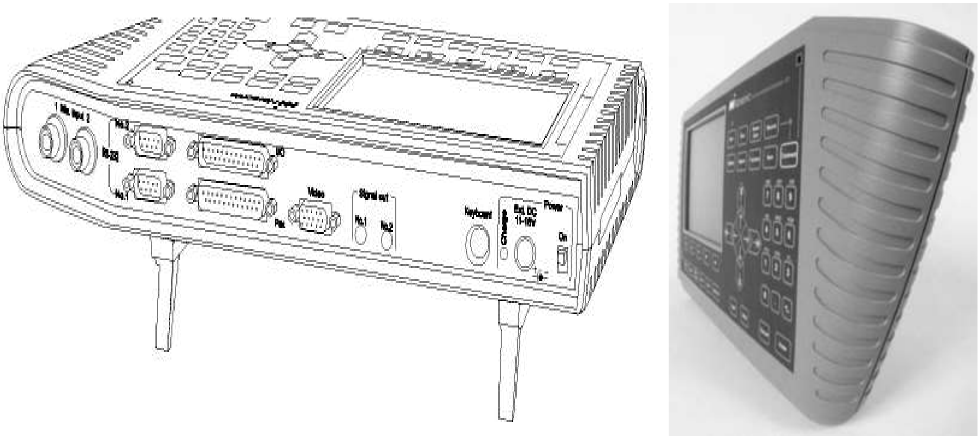

Fig. 3 The NOR 121, environmental noise analyzer

The apparatus is able to measure the noise on A, B, C, D and F waiting curves, in accordance with general prescriptions regarding the equivalent noise evaluation. The measured values are saved in the processor memory for a later complete evaluation.

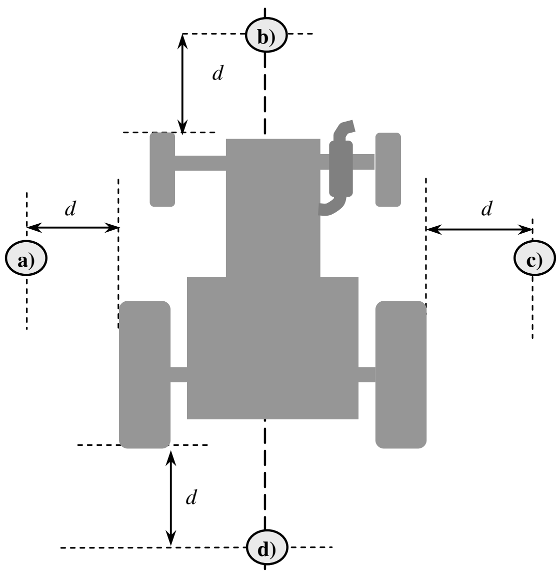

Fig. 4 The microphone position around the tractor for stationary noise measurements

The RFT analyzer, equipped with a piezoelectric velocity of vibration transducer has the ability to detail the engine vibration in 1/3 frequency band.

The test for the noise produced by the tractor in running conditions were carried out in a special marked area in accordance with R 59 and D 88 special requirements (fig. 4 and 5). For the tests we used the U800 tractor which is equipped with the D 118 Diesel engine.

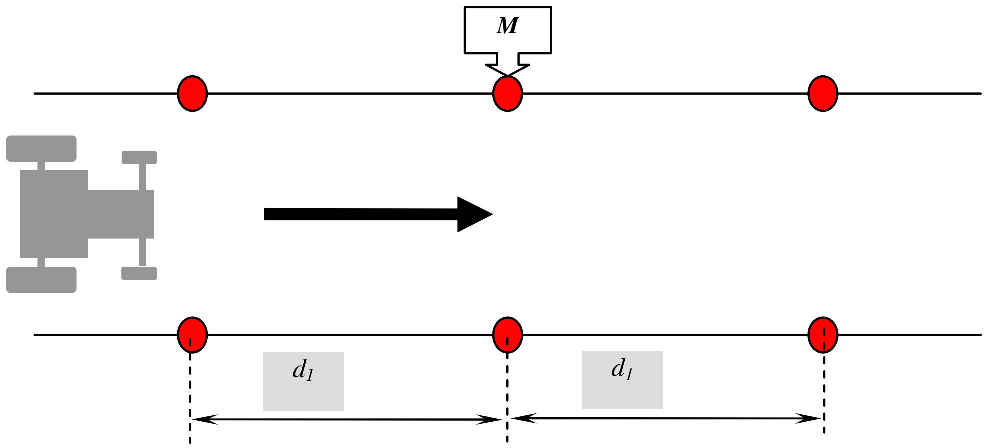

Fig. 5 The driving marked area for measured the noise in run conditions

TEST RESULTS

In the laboratory conditions the noise, back pressure and the vibrations measured for the engine D 118 fueled with rapeseed oil mixture show some differences compared to the petrol. Regarding the noise produced in different running conditions of the engine, the results are presented in table 1.

Table 1 The noise emission depending on the engine speed in idle conditions.

Biofuel		Petrol	
Engine speed r.p.m	Noise level dB(A)	Engine speed r.p.m	Noise level dB(A)
850	76,5	900	76,9
1150	78,7	1175	78,0
1375	83,1	1400	84,3
1500	84,4	1575	85,2
1800	87,9	1800	87,7

Table 2 The noise level variation in engine load conditions; test for biofuel

No. determination	Engine speed [r.p.m]	Engine load [daN*m]	Noise level [dB(A)]	Back pressure [Pa]
1	1720	0	87,2	2,4 *^{4}
2	1530	8	86,6	2,3*10^4
3	1340	16	86,0	2,5*10^4
4	1130	26	84,6	2,7*10^4
5	1020	30	84,9	2,7*10^4

Table 3 The back pressure measured in laboratory conditions

No. determiner	Back pressure [Pa] *10^4		
	petrol	Biofuel	Average difference
1	2,1	2,4	0,16
2	2,3	2,5	
3	2,4	2,4	
Average values	**2,27**	**2,43**	

The vibration spectrum in 1/3 band frequency is presented in figure 6, for the two fueled conditions: biofuel and petrol. Significant differences were observed regarding the engine specific frequency magnitude of vibrations.

The differences of the level and the characteristic frequencies where the peak of vibrations appear demonstrate that the engine fueled with biodiesel has the tendency to be more vibrated. We observed some peaks at low frequency at the same time with the tendency to maintain this characteristic at high frequencies too.

This is due to the different burning conditions and if we correlate these results with the average increase of the back pressure, an important observation will be made regarding the engine functioning parameters: the engine must be reevaluated from the dynamic equilibrium point of view.

It is interesting that the noise is maintained in appropriate values and significant changes occur only regarding the engine vibrations.

The tests carried out with the tractor equipped with D 118 engine, according with the European regulations show some differences regarding the noise emissions for the considered fuels.

The running conditions for the tractors were: gear box coupled in IIIrd positions, the engine speed 1800 r.p.m and the tractors speed 18 km/h.

The results are presented in table 4.

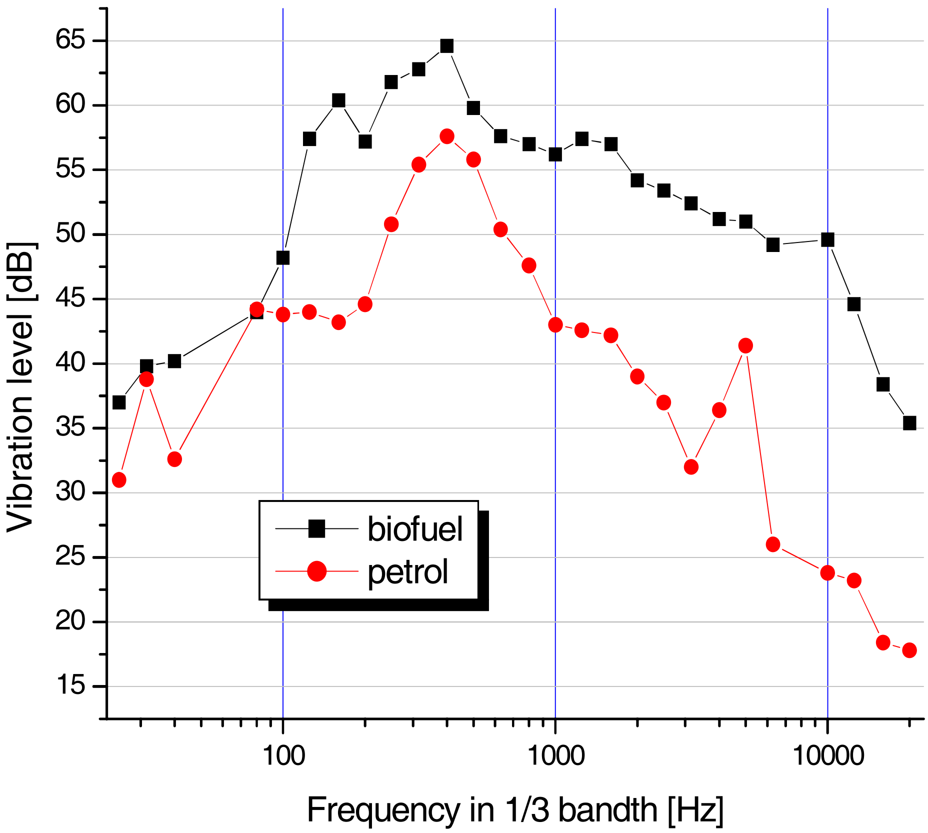

Fig. 6 The engine measured vibrations for two different fuels

Table 4 The tractor noise measured in imposed running conditions

Fuel type	No. determination	Maximum registered noise level [dB(A)]	Average noise calculated [dB(A)]
Biofuel	1	81,5	81,285
	2	81,7	
	3	81,6	
Petrol	1	80,8	80,637
	2	80,7	
	3	80,4	

The noise measured around the tractor for engine speed 1800 r.p.m. is presented in table 5.

Table 5 The noise measured according with D 70 Regulation: engine rotation speed 1800 rpm

Fuel type	No. of determination	The noise measured with the microphone position according with the points marked in figure 4. [dB(A)]			
		a)	b)	c)	d)
Biofuel	*1*	80,5	81,6	81,7	78,9
	2	80,0	81,1	81,9	78,7
	3	80,8	81,5	81,3	78,7
Petrol	*1*	79,4	80,2	80,4	78,2
	2	79,0	80,4	80,1	78,6
	3	79,0	80,3	80,7	78,1

CONCLUSIONS

Due to the differences in the burning process of the biofuel, a new noise attenuator for the tractors must be designed in accordance with the thermodynamic parameters of the exhaust gases.

Significant differences also appear regarding the engine vibrations. This happens because of the back pressure measured and in accordance with the different burning characteristics. The pressure evolution in the combustion chamber is different if we use biofuel from rapeseed oil.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

CHARACTERISTICS OF TRACTOR ENGINE USING BIODIESEL FROM DECENTRALIZED PRODUCTION AND MINERAL DIESEL FUEL

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ABSTRACT

For the evaluation of tractor diesel engine characteristics, three types of biodiesel from decentralized production and mineral diesel fuel were introduced in research. They were the following: biodiesel from waste vegetable oil (WVOME), from mixture of new soy and sunflower oil (MVOME) and rapeseed oil (RME). None of the used bio fuels complies with all the items of the standard. The main problem is viscosity and water content. Torque and rotational speed was measured on PTO shaft. The maximal power using biodiesel from new vegetable oils is by 6.6 % lower on average but the rated power is higher in comparison with D2. Torque relations are similar as with power analysis. MVOME and RME give significant lower torque increase, for 51% and 36% respectively. Using WVOME, RME and D2 the speed drop is almost the same. Something higher value (18% from D2) can be observed at MVOME. Rotational speed at minimal specific fuel consumption of engine, when using MVOME or RME, is about 30% higher than D2. Using MVOME and RME the specific consumption is, at engine working with maximal power, about 10 % higher. This is on the average the same value as the energy content of observed fuels is lower in comparison with the D2 fuel. Biodiesel from waste vegetable oil gives less advantageous characteristics of engine.

Key words: *energy, biodiesel, tractor*

INTRODUCTION

One part of the near future fuel supply can undoubtedly come from the production of rapeseed oil and making of biodiesel from it. It presents the possibility for mankind to start caring about the environment. With the rapeseed production land use can be regulated and preserved, probably in the rotation with wheat and sugar beet or other crops used for the production of food or as a different renewable energy source (B 2005). Next effect of the same importance is decreasing of greenhouse gas emissions. Biodiesel is produced domestically, so its use helps reduce the nation's dependence on imported oil and can help boost the agricultural sector of the economy (D 2005). Biodiesel can be used as a substitute for diesel fuel, or as an additive for blending with diesel in various ratios. It can be used today without any great changes of engine technologies or supply systems. Development of other alternative sources of energy (such as photovoltaic, fuel cells, hydrogen and others) has not yet reached such a stage as to be widely used at present. But in future they will probably play an additional or even the main role in energy supply. The production of biodiesel from new or waste vegetable oils or animal fats has been increasing in the last years. The main users of biodiesel fuel are tractors and other machines working in agriculture, forestry and municipal engineering, especially those which work near or above water sources. Also, biodiesel has been used more and more in the public transport as fuel for buses and taxi cars.

In Slovenia the farms are small on the average and a large part of fields are situated in the area of limited possibilities for agriculture. Decentralized production of biodiesel in such conditions can also mean one of possible additional activities on some farms. The benefit is also low energy consumption; 6 times lower than for industrial extraction on the average (C 2005). However, a great problem at small scale production of biodiesel is to ensure the quality of fuel to meet the requirements stated in the standard for biodiesel fuel. We wanted to find out what was the influence of using decentralized produced bio fuels in small tractor on some of its engine characteristics.

MATERIAL AND METHODS

Hardware

For the purpose of evaluating the influence of different fuel types on the mechanical and usable diesel engine characteristics the tractor Agromehanika AGT 835 was used. This is a small multipurpose tractor with isodiametrical wheels for the use in agriculture, fruit, vine and vegetable growing, and municipal engineering. The tractor was equipped with water cooled three-cylinder diesel engine, mechanical transmission with 6 gears for forward and 3 gears for backward driving. For the connecting tools, the tractor is equipped with the standard three-point linkage and power take off shaft with rated speed of 540 and 1000 rpm. Engine characteristics are given in Table 1.

Table 1 Technical data of engine used

Make	LOMBARDINI	Compression ratio	22:1
Type	LDW1503	Rated speed	3000 rpm
Cylinders	3	Rated power	26.4 kW (ISO 1885)
Displacement	1551 cm^3	Rated torque	84.5 Nm
Bore	88 mm	Max. torque	95.4 Nm at 2100 rpm
Stroke	85 mm	Min. spec. fuel consumption	268 g/kWh at 2400 rpm

The tractor engine was loaded through PTO shaft by means of hydraulic-brake dynamometer type HD Andersen. Torque and rotational speed were measured on PTO shaft by using standard HBM T 30 FN probe which was connected through HBM MD and Spider 8 excitation and signal conditioning system to a PC. The measuring frequency was 10 Hz (10 records per second). The measured values were treated with HBM Catman software. The measured values of torque, speed and calculated values of power were recorded. Fuel consumption was established by measuring time in which a defined volume of fuel was consumed. Schematic view and measuring chain are shown in Fig. 1. Speed ratio between the engine main shaft and the tractor PTO shaft is 4.438, hence at rated engine speed 3000 rpm the PTO rotational speed is 676 rpm.

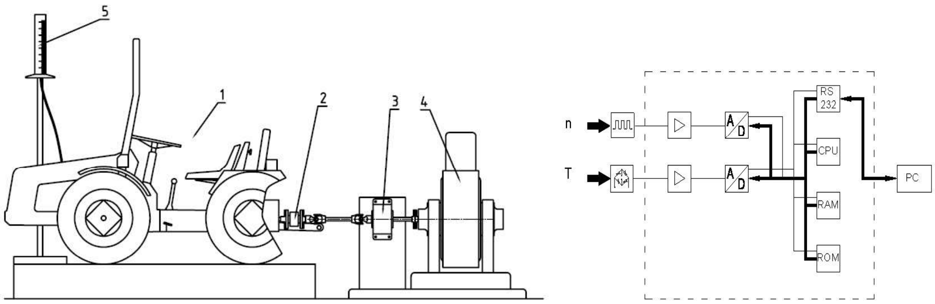

Fig. 1 Schematic view and measuring chain (1. tractor, 2. torque/speed measuring probe, 3. multiplication gearbox, 4. hydraulic measuring brake, 5. fuel measuring cylinder)

Fuel

Three types of biodiesel fuels were used in the experiment: waste vegetable oil methyl ester (WVOME), mixture of soy and sunflower vegetable oil methyl ester (MVOME) and cold pressed rapeseed oil methyl ester (RME), all made in decentralized (small scale plants on farms, not the industrial production) production. The analysis was done at accredited laboratory in accordance with the standard test methods. Standard diesel fuel D2 was used as reference.

Table 2 Properties of biodiesel fuel types used

Parameter	Unit	Test method	Limits EN 14214	WVOME	MVOME	RME
Density at 15°C	kg/m^3	SIST EN ISO 12185	860 – 900	891.1	890.0	893.7
Kinematic viscosity at 40 °C	mm^2/s	SIST EN ISO 3104	3.5 – 5.0	5.340	4.982	10.820
Flash point	°C	SIST EN 22719	above 101	137	161.0	97
Total contamination	mg/kg	SIST EN 12662	Max 24	24	11	14
Look	-	PML 07.09		Clear, yellow	Clear, yellow	Clear, yellow
Water content	mg/kg	SIST EN ISO 12937	Max 500	> 1000	>1000	> 1000

None of the used types of biodiesel complies with the standard EN 14214. The main problem in all three fuels is the water content and viscosity. RME fuel does also not comply with the limit value for flash point. Other producers of biodiesel also mentioned that it was not so easy to achieve limit values for these characteristics (Rice et al. 1997, Groschen 2002, Korus et al. 2002). Biodiesel has also a lower specific energy value than mineral diesel fuel (Liljedahl et al. 1989, Srivastava et al. 1996, Pavletič 2000). The mean specific energy for diesel fuel D2 is between 36-45 MJ/kg and for biodiesel between 37-41 MJ/kg. The energy content of fuel is not a fixed value but it depends on quality, purity, water content, supplier... (Booz 2002, Hofman 2003, A 2005, B 2005, D 2005). Different references report on different values for energy content of D2 and biodiesel fuel. But the average literature values show that biodiesel has 8.5% lower energy value than D2 at the same mass of fuel (Booz 2002, Hofman 2003, A 2005, B 2005, D 2005). If volume values are compared, the difference in density has to be taken into account. The density of biodiesel is about 6% higher then D2. The temperature of fuel and the ambient temperature was 20°C.

Procedure

Prior to carrying out the measurement, the engine was left running for one hour to warm up all parts and liquids to working temperature. Also, before each measurement with different fuel, the whole system (engine with PTO turned on, measuring probe and hydraulic brake set on torque 0) was running for 10 min at full throttle. Then the two minute long measurement of torque and rotational speed on PTO shaft at certain load setting and at full throttle started. During this time also the time required for the consumption of 0.1 l of fuel was measured. The first measurement was carried out at zero load setting, the load being only the friction between moving parts. For the next measurement the load on hydraulic brake was increased so that rotational speed of PTO decreased for about 100 rpm and in the next two minutes the measurement was done. All engine settings (throttle, cooling...) stayed unchanged during the measurement with particular fuel. Based on such method 7 measurements were performed for each type of fuel. At fuel change, all the previous fuel was removed from pipelines and filter system. Then the system was filled with new fuel and ventilation pipe was let open to flow about two litres of fuel through it. Afterwards the next measurement started with 10 minutes of warming up at full throttle and was proceeding as described above.

From the recorded values the average values of torque, rotational speed, power and specific fuel consumption were calculated. On the basis of these values we compared the observed parameters at different working points of engine and with different fuel types.

RESULTS

The main aim of the research was to find out if there is any and what is the difference of engine characteristic parameters at the use of different fuel type. On this spot we have to lay great stress upon the fact that measurements of torque and power were carried out on a PTO shaft and not on an engine main shaft or a flywheel. So it is normal that these values differ from the catalogue values.

Power

We compared two power values on PTO shaft: power at rated engine speed 3000 rpm or 676 rpm of PTO shaft and maximal power with all four types of fuel.

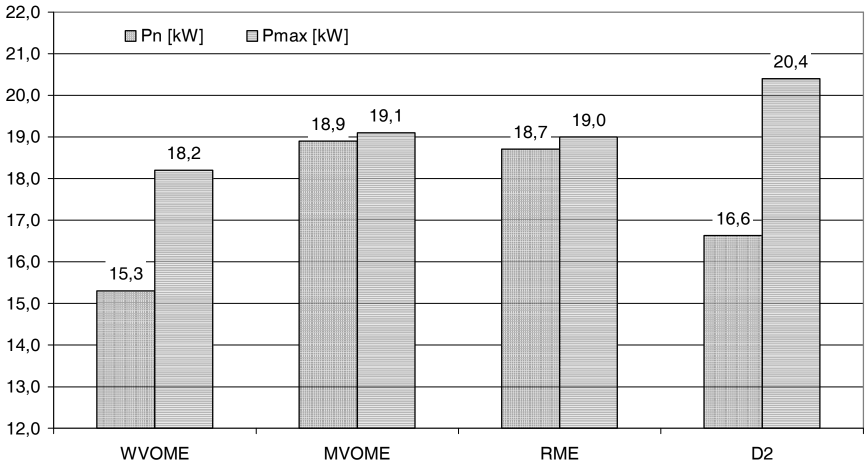

Fig. 2 Rated power (P_n) and maximal power (P_{max}) on PTO shaft at different fuel type

Maximal rated power is obtained by engine with biodiesel from new vegetable oils. The use of biodiesel from waste vegetable oil gives the lowest power, rated and maximal, by 8% and 11% lower than D2 respectively. The maximal power using biodiesel from new vegetable oils is by 6.6 % lower on the average in comparison with D2.

Torque

Generally, the relations are similar as in power analysis. The average rated torque with MVOME and RME is 12% higher than with the D2. If WVOME is used, the rated and maximal torque is lower. But it is rather interesting that RME gets the same torque as D2 (0.6% higher). The use of MVOME results in a little lower (3%) maximal torque than D2.

Torque increase and corresponding speed drop (dn) are very useful engine characteristics for the comparison. This characteristic shows what the ability of engine to overcome temporary overloadings is. The value of E is percentage and represents the ratio between the increases of torque from rated to maximal value and rated one. WVOME and D2 result in almost the same E, but MVOME and RME give a significantly lower E, by 51% and 36% respectively. This is because of higher torque near the rated rotational speed of engine and lower maximal torque than with D2. At torque increase the rotational speed drop (dn) is also important. Engine with a large speed drop at torque increase is not very useful, because of a too low rotational speed regardless of high torque. Using WVOME, RME and D2 the speed drop is also almost the same. A something higher value (18% from D2) was observed at MVOME which means that the engine is able to work with high torque already at lower rotational speeds and the torque does not drop much at higher ones.

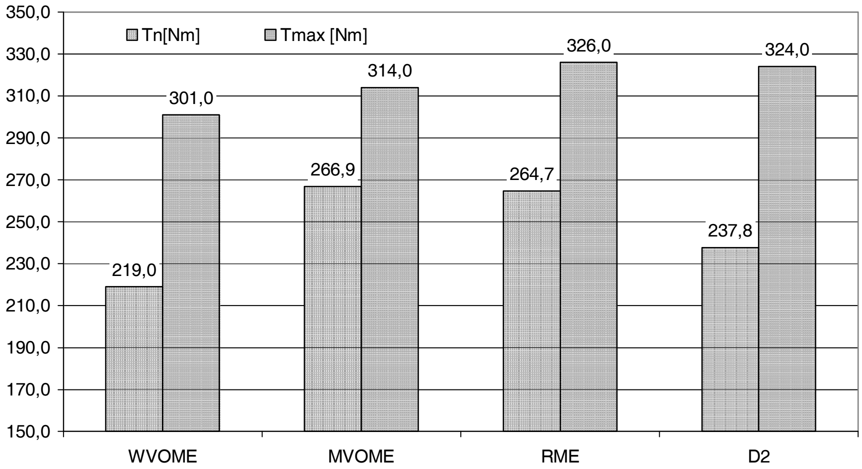

Fig. 3 Rated torque (T_n) and maximal torque (T_{max}) on PTO shaft at different fuel type

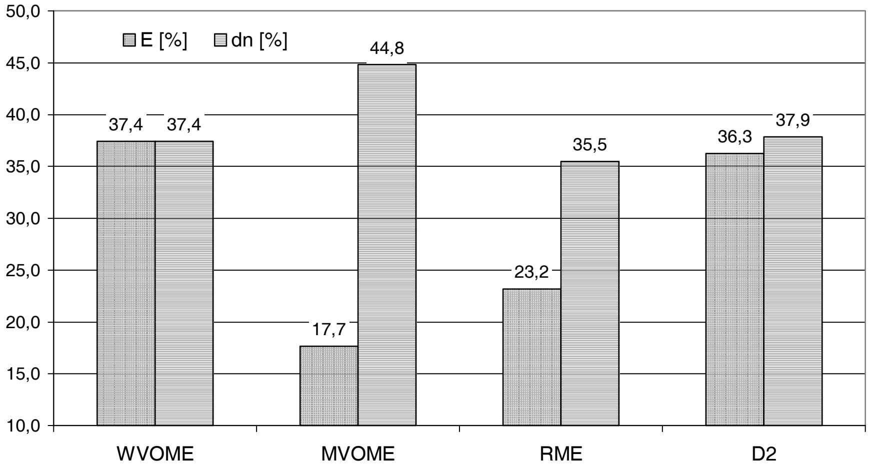

Fig. 4 Torque increase (E) and corresponding speed drop (dn) at different fuel type

Rotational speed

Rotational speed at different characteristic engine working conditions is also interesting. In case of using WVOME the engine reaches maximal power and torque at almost the same speed as if D2 fuel is used. The speed at minimal specific fuel consumption is only a little bit higher (for 4.6%) from the same value as when using D2. When using MVOME fuel, the engine reaches maximal power and torque at lower rotational speeds (3% and 11% respectively) but the speed at minimal specific fuel consumption is about 33% higher as when using D2. When using RME, it is interesting that maximal torque and minimal specific fuel consumption is at almost the same rotational speed. In comparison with D2 fuel these values are about 4% and 27% higher respectively. It is advantageous that when using any of the fuels, the rotational speed of PTO shaft at maximal torque is always lower than the rated value (540rpm). That means that there is always a stock of torque left for the case of overloading when tractor is used for driving tools via PTO.

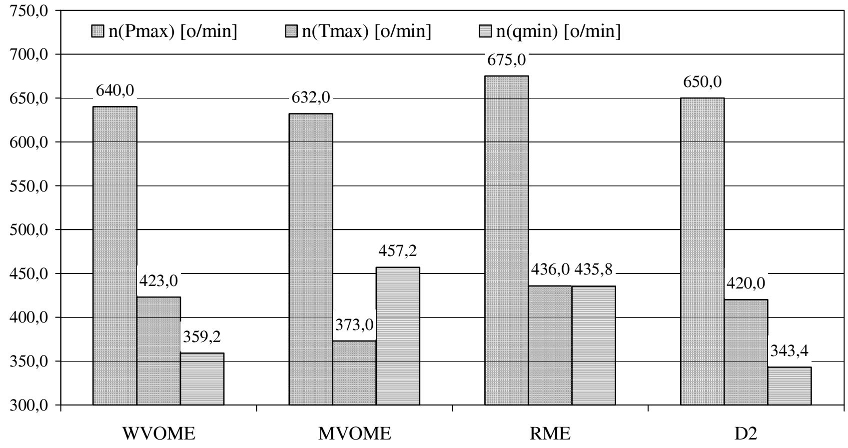

Fig. 5 Rotational speed of PTO at characteristic working points and different fuel type

Specific fuel consumption

The highest specific fuel consumption is reached when using WVOME and it is 19.5% higher on the average than when D2 fuel is used.

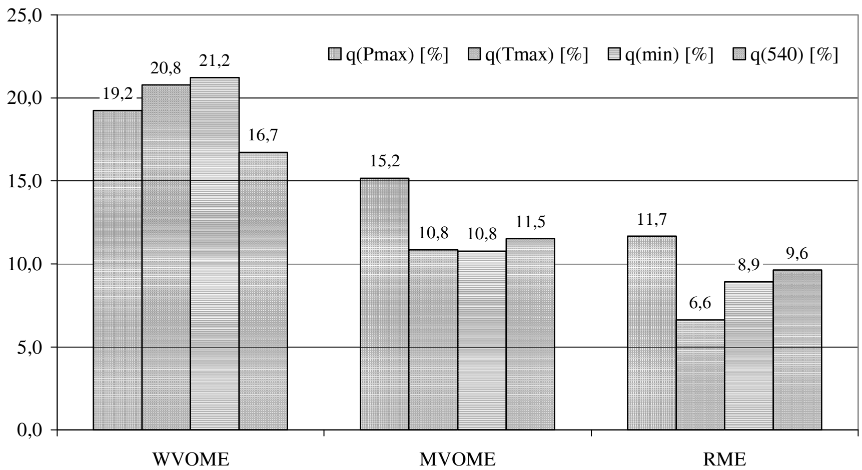

Fig. 6 Specific fuel consumption (q) in comparison with D2 fuel at different characteristic working conditions

With MVOME and RME the specific consumption is about 10 % higher if engine is working with the maximal power. This is on the average the same value as the energy content of observed fuels is lower in comparison with the D2 fuel. On the basis of these results we can conclude that for fuels from new vegetable oils the energy conversion in the engine is almost in the same range as when using D2. Greater difference at using fuel produced from waste vegetable oil can be observed because of much lower energy value or lower efficiency of energy conversion in engine using this type of fuel.

CONCLUSIONS

When using biodiesel produced from different type of source vegetable oils, some motor characteristic parameters change in comparison with mineral diesel fuel. The main reason is a lower energy value of biodiesel and also the deviations of physical and chemical properties of biodiesel.

Maximal engine power is lower but the power at rated rotational speed is higher than D2 when using biodiesel from the new vegetable oils.

Maximal torque is similar when comparing biodiesel from the new vegetable oils and D2 fuel. Rated torque is a little bit higher with the bio fuels mentioned.

The torque increase is significantly lower when using biodiesel from the new vegetable oils because of high values of rated torque.

Rotational speed at minimal fuel consumption is higher when using biodiesel.

Specific fuel consumption is about 10% higher when comparing biodiesel from the new vegetable oils and D2 fuel.

Biodiesel from waste vegetable oil gives less advantageous characteristics of engine.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 620.95:665.75](497.4)
Stručni rad
Expert paper

STANJE NA PODRUČJU BIODESELA U SLOVENIJI

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SAŽETAK

Slovenija se je s podpisom Kjotskega protokola (podpisan leta 1998, ratificiran 2002) namenila do obdobja 2008-2012 izpuste toplogrednih plinov zmanjšati za 8 % (glede na stanje leta 1986). Operativni program zmanjševanja emisij toplogrednih plinov pa je bil sprejet leta 2003. Raba biogoriv je eden izmed ukrepov Strategije in kratkoročnega akcijskega načrta zmanjšanja emisij toplogrednih plinov. V sklopu strateškega cilja Slovenije za povečanje stopnje samooskrbe z energijo, lahko kmetijstvo odigra pomembno vlogo na področju alternativnih virov energije, predvsem biogoriv. V skladu z direktivo EU (2003/30/EC) naj bi namreč težili k doseganju dveh zastavljenih ciljev, kar pa sta 2-odstotni delež biogoriv glede na količino goriv za transport, danih na trg do 31. decembra 2005 ter 5,75-odstotni delež biogoriv glede na količino goriv za transport, danih na trg do 31. decembra 2010. Za slovenski prostor je izredno zanimiva decentralizirana oblika pridelave olja za biodizelsko gorivo v manjših proizvodnih enotah, ki stisnejo od 0,5 t do 5 t/dan in se lahko nahajajo na različnih lokacijah po državi. Decentralizirane proizvodne enote lahko ekonomsko in okolju prijazno obratujejo, če je njihova tehnična oprema in delovni proces čim bolj enostaven ter povezan z nizko porabo energije.

Na gospodarnost pridelave oljne ogrščice namenjene za proizvodnjo goriva pomembno vpliva tudi prodaja in uporaba tropin oljne ogrščice, ki ostanejo po stiskanju olja in predstavljajo beljakovinsko močno krmilo. Ker Slovenija pretežni del beljakovinske močne krme uvaža, obstaja precejšen interes mešalnic močnih krmil za domačo surovino.

***Ključne besede**: biodiesel, decentralizirana proizvodnja, oljna ogrščica*

UVOD

Obnovljivi viri energije, med katere se uvrščajo sončna energija, energija vetra, energija iz biomase itn., postajajo vse pomembnejši, kajti z uvajanjem novih tehnologij postaja njihovo izkoriščanje zanimivo tudi na področjih, ki v preteklosti niso bila ekonomsko zanimiva. Po predvidevanjih nekaterih strokovnjakov naj bi bila do leta 2050 ena tretjina svetovnih potreb po energiji zagotovljena iz obnovljivih virov energije.

Slovenija se je s podpisom Kjotskega protokola (podpisan leta 1998, ratificiran 2002) namenila do obdobja 2008-2012 izpuste toplogrednih plinov zmanjšati za 8 % (glede na stanje leta 1986). Operativni program zmanjševanja emisij toplogrednih plinov pa je bil sprejet leta 2003.

Ogljikov dioksid, ki nastane pri izgorevanju obnovljivih virov energije, ne prispeva k toplogredni obremenitvi podnebja, saj gre za ogljik, ki so ga rastline zajele iz zraka. Raba biogoriv je eden izmed ukrepov Strategije in kratkoročnega akcijskega načrta zmanjšanja emisij toplogrednih plinov.

Znotraj segmenta energije, ki jo lahko pridobimo iz biomase, so poleg trdih in plinskih produktov biomase tudi tekoča goriva iz biomase. Od tekočih goriv iz biomase so najpomembnejša goriva, bioetanol, biometanol ter biodiesel. Za evropsko razmere (povezano s kmetijsko problematiko ter ceno biogoriv) je od tekočih goriv iz biomase trenutno najbolj primerno gorivo biodiesel narejen iz rastlinskih olj..

BIODIESEL

Pri zgorevanju biodiesla v motorjih z notranjim zgorevanjem nastajajo izpušni plini, ki v največji meri vsebujejo ogljikov dioksid, ki se s pomočjo fotosinteze v rastlinah spet preoblikuje v osnovo za proizvodnjo energije. Zelo pomembno je, da lahko biodiesel, proizveden s postopkom zaestrenja iz olja oljne ogrščice, sončnic, soje, itn., uporabimo za že obstoječe izvedbe dieselskih motorjev na vozilih in stacionarnih strojih, ki so v uporabi v vseh segmentih človeške dejavnosti. To mu daje ogromno prednost pred nekaterimi drugimi viri energije, za katere je potrebno zasnovati popolnoma nove motorje, npr. gorivne celice za izkoriščanje vodika itn. Biodiesel se lahko uporablja za pogon večine osebnih avtomobilov in gospodarskih vozil z dieselskim motorjem, kot tudi na traktorjih in drugih vozilih.

Prednosti uporabe biodiesla:

- netoksičnost
- biorazgradljivost (v treh tednih se razgradi 99 %)
- zmanjšanje emisij CO_2, SO_2, CO, ogljikovodikov itn.
- možnost proizvodnje iz uporabljenih jedilnih olj, živalske maščobe
- možnost uporabe v obstoječih dieselskih motorjih (v primeru nekompatibilnosti tesnil je potrebna zamenjava tesnil s tesnili z materiali, ki so odporni na biodiesel)
- visoko cetansko število

- dobre mazalne lastnosti
- meša se v vseh razmerjih z mineralnim dieselskim gorivom
- majhno onesnaževanje okolja v primeru razlitja pri transportu in manipulaciji

Slabosti uporabe biodiesla:

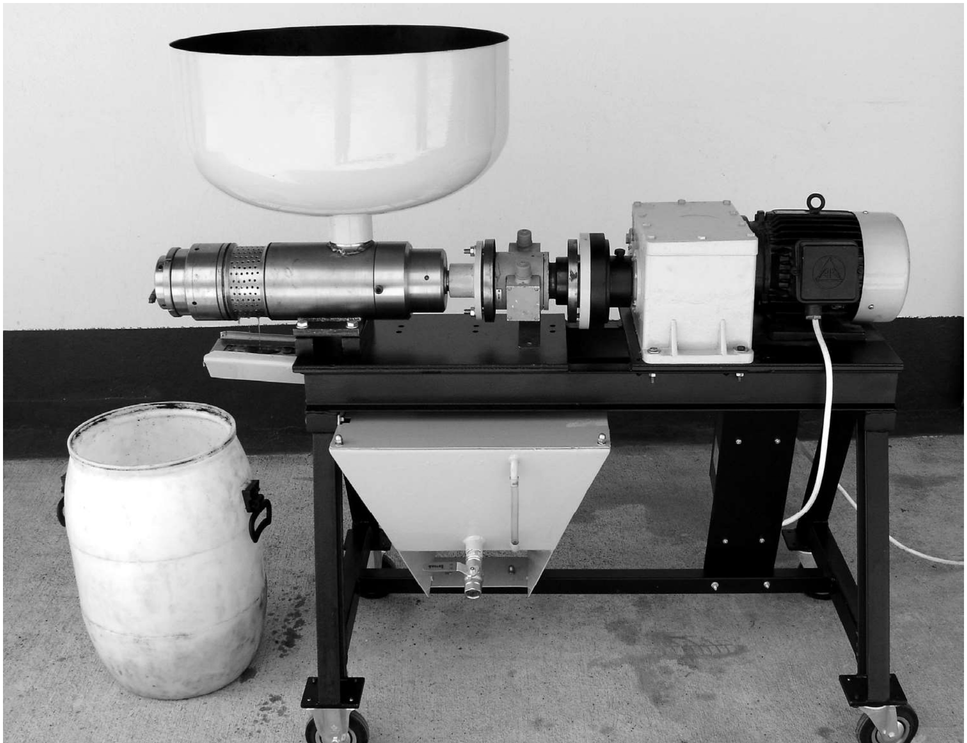
- nekompatibilnost določenih gumijastih tesnil in vodov na motorju z gorivom (možnost menjave tesnil in vodov)
- slabše nizkotemperaturne lastnosti (možnost dodatka aditivov)
- problemi skladiščenja na visokih temperaturah (upoštevati pravila za pravilno shranjevanje)
- minimalno povečanje emisij NO_x
- cena (ustrezna davčna politika)

Biodiesel iz oljne ogrščice

Uvedba pridelave oljne ogrščice v večjem obsegu ima velik pomen z vidika trajnega ohranjanja rodovitnosti tal in za uravnoteženje močno sicer močno zoženega vrstenja poljščin. Oljna ogrščica se odlično vključuje v kolobar, preko zime varuje zemljišča pred erozijo in je zelo dober predposevek za strna žita, krmne rastline in stročnice. Oljna ogrščica ima zelo pozitiven vpliv na tla, ker v obdelovalnem sloju formira gosto razvejan koreninski sistem, z njegovim razkrajanjem pa nastane precej humusa in zato jo je potrebno v čim večji meri vključevati v kolobar. Pogoji za pridelovanje oljne ogrščice pri nas so dobri, s tem pa tudi možnosti za doseganje dobrih pridelkov (klima, tla, kolobar). Uvajanje tretje kulture (razen pšenice in koruze) bi omogočilo dodaten vir prihodkov proizvajalcem, boljšo izkoriščenost kmetijske mehanizacije in dodatne pedološke prednosti. Z uvajanjem oljne ogrščice v pridelavo bi zagotovili dodaten prihodek kmetov, izboljšali izkoriščanje kmetijskih zemljišč, preprečili zaraščanje zemljišč in z boljšim izkoristkom mehanizacije povečali rentabilnost kmetijske proizvodnje. Na gospodarnost pridelave oljne ogrščice namenjene za proizvodnjo goriva, pomembno vpliva tudi prodaja in uporaba oljnih pogač, ki so stranski produkt stiskanja in predstavljajo beljakovinsko močno krmilo. Biodizelsko gorivo je tudi za kmetijstvo izredno zanimivo, ker omogoča samooskrbo z lastnim virom energije za pogon traktorjev, samovoznih in drugih strojev, ki se uporabljajo v procesu kmetijske pridelave. S proizvodnjo domačega biodizelskega goriva bi se odprla možnost odpiranja novih delovnih mest v kmetijstvu in predelovalni industriji. Uporaba biodizla pa bi v nekaterih primerih morala biti obvezujoča (uporaba kmetijske mehanizacije na tleh, ki se nahajajo na vodovarstvenih območjih, območja kmetovanja na kraškem terenu, ogrevanje različnih gospodarskih objektov na ekološko usmerjenih kmetijah, dosuševanje ekološko pridelanih pridelkov itn.). Nadomeščanje dela fosilnih goriv v kmetijstvu z biodizelskim gorivom iz domače surovine bi omogočilo da del zaslužka, ki se odliva v države proizvajalke nafte ostane v državi oziroma v samem kmetijstvu.

Decentralizirna proizvodnja olja iz oljne ogrščice za biodiesel

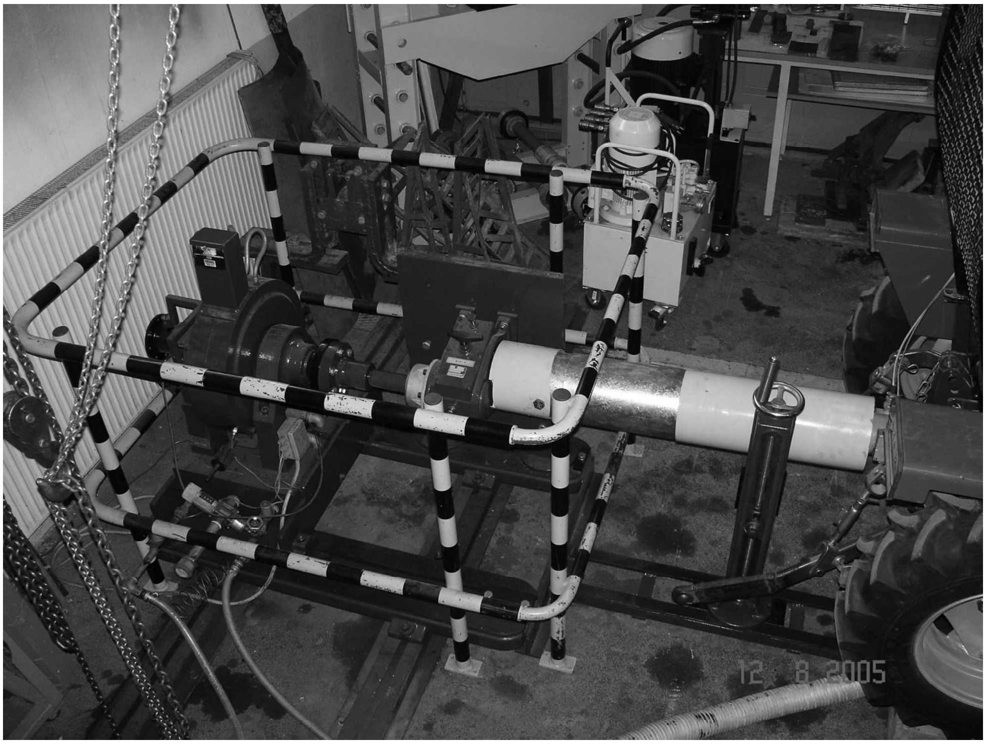
Zadnje čase se v Nemčiji in v nekaterih državah EU pojavljajo decentralizirani proizvajalci olja za biodizelsko gorivo. Tudi v slovenskem prostoru zagovarjamo decentralizirano obliko pridelave olja za biodizelsko gorivo v manjših proizvodnih enotah, ki se lahko nahajajo na različnih lokacijah po državi (pomembnost razpršenosti proizvodnih enot). V večjih tovrstnih enotah za stiskanje olja pa bo v prihodnosti možno tudi proizvajati biodieselsko gorivo. Za decentralizirano proizvodnjo olja gre takrat, ko enote za predelavo stisnejo od 0,5 do 5 t semena oljne ogrščice na dan. Decentralizirane proizvodne enote lahko ekonomsko in okolju prijazno obratujejo, če je njihova tehnična oprema in delovni proces čim bolj enostaven ter povezan z nizko porabo energije. Profitabilnost decentralizirane proizvodnje olja je odvisna od: višine investicije, trajanja delovne sezone, stroškov za seme, prodajne cene oljnih pogač in vloženega človeškega dela. Decentralizirana proizvodnja biodizla je zaradi krajših transportnih poti in s tem tudi manjših stroškov, ki obremenjujejo ceno proizvodnje, primernejša od centralne proizvodnje v velikih rafinerijah. Ekonomičnost takšne proizvodnje je pogojena s strukturo trga v smislu dobave surovine, kakor tudi možnosti sprejemanja produktov (olja in krmne pogače).



Slika 1 Poskusno pridobivanje olja iz semena oljne ogrščice s postopkom kontinuiranega stiskanja semena, olje je osnovna surovina za proizvodnjo biodiesla (stiskalnica je razvita na Kmetijskem inštitutu Slovenije - Oddelku za kmetijsko tehniko). Enostavne tehnične rešitve bodo verjetno v prihodnosti omogočile samooskrbo kmetij s tekočimi gorivi, kot stranski produkt pa bodo na kmetijah ostale še z beljakovinami bogate oljne pogače.

Biodiesel v Sloveniji

Področje biodizla je vse bolj aktualno tudi v Sloveniji. V skladu z direktivo EU (2003/30/EC) naj bi namreč težili k doseganju dveh zastavljenih ciljev, kar pa sta 2-odstotni delež biogoriv glede na količino goriv za transport, danih na trg do 31. decembra 2005 ter 5,75-odstotni delež biogoriv glede na količino goriv za transport, danih na trg do 31. decembra 2010.



Slika 2. Testiranje domačega biodieselskega goriva na traktorju AGT 835 – Agromehanika Kranj, na hidravlični merilni zavori na Kmetijskem inštitutu Slovenije - Oddelku za kmetijsko tehniko; traktor že nekaj let deluje na 100 % biodiesel.

V sklopu strateškega cilja Slovenije za povečanje stopnje samooskrbe z energijo, lahko kmetijstvo odigra pomembno vlogo na področju alternativnih virov energije predvsem biogoriv na osnovi olja iz oljne ogrščice. V Sloveniji se oljna ogrščica goji trenutno na cca 2400 ha, kar omogoča trenutno proizvodnjo cca 2400 t biodiesela iz domače surovine na leto. Proizvodnja biodiesela v večjem obsegu v Sloveniji se trenutno odvija na nekaj lokacijah (obstaja tudi nekaj deset manjših proizvajalcev, ki trenutno nimajo še urejenega statusa proizvajalca). Od večjih enot je v letu 2005 obratovala ena enota za decentralizirano obliko proizvodnje biodiesela kapacitete do 2000 t/leto (bazira na domači surovini – oljni ogrščici) ter enota za proizvodnjo v večjem obsegu na industrijski način v podjetju Pinus, Rače. V planu so tudi nekatere večje proizvodne enote, ki naj bi začele obratovati v letošnjem oziroma naslednjem letu. Proizvodnja vseh novih enot bo bazirala v majhni meri na domači surovini – oljni ogrščici v največji meri pa na uvoženih oljih ter odpadnih jedilnih oljih in maščobah živalskega porekla. Za slovensko kmetijstvo je biodiesel zanimiv z aspekta pridelave surovine za proizvodnjo biodiesela in možnosti njegove uporabe v pridelovalnem procesu (pogon kmetijskih strojev, ogrevanje kmetijskih objektov, dosuševanje pridelkov itn). Uporaba biodiesela pa bi morala v nekaterih primerih v kmetijstvu biti obvezujoča (uporaba kmetijske mehanizacije na vodovarstvenih območjih, ogrevanje različnih objektov na ekološko usmerjenih kmetijah, dosuševanje ekološko pridelanih pridelkov itn.). Uporaba biodieselskega goriva na vodo varstvenih območjih bi omogočila zaščito podtalnice in pomembno zmanjšanje emisij škodljivih plinov v zrak (toplogrednih plinov CO_2, CO, ogljikovodikov, policikličnih aromatskih ogljikovodikov, trdih delcev, žveplovih spojin).

Pričakovani rezultati uvajanja biodieselskega goriva

Gojenje oljne ogrščice omogoča pozitivne efekte v kmetijstvu, gospodarstvu in na področju zaščite okolja. Z uvajanjem oljne ogrščice v pridelavo zagotavljamo dodaten prihodek kmetov, izboljšamo izkoriščanje kmetijskih zemljišč, preprečimo zaraščanje kmetijskih zemljišč in z boljšim izkoristkom mehanizacije povečamo rentabilnost kmetijske proizvodnje. Zaradi pozitivnega vpliva na tla bi oljna ogrščica omogočila dolgoročno ohranjanje rodovitnosti ogroženih kmetijskih tal. Uvajanje oljne ogrščice v kolobar pa bi omogočilo prej omenjene dodatne pedološke prednosti. S proizvodnjo domačega biodieselskega goriva bi se odprla možnost odpiranja novih delovnih mest v kmetijstvu in predelovalni industriji.

Biodieselsko gorivo bo zanimivo za vozila za transport blaga in vozila javnega potniškega prometa (verjetno v začetku največji poudarek), komunalne dejavnosti, itn. Biodieselsko gorivo je tudi za kmetijstvo uporabo izredno zanimivo, ker omogoča samooskrbo z lastnim virom energije za pogon traktorjev, samovoznih in drugih strojev, ki se uporabljajo v procesu kmetijske pridelave. Uporaba biodiesela pa bi v nekaterih primerih morala biti obvezujoča (uporaba kmetijske mehanizacije na tleh, ki se nahajajo na vodovarstvenih območjih, območja kmetovanja na kraškem terenu, ogrevanje različnih gospodarskih objektov na ekološko usmerjenih kmetijah, dosuševanje ekološko pridelanih pridelkov itn.). Nadomeščanje dela fosilnih goriv v kmetijstvu z biodieselskim gorivom iz domače surovine bi omogočilo da del zaslužka, ki se odliva v države proizvajalke nafte ostane v državi oziroma v samem kmetijstvu.

Ogrščične pogače – stranski proizvod visoke kvalitete

S prepovedjo krmljenja krmil živalskega izvora se je svetovna ponudba beljakovinskih krmil z majhno razgradljivostjo močno zmanjšala. Za evropsko kmetijstvo je značilen velik primanjkljaj beljakovinskih krmil. Z lastno pridelavo v EU pokrijemo le približno 30 % potreb živinoreje. Ogrščične tropine in pogače predstavljajo približno 10 % beljakovinskih krmil in kar 90 % porabljenih količin pridelamo sami v EU. Pričakujemo, da se bo s povečevanjem pridelovanja ogrščice za potrebe proizvodnje biodizla, njihov delež v strukturi porabljenih krmil povečal. Ogrščične pogače bi lahko predstavljale pomemben vir beljakovin za ekološko živinorejo. Slovenski pravilnik o ekološki pridelavi in predelavi kmetijskih pridelkov oziroma živil (U.l. RS št. 31/2001, 52, 2003) namreč prepoveduje krmljenje vseh stranskih proizvodov oljne industrije, ki so pridobljeni ob pomoči topil, torej tudi sojinih tropin. Na gospodarnost pridelave oljne ogrščice namenjene za proizvodnjo goriva pomembno vpliva tudi prodaja in uporaba tropin oljne ogrščice, ki ostanejo po stiskanju olja in predstavljajo beljakovinsko močno krmilo. Ker Slovenija pretežni del beljakovinske močne krme uvaža, obstaja precejšen interes mešalnic močnih krmil za domačo surovino. Predvidevamo, da se bo zaradi aktualnih dogajanj v kmetijstvu (mesno kostna moka in pojav BSE, večji del pridelka soje izhaja iz gensko spremenjenih sort) interes za doma pridelani močno krmo v prihodnje še povečeval. Z domačo proizvodnjo olja iz oljne ogrščice se odpira možnost pridobivanja ogrščičnih pogač posebne kakovosti. S prepovedjo krmljenja krmil živalskega izvora se je namreč svetovna ponudba beljakovinskih krmil z majhno razgradljivostjo močno zmanjšala. Ogrščične pogače bi lahko predstavljale pomemben vir beljakovin za ekološko živinorejo. Evropska uredba o ekološkem kmetovanju (EC No. 1804/1999) prepoveduje krmljenje vseh stranskih proizvodov oljne industrije, ki so bili pridobljeni ob pomoči topil, torej tudi sojinih tropin. Tej uredbi sledi tudi slovenski Pravilnik o ekološki pridelavi in predelavi kmetijskih pridelkov oziroma živil (UL št. 31, 28.04.2001). V primerjavi s sojinimi tropinami bi kazalo pri domačih oljnih pogačah izkoristiti tudi prednost, ki jo prinaša nadzorovana pridelava in prepoved uporabe semena gensko spremenjenih rastlin v Sloveniji. Potencialni uporabniki oljnih pogač bi bile mešalnice krmil in kmetje, ki si pripravljajo krmne mešanice sami. Za prodajo oljnih pogač bi bilo možno uporabiti obstoječe prodajne poti, trgovine z repromaterialom za kmetijstvo.

Evropska pobuda CIVITAS v Ljubljani

Velik delež emisij toplogrednih plinov prihaja iz prometa, zlasti cestnega prometa in ta je najbolj zgoščen prav v mestih, kjer pomembno vpliva na kakovost življenja ljudi.

Zato je Evropska komisija s pobudo CIVITAS v 6. okvirnem raziskovalnem programu posebna sredstva namenila uvajanju čistejših goriv v mestnem prometu in ukrepom, ki spodbujajo uporabo javnega mestnega prevoza, kolesarjenje, pešačenje itn.

CIVITAS je okrajšava za "**CI**ty–**VITA**lity–**S**ustainability" (Mesto/vitalnost/trajnostni razvoj), v latinščini pa pomeni "mesto, država". Pobuda, ki je dejansko namenjena mestom, zahteva celovit in inovativen pristop in podpira demonstracijske projekte, ki uvajajo novosti na področju tehnologije in prometnih politik v mestih.

Tudi Ljubljana se sooča z lokalnimi posledicami globalnih problemov, ki imajo vedno lokalni vir nastanka. Skrb za mesto in kakovost življenja v njem je Ljubljano vodila k temu, da se je želela priključiti pobudi CIVITAS. Ljubljana se vključuje v prizadevanja Slovenije za varstvo okolja in zmanjševanje emisij toplogrednih plinov, k čemur nas zavezujeta tudi pravni red EU in Kyotski protokol. Ljubljana se je v pobudo CIVITAS vključila kot partner v projektu **MOBILIS**. Skupno je v projekt vključenih 30 partnerjev iz petih evropskih držav (Francija, Italija, Danska, Slovenija in Madžarska), v administrativno delo pa sta vključeni tudi dve svetovalni družbi iz Nemčije. Projekt MOBILIS smo začeli izvajati 1. februarja 2005, trajal bo štiri leta.

Partnerska mesta v projektu so: Toulouse (Francija) – skupni koordinator projekta, Debrecen (Madžarska), Ljubljana (Slovenija), Benetke (Italija) in Odense (Danska).

Slika 3. Ljubljanski potniški promet v okviru evropskega projekta MOBILIS testira biodiesel kot pogonsko gorivo za mestne avtobuse (trenutno sta v fazi preizkušanja dva avtobusa)

V okviru projekta bo Mestna občina Ljubljana preizkusila biodiesel kot pogonsko gorivo za mestne avtobuse. Posebej zanimivo je to, da bodo raziskave in testiranja, predvidena v projektu, zajeli celo verigo: od surovine in predelave do distribucije in uporabe. Poleg Mestne občine Ljubljana, ki koordinira projekt, v njem sodelujejo Ljubljanski potniški promet, Teol, Strojna fakulteta iz Maribora, Kmetijski inštitut Slovenije in Regionalni center za okolje za srednjo in vzhodno Evropo. Pomembni lokalni partnerji so tudi Petrol, Regionalna razvojna agencija Ljubljanske urbane regije, Svet za preventivo in varnost v prometu in Ekspertni center za presojo vplivov na okolje pri Inštitutu Jožef Štefan kot evalvator projekta.

ZAKLJUČEK

Stanje na področju biodiesela je bilo v lanskem letu v Sloveniji zadovoljivo (s stališča da se še leta 2004 praktično ni nič dogajalo razen eksperimentalne proizvodnje biodiesela v laboratorijih in v malih količinah pri proizvajalcih, ki so pripravljali proizvodnjo). Za slovenske razmere za prihodnost je izredno zanimiva decentralizirana proizvodnja olja iz oljne ogrščice saj lahko pridobivamo olje in oljno pogačo, ki je zanimiva kot visokovredno beljakovinsko krmilo. Decentralizirana proizvodnja lahko poteka tudi na večjih kmetijah, ki so razpršene po celotni državi, ker majhne proizvodne enote lahko ekonomsko in okolju prijazno obratujejo zaradi enostavne in cenene tehnične opreme in enostavnega delovnega procesa, ki je povezan z nizko porabo energije.

Vzpodbujanje pridelave oljne ogrščice v prihodnosti za biodiesel v slovenskem kmetijskem prostoru v prihodnosti bo omogočilo:

- Možnost aktiviranja površin v zaraščanju ali zaraščenih kmetijskih površin
- Možnost vpeljave oljne ogrščice v kolobar v skladu s kodeksom dobre kmetijske prakse

Vzpodbuditev uporabe biodiesla poleg uporabe na področju transporta se lahko razširi v prihodnosti tudi na kmetijska in vodovarstvena območja.

V prihodnosti bo potrebno definirati področje obvezne uporabe biodieselskega goriva (vodovarstvena območja, ekološka kmetijska pridelava, itn.), kakor tudi ustrezne mere za spodbujanje pridelave in predelave oljne ogrščice ter uporabe biodieselskega goriva v samem kmetijstvu (pogon kmetijskih strojev, ogrevanje kmetij, dosuševanje pridelkov itn.).

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THE PRESENT SITUATION OF BIODIESEL IN SLOVENIA

ABSTRACT

By signing the Kyoto Protocol (signed in 1998, ratified in 2002) Slovenia resolved to cut the greenhouse gas emissions by 8 % (with regard to the 1986 situation) by the 2008-2012period. The operational program of reducing the greenhouse gas emissions was passed in 2003. The use of biofuels is one of the measures laid down in the Strategy and Short-Term Action Plan of Reducing the Greenhouse Gas Emissions. In the complex of the strategic goal of Slovenia to increase the degree of self-supply with energy, agriculture could play an important part in the area of alternative energy sources, especially biofuels. According to the EU Directive (2003/30/EC) we should aim at the realization of two goals: 2% share of biofuels regarding the quantity of transport fuels put on the market until 31 December 2005 and 5.75% share of biofuels regarding the quantity of transport fuels put on the market until 31 December 2010. For the territory of Slovenia, a decentralized form of oil production for biodiesel fuel in smaller productional units pressing from 0.5 t to 5 t/day and situated on different locations over the country is of extraordinary interest. Decentralized production units could operate economically and environmentally friendly if their technical equipment and working process are as simple as possible and use as little energy as possible.

The economy of rape growing intended for fuel production is significantly influenced by the selling and use of rape seed cake which is left after the pressing of oil and which is considered as a strong protein feed. Since Slovenia imports a predominant part of protein feeds, a rather great interest of feed mixing plants for a domestic raw material exists.

***Key words**: biodiesel, decentralised production, rape seed*

34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Pregledni rad
Review paper

PROSPECTS OF WOODEN BIOMASS PRODUCTION IN SOUTHEASTERN EUROPEAN AGRICULTURAL AREAS

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SUMMARY

The need of restructuring agricultural production – reducing acreage and introduction of renewable energies in the countries of Southeastern Europe has been identified. One possibility, which can result with accomplishment of both demands, is growing of energy crops. In this paper short rotation coppices (SRC), a form of wooden biomass, has been focused. The current situation in this sector in Southeastern European countries is presented in the form of short national reports. Introduction of growing of SRC, their harvesting, processing and use as fuel have been reviewed from thee points of view: environmental, economic and societal.

It was concluded that the most of assessments done for EU countries, i.e. Germany, should have same or similar validity in Southeastern European countries, with several exceptions. One example of exceptions is the economy of production, harvesting, and use as a fuel. The growing without subsidies rigorously influences cost-effectiveness. On the other hand, lower labor costs in the region considerably influence reduction of total costs. It was concluded that there are additional investigations needed to check cost-effectiveness of production and energy use of SRC in Southeastern Europe, and/or to define national programs for its support.

***Key words**: renewable energy, solid biomass, short rotation coppices*

INTRODUCTION

The countries of Southeastern Europe (SEE) are either in access or preparatory phase of joining European Union. Due to expected status in the future, they should also follow

European Union policy in the field of agricultural production, environment protection and energy. The brief description of the goals that have been set up would be: reduction of food production, producing and using of renewable energy sources, and improvement of energy facilities concerning efficiency and emission of pollutants. Reduction of agricultural land and non-food production have been declared and supported in order to overcome the problem of surplus some agricultural products and enormous subsidies on the EU level. Policy aimed at reduction of CO_2 imbalance and fossil fuels consumption has been clearly declared (Anonym, 1997).

Production of short rotation coppice (SRC) – wooden biomass is already practiced in some EU countries. This is supported by set-aside (of agricultural land) premium and other measures.

The objective in SEE is to prepare for the future fulfilling of EU demands – reduction of CO_2 and agricultural production. This should be elaborated in the sense of getting optimal outcomes, i.e. best compromise, between EU on one side and geopolitical demands, applicability of new technologies, local environmental, economic, and societal sources and conditions on the other.

Agricultural regions of SEE, especially these situated in plains, are producing considerable amount of crop residues. The potentials of this form of solid biomass, its status and prospects of use have been elaborated by many national or international surveys. Growing of energy plants would be, for these regions, almost new from point of view of production, marketing and using as energy sources. SRC can be grown as any other crops, covering the whole field, and/or headlands, whereby it could also reduce wind erosion, improve micro climate and bring positive effects for other crops, (Röhricht and Ruscher, 2004).

According to previous, following hypotheses have been set up:

1. Reduction of food production accompanied by support measures leads to profitable growing of SRC – wooden biomass.
2. Proper selection of crops, harvesting–conditioning techniques and use of adequate energy facilities enables profitable production.
3. The production and use of SRC has positive environmental, economical and societal effects.

The experiences in the field of production and use of SRC in Europe are used for benchmarking in order to identify the future development steps in SEE.

EU EXPERIENCES

Crops and yields

Selection of plant species is very important for wooden biomass production under certain agro ecological conditions. At the Institute for Agricultural Engineering Potsdam–Bornim, the investigation on several SRC has been performed in the ten year period (Scholz, Hellebrand, Höhl, 2004).

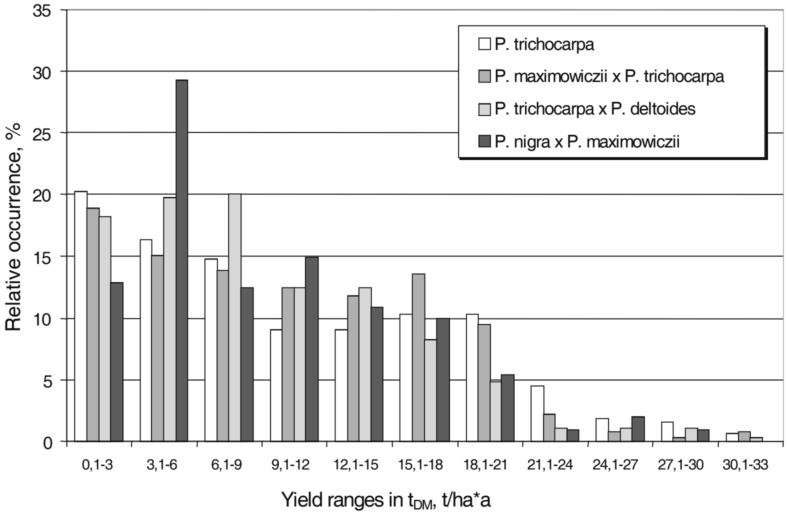

Figure 1 Frequency of occurrence of different annual yields of poplar, summarized results of 1,484 investigations made in Europe, (Scholz, 2004)

Simultaneously it has been studied and summarized the results of other institutions and researchers on this topic. It has been concluded that the most proper wooden crops for European conditions are poplars and willows. In Fig. 1 are shown systematized results of European investigations on poplar yields. It can be expected that the annual dry mater yield of poplars in normal conditions in Europe is about 10 t/ha.

The energy analyses for SRC have been done by many authors, whereby diverse approaches to the energy balance–gain–productivity calculation were used. Nowadays is widely applied the approach that includes all energy inputs except solar energy (Ortiz-Caňavate, Hernanz, 1999). The definition and method of energy yield is sublimated in the guidelines of the VDI (Verein deutscher Ingenieure – Union of German Engineers) (Anonym, 2000a, Scholz et al, 1998) applied this approach in a form of software for energy balance calculation. The waste disposal was also included in the total energy demands. This method has been applied for production of diverse solid bio-fuels for same or similar agro ecological and production (transport distance, storage etc) conditions in Germany. Results showed good energy balance of many SRC, whereby the poplar showed highest energy balance and the lowest need of environmental harmful inputs.

Harvesting and post harvesting techniques

Depending on rotation period two different forms of wood material can be used. For the rotation period from 2 to 4 years the plants should be harvested in the wood chips form (Burger, Scholz, 2004). The process can be semi-mechanized, cutting down the trees using powered saw and then chipping, immediately or after certain period of natural drying, or full mechanized, whereby the machine cuts the wood and chips immediately.

For a longer rotation period, which also means bigger trunk diameter, the products are wood logs and chips. The chips are in this case made only of residual branches. Harvesting of wood in the form of firewood logs can be performed in different ways, as it is commonly practiced in forestry. Branches with smaller diameter than firewood logs can be chopped or locally used on traditional way for heating, cooking etc.

Comparison of diverse SRC harvesting procedures done in Germany shows considerable difference in costs. Harvesting costs for manual harvesting are 57 € per ton of air dried wood, and for full mechanized procedure about 10 €/t (Burger et al. 1996). By another analysis the costs were 10 €/m^3 for semi mechanized process, and 4.6 €/m^3 (Burger, Scholz, 2004). The labor costs have a great influence in Germany, on the other hand in Southeastern Europe the impact of investment costs is expected to be much higher, as the consequence of the high price of harvesting machines, which is between 20,000 and 175,000 € (Burger, Scholz, 2004). From this point of view rather different results of costs calculation in countries of SSE should be expected.

The wide spectrum of wood chipping machines is available on the market; tractor mounted, trailed or self-propelled. The tractor engine, via PTO, or separate engine can be used as power source. The machines are, depending on design, aimed at different diameters of trunks; most of them for trunks with diameter up to 12 cm.

Regarding cutter design there are generally tree types: disc, drum and auger type. The most of disc and drum chippers have possibility of cutting length adjustment by changing of feeding velocity. The classification and field of wood chips size has been determined by Austrian standard (Anonym, 1998) and the draft of European standard prCEN/TS 14961. The standards define classes according to the moisture content, chip particle distribution and content of under- and over-sized chips, content of ash and bulk density. The European standard, in addition, gives the classes according to the nitrogen and chlorine content (Neff et al, 2004). The aim of standard is also to enable design of appropriate stoking device and design of combustion chamber. Chips particle size, their form and distribution influence combustion process and thermal power of the boiler.

The moisture content of harvested wood is mostly in the range from 45 to 55%. Reduction of moisture content to the level safe for storage, which is less than 30%, needs a long period or artificial drying. The period of natural drying depends on weather conditions, art of wood storage, wood type and form; for trunks-logs form one year (poplar) to 2.5 years (oak) (Hartmann, Thuneke, Höldich, Rossmann, 2003). Diverse processes of microbiological decomposition and transformation occur in the wet material. Some of processes, still not fully explained, are followed with temperature increase even over 100º C, causing so-called self-ignition of the material (Kaltschmitt, Hartmann, 2001). The annual loss depends on material source characteristics and storage type. They are between 2 and more than 35%. Especially bad effects have fungi, which do not only destroy solid mater, but produce environmental harmful emissions and odors. The conditions of fungi's development are related to material moisture content and ambient air temperature, Fig. 2.

Thorough investigation of fungi development in stored wood chips has been provided by Scholz et al (2005). It has been concluded that generally bigger sized chips are more convenient for drying and storage, and smaller for transportation and stocking.

Drying or active ventilation of chips causes additional investment and energy costs. Usable instructions for this were presented by Hartmann et al (2003).

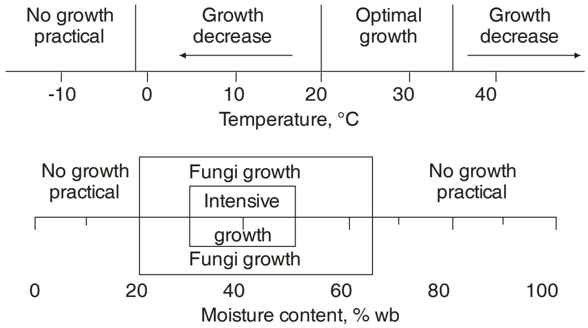

Figure 2 Temperature and moisture content influence on wood fungi development (Hartmann, Thuneke, Höldich, Rossmann, 2003)

Wood logs and chips are less suitable for transportation and storage out of farms. Pressed forms, as briquettes and pellets, enable transport on longer distances and usage of wooden biomass in non agricultural households. These forms are also more suitable for use in conventional furnaces designed for wood logs and coal. On the other hand both pressed forms, but much more pellets, are convenient for continuous - automated feeding of boilers, and newly furnaces. Production of pellets is well known and adequate equipment is available. The only problem is profitability, i.e. the high price of this type of fuel. The prices of light heating oil and other fossil fuels has not yet reached level to make the use of pellets profitable without subsidies, (Strehler, 2001)

Energy conversion techniques

There are few possibilities of wooden biomass energy conversion. The most significant are: combustion - heating or technology heat production, gasification and pyrolyze.

Contemporary research efforts are now focused on bio-to-liquid processes of solid mass gasification or pyrolyze products, but first results could be expected in ten years (Thrän et al, 2004).

The most common is use of wood for combustion in heating facilities, furnaces and boilers. The contemporary furnaces and boilers have been improved to the upper possible limit, and some solutions have efficiency 90%, (Anonym, 2000b). Generally, constant goal is to increase efficiency of wood combustion facilities, as it has been already defined for oil and gas facilities (Anonym, 2004). The striving values of efficiency are 40-70% for furnaces, and 70-90% for boilers (Anonym, 1998b). The estimation of facilities efficiency and emission of pollutants has not been done in SEE countries. The first attempt has been done for furnaces and boilers, mostly using crop residues, in rural areas of Pannonia plane in Vojvodina, Serbia and Montenegro. The results showed very low level of design of facilities and their efficiency has been estimated to be lower than 60%, (Martinov, 2005). Future coordinated efforts in the use of wood as a fuel should imply the defined efficiency level and considerable reduction of pollutants emission.

Split and shortened logs can be used primarily in furnaces, including traditional ones. The furnaces should be properly designed for user's needs, with adequate chimney – draught. The regulation of amount of primary and secondary air should be enabled, and it should have appropriate temperature of gases at the place of secondary air inlet. The surface of the furnace should be properly designed to enable the heat delivery to the heated space, i.e. the exhaust gases temperature should not be more than 220º C. Hartmann et al (2003) have presented wide pallet of well designed solutions for wood logs furnaces, tiled furnaces, fireplaces and cooker-heaters used in Germany and Austria. The furnaces development results with efficiency over 60%, and reduced emission of pollutants.

In the last ten years two stage combustion boilers with separate gasification and gas combustion have been developed. Contemporary solution for wood logs is presented in Fig. 3a). The overall efficiency could be, even in units with les than 50 kW, more than 90%. In the same time the content of CO in exhaust gases is under 1 g/m^3, this both for boilers and furnaces.

Wood chips can be continuously feeding what enables better control of combustion process. The automation of ignition, ash removal and heat energy output control are possible, offering high level of user comfort. The different solutions of wood chips boilers are since more than twenty years applied in Austria, Sweden, Germany and some other countries. Quality of combustion is acceptable also for partial load and using of heat accumulator is not necessary. Values of efficiency and emission are comparable with corresponding values for contemporary logs boilers.

In the most of cases augers are used for feeding. As for previous example, combustion process is divided into two separate phases: gasification and gas combustion. Gasification is mostly provided in bowls or cascade grate type of fireboxes, integrated in the boiler, or in pre furnaces, Fig. 3b).

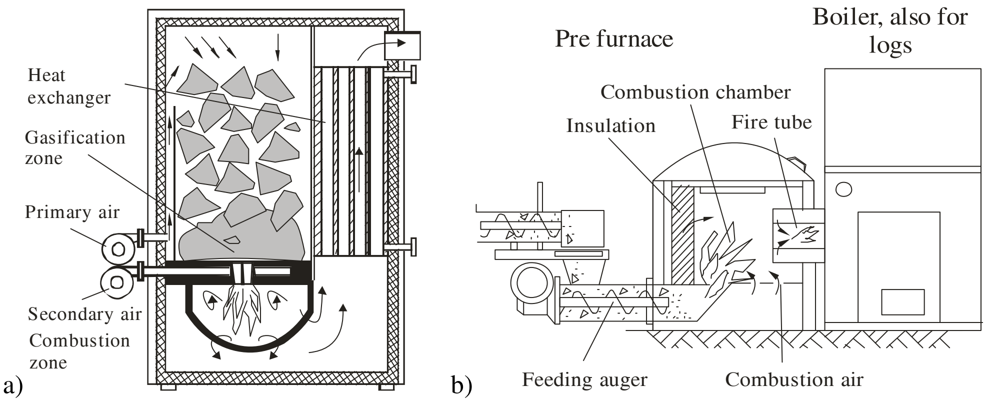

Figure 3 Contemporary wood boilers, (Hartmann, Thuneke, Höldich, Rossmann, 2003)
a) wood logs boilers, two-stage combustion chamber type ("gasifier"), b) wood chips boiler with pre-furnace and continuous feeding

District or central heating means providing heat to user with connected pipelines from the centralized unit with higher thermal power. The boiler thermal power is in this case over 500 kW. These facilities have the most advanced combustion process regulation and exhaust gas purification. The costs of heating pipelines are eight times higher than natural gas pipelines. That is why such plants have to supply beside regular users in its vicinity at least one bigger consumer like school, swimming pool, company, public or administration building or similar.

District heating units are widely used in Denmark, and newly in Germany within organized production of wood chips.

Environmental impacts

Some environmental effects can be achieved already by growing of SRC, e.g. soil erosion protection, and positive impact on biodiversity. Results in this regard have been obtained, and new flora and fauna organisms for that area have been recorded (Burger, 2004a, Scholz, Hellebrand, Grundmann, 2004). Improvement of soil properties has been also recorded (Kahle, Boelcke, 2004) as well as positive effects which led to growing without or with considerably reduced amounts of fertilizers (Scholz et al, 2005).

Some negative impacts on environment and human health in the form of moulds development by storage of wet wood, especially wood chips can occur. By using proper harvesting technique, storage and adequate chips size (bigger and longer) this problem could be overcome (Scholz et al, 2005).

The direct environmental contribution of using wood as a fuel is replacement of fossil fuels and therefore reduction of CO_2 imbalance. Tab. 1 shows specific net emission of diverse fuels.

Table 1 Specific net emission of CO_2 and other GHG gases (Anonym, 1998c)

Energy source	Net CO_2 emission, kg/MWh	Emission including processing, kg/kWh	Total including also other GHG gases, kg/kWh
Natural gas	199	211	230
Light heating oil	267	299	307
Mineral coal	333	351	381
Brown coal	353	436	448
Brown coal briquettes	340	650	681
Wood chips	0	14	33
Solar heater	0	33	36

The example of combined district heating system, which is the combination of wood and heating oil, shows that for annual heating energy need of 2,392 MWh about 1.9 t of CO_2 release, in comparison with only fossil fuel use can be omitted.

On the other hand the emission of other harmful products, i.e. SO_2, NO_x, CO and solid particles is for wood combustion facilities significantly higher, more than two times in comparison with natural gas and about 10% with heating oil.

The improvement of wood combusting facilities concerning reduction of emission of pollutants is in progress and shows considerable results (Anonym, 2000b). The limits for contents of harmful components are defined in some countries, example Germany.

The survey aimed to get impression on solid biomass practice in rural areas of Pannonia plane has shown catastrophic situation regarding emission. The average emission of pollutants has been estimated to be considerably over desirable level (Martinov, 2005).

ECONOMIC AND SOCIETAL ASPECTS

The most of analyzed publications give data on biomass production costs (Burger, 1996, Burger, Scholz, 2004, Scholz et al, 2005). The realistic price should include some added value for producer. The data for Germany for log woods shows the range between 7.7 and 8.8 € per GJ of primary energy (Hartmann, Thuneke, Höldich, Rossmann, 2003). The same source gives the data for pellets prices in the range from 9.2 to 13.8 € per GJ, and for briquettes from 16.1 to 21.0 € per GJ. This higher value, with included producer's profits, has to be used for comparison with other fuels and for the real profitability calculation. The energy price of wood should be roughly comparable with the price of brown coal. A higher level would not be acceptable for the user, and much lower for the wood producer.

Most of EU countries support implementation of wood and other renewable energies with different measures, tax free buying, special loan arrangement, direct or indirect subsidies (up to 20%, and up to certain limit amount), etc in order to make the price of wooden biomass energy acceptable for the user. The money for this support is mostly collected as so called fossil fuel taxes. The price of solid biomass boiler, depending on level of equipment, is two to five times higher than for heating oil one. This should be considered by every planning and cost calculation. On the other hand, the biomass heating facility consists of many common elements, e.g. pipelines, which sometimes make the boiler cost less than 20% of total costs (Steffens, 2002). In that case the difference of boiler prices for solid and fossil fuels can be very easy covered even with low subsidies if they are related to the total costs. In developing countries it is still practiced lower level of exhaust gases purification and heating facility automation. Consequently are the prices for solid biomass boiler closer to the costs of fossil fuel boiler (Martinov, 2005).

Some institutions and documents give concrete instructions for the cost calculation, e.g. Austrian ÖKL-Merkblatt Nr. 67, presented and demonstrated by Steffens (2002). These materials can be used as the base for own calculations.

For the proper spreading of use of renewables both private and public economic interest should be considered. In some cases these interest are opposite. It should be well calculated if the public interest could also be positive if the private users are financially supported from public sources. For example: supporting of locally produced energy can contribute positive export-import ratio, local employment, fulfilling of international obligation concerning environment protection etc. Here are economic and societal issues very close to each other. The rural areas, in which is the wooden biomass produced, are in many countries economically week. Supporting of wooden biomass production and its use as a fuel for heating can contribute better employment and use of material and human resources in these areas. This is typical for all countries in SEE.

WOODEN BIOMASS IN SEE – STATE OF THE ART AND PROSPECTS

The status and prospects of wooden biomass production and use as a fuel is presented in a form of country reports for almost all SEE countries (alphabetic ordered).

Bosnia and Herzegovina

The agricultural land in Bosnia and Herzegovina has total 2.5 10^6 ha of agricultural land, 2.3 10^6 ha of forests and 0.3 10^6 ha of miscellaneous land, primarily marshland and reed. As for arable land 44.2% are being cultivated (plough-land 40.4%, orchards 3,6% and vineyards 0,2%) and these rest includes pasture land 36.8%, meadows 18.8% and fish ponds 0.2%. So far, there has been no organized use of agriculture residual biomass, apart from the prewar attempt of production of biogas from cattle-excrements. Forests cover almost half of the territory (46.5%) and constitute a significant resource of renewables. It needs to be emphasized that a vast majority of wood processing residual material (small branches, barks, blocks, etc.) is insufficiently used as a fuel.

Support of agricultural production has priority for self supply of food, but as a possibility of creation of new working places. The production of short rotation coppices is of interest of the country, first of all to enable new activities in rural areas, but now for this purposes can be used only land not suitable for agricultural production. There are no data available about surface that can be used for this purpose. It is also missing governmental program on renewable energy use. Bosnia and Herzegovina is interested in regional program on this issue, whereby national recourses and prospects can be defined.

Bulgaria

The agricultural land in Bulgaria is 5.78 10^6 ha. Forest covers 3.4 10^6 ha. National study on renewable energies showed that the biggest potential of solid biomass are agricultural residues 52%, and the second one are energy plants with 23% (Mihailov, Hrisotva, 2002). The potential of SRC has been estimated to be round 840 10^3 toe.

Biomass energy potential has been estimated to be 2.8 times higher than water energy in Bulgaria. In 2003 solid biomass has a share of 3.6% of total primary energy consumption. Use of biomass increase in period 1997-2004 3.4 times. Biomass is primarily used for heating.

Since 2003 is new energy law into power. This law stimulates use of renewables and enables trade with green certificate energy since 2006. It has been set up minimal price for renewable energy at 30 €/MWh for plants up to 10 MW. The same is for micro water power station 40 €/MWh, and for wind power station 60 €/MWh (without VAT).

Strong restructuring agriculture is expected. It is still not know which level of subsidies will be after entering EU, but considerable reduction is expected. Bulgaria should also fulfill all European rules concerning environment protection and replacement of fossil fuels. New field for production in agricultural area are renewable energies. For SRC can be used soils of lower quality. The concrete development plan should be strategically and economically justified.

Croatia

Bioenergy, especially fuelwood has always played a part in domestic cooking and heating (wood accounted for 8.7% of primary energy production in 2003), but official consideration has only recently been given to the use of biomass as an energy source. Woodland comprises 44% of the total surface area of the state mainland, and technical annual energy potential, of around 1.3 million m^3 of forestry residues, is estimated at 33.8 PJ/a (Domac, 2004).

In recognition of the Croatian potential and to fulfil duties under agreements such as Kyoto and EU accession preparations, Croatia has joined international collaborations, created legal instruments and devised programmes such as 'BIOEN', an initiative aimed at obtaining 15% of primary energy from biomass and waste by 2020.

The Energy Act, enacted in 2001 and amended in 2004, foresees the elaboration of renewable energy sources (RES) Regulations that would define their rights and obligations, price for the energy delivered (feed-in tariffs), as well as other forms of incentive mechanisms. It should be stressed that this Law, for the first time, precisely articulates the positive attitude of the Republic of Croatia toward renewable energy sources, thus representing a small but significant shift in view of a positive message to the investors interested. A key step as regards the legislative treatment of RES is also included in the Law on Electricity Market that establishes the legislative obligation of electric energy purchase generated from renewable energy sources. The quota, i.e. the minimum RES share for the energy entity supplying electric energy as a public service, will be determined by a special direction of the Croatian Government.

In Croatia, industrial bio-energy concepts vary from modest to very interesting, from an economical and environmental point of view. Nonetheless, a breakthrough in bio-energy utilization will have to be forced. Awareness and understanding of economical and environmental benefits of bioenergy will have to be raised.

FYR Macedonia

From total area of Republic of Macedonia the agricultural land is about 2.6 10^6 ha and arable land, mostly in volleys is about 569 10^3 ha. According to statistical data forest covered about one million of hectares, or about 38% of total surface. The poplars, as SRC, cover only 0.12% of surface.

The biomass as an energy resource is used relatively modest, about 10.7%, like wood raw material and waste from wood processing. Briquettes from secondary agricultural products in the country are not produced, but only from wood processing waste.

The energetic value of secondary agricultural products and waste material of forestry and wood processing in the Republic of Macedonia is 26.794 TJ (1999-2001). It is equivalent to 634,9 thousand tons liquid fuel (petrol). Out of this, 73,8% is produced in agriculture and 26,2% in forestry and wood processing. But, the real possibilities for agriculture production are 35,5%, and 90% in forestry and wood processing or in total only 13.3 TJ which is 49,8% from the total energetic potential.

Capacities for biogas production are built in two cities (Delcevo and 'Rzanicino village near Skopje), but these are not in function at the moment.

Republic of Macedonia haven't legal regulated production and consumption of unconventional energetic resources to this moment. On this way, it would be intensifed researches in agriculture and would be stimulated farmers for enormous production of SRC.

Romania

The agricultural area of Romania is 14.79 10^6 ha whereby is 9.34 10^6 ha arable land. Forest covers (6.24 10^6 ha, around 28 percent of the total land area of Romania. According to the latest survey, in year 1998, the potential of biomass was 126.3 PJ, what makes 11% of total primary energy production in 2010. The main biomass sources are firewood and agricultural waste that account about 95 % of the total, and wood waste from industrial processes with 5 %. About 90 % of the firewood and 55% of the wood waste are located in the Carpathians and Sub-Carpathian mountains. Around 54% of agricultural wastes are found in the South-Plain and Moldavia. From the total firewood and agricultural waste it is estimated that only a share of 30% is commercial biomass and the share of 70% represents the contribution of the biomass harvested by the owners from the private forests and gardens and the of the agricultural waste resulted in the rural households. In 1995 year, wood used for heating and cooking was around 39 000 TJ and this amount was kept constant till 2000. About 10 000 TJ of wood wastes are used in industrial steam boilers. The biomass briquettes manufacturing from wood wastes (sawdust, leaves) and agricultural residues (corn, straw, sunflower stocks) and their utilization for cooking and heating is under development. In present some companies study the technological process for the future use of pellets.

The R&D activities and implementation of SRC production and use is in progress. The main species are poplars and willows. Many rural areas and especially Danube Delta offer favorable pedo-climatic condition for SRC plantations.

The Romanian legislations are focused on integration of domestic regulation in accordance with EU Directive 2001/77/CE. In 2010, According to the new regulation, Romania has to produce 33% of the total electricity from renewable energies, including hydro-energy.

Serbia and Montenegro

The total agricultural land is around 5 10^6 ha. It is expected that EU will request to set-aside about 20% of agricultural land, which means about one million hectares and use it for non-food production. The surface of non-arable, high underground water and flood threatened areas in Vojvodina is estimated to be around 150,000 ha. Approximately the same proportion is in the whole region. About 50% of this land in Vojvodina is already now used for poplar growing. Poplars are preferably used as a raw material for paper, timber/lumber and packaging industry, and less as fire wood. The national Poplar institute covers research, development and extension services.

The problem of eolian soil erosion has been identified. It has huge effects in low land regions and its control and reduction is needed. The setting up or green bands of trees is planed as a reasonable and effective solution, and poplars could be used for the first phase of its development. The total area of wind erosion diminishing wood bands is assessed to be between 50 and 150 thousand hectares.

There are positive impulses for use or renewable energies in the current policy. The Government has set up official objective, following EU trends, to increase the share of renewables use from current 1.5% to 3% of primary energy up to 2010. Unfortunately the adequate supporting measures have not been ensured and realization of the program can not be successful without financial support.

Summarized, between 0.5 and more than one million hectares could be available for growing of SRC for energy purposes.

CONCLUSIONS

Production of wooden biomass for energy purposes has to be an issue of high priority for all SEE countries from the point of view of:

1. Worldwide and EU environmental demands to reduce emission of *greenhouse affecting gases* and reduction of fossil fuel consumption.
2. Restructuring of agriculture toward production of non-food, raw materials and energy.
3. Improvement of export-import balance.
4. Development of rural areas by much better using of material and human resources and improvement of living standards.

Based on achievements and experiences in EU, one regional multidisciplinary and well coordinated program, based on listed hypotheses should elaborate production and use of short rotated wooden biomass. This should be done in cooperation with EU countries as cross-border investigation in order to give guidelines for future oriented development activities. High environmental, economic and societal benefits can be expected from wooden biomass use as energy source, especially for economically week rural areas in SEE.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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THE POSSIBILITIES OF USE OF THE BIOMASS IN HUNGARY

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SUMMARY

The present essay focuses on the state of energy consumption, the possibilities of the energetic use of the biomass, biogas, biodiesel and the bioethanol, in Hungary.

According to surveys there is a significant biomass potential in Hungary. The total quantity of the biomass in the country is 350-360 million tons out of which 105-110 million tons (some 30 %) reproduces itself annually. The energy content of the yearly produced biomass is as high as 1185 PJ, which is about 5 % more than the annual energy consumption of the country. The fact that the quantity of the plant produced carbon is four times higher as the annual production of mineral carbon for energetic purpose – 30.4 million tons - is characteristic of the nationwide biomass potential.

The biggest biomass-producer is the agriculture which produces 58 million tons of organic material a year, 53 % of which is main product (30.5 million tons), and 47 % by-product. The quantity of biomass used for energetic purposes is only 1.8 million tons, 0.3 % of the total quantity.

The renewable energies witch can be retrieved form part of the biomass produced by the agriculture, could cower 10 % of the energy demand of the country on the short term.

***Key words**: energy, biomass, biogas, biodiesel, bioethanol, Hungary*

ENERGY CONSUMPTION IN HUNGARY

The annual energy consumption of Hungary was declining continually till 2000 and started to grow again afterwards. In 2003 the energy consumption of the country amounted to 1213 PJ. Within the total energy consumption the share of the imported energy sources is growing constantly at the expense of the domestic production. In 2003 the energy import exceeded 780 PJ, which equalled 64.3% of the total consumption (**Figure 1**). This fact means that **the country is becoming more and more dependent on imported energy.** The natural gas represents the greatest share among the utilized energy sources with 42.2 %, followed by oil derivatives with 29.9 %, the proportion of coal is 13.0 % whilst the share of renewable energy sources is not more than abt. 3 %. Natural gas is especially popular with the population due to its favourable price in international comparison first of all, but the industrial consumption is also significant, though the price they pay can be considered international.

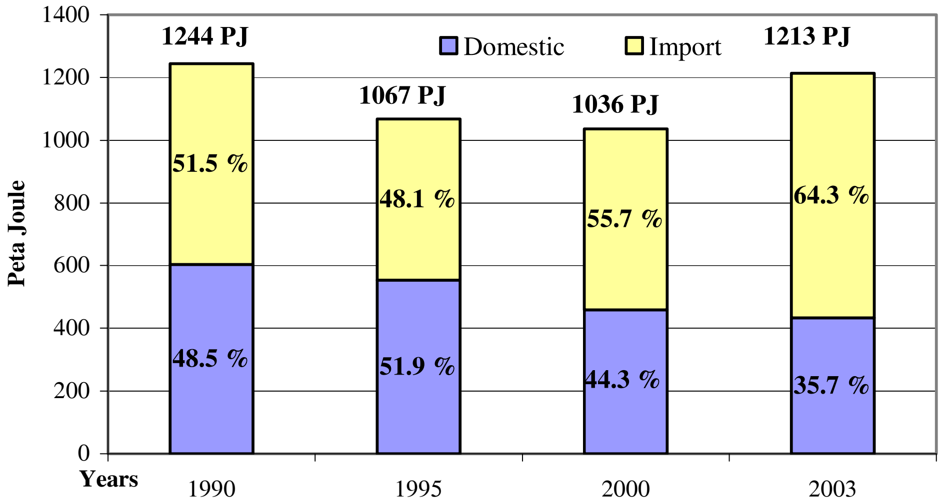

Figure 1 The Hungarian energy consumption (1990 - 2003)

The biggest share of the total energy consumption is represented by that of the households with 38.3 % which can be considered constant on the long term. The other major consumer is the industrial sector with a continually decreasing share of 34.9 %. The consumption of the communal sectors is increasing, their share was up to 18.9 % in 2003 (**Figure 2**).

The Hungarian agriculture is considered to be a small consumer within the national economy with a share of 3.4-4.0 % which has not changed considerably in the last ten years. Among the energy sources utilized by the agriculture the diesel engine fuel of tractors and self-propelling machines represents the greatest share - 43 %. At the same time the proportion of natural gas utilized by the agriculture is also significant with 29 % and 13 % of the energy demand is covered by electric energy.

The proportion of the renewable energies gained from the biomass hardly exceeds 1 % in the energy consumption of the agriculture.

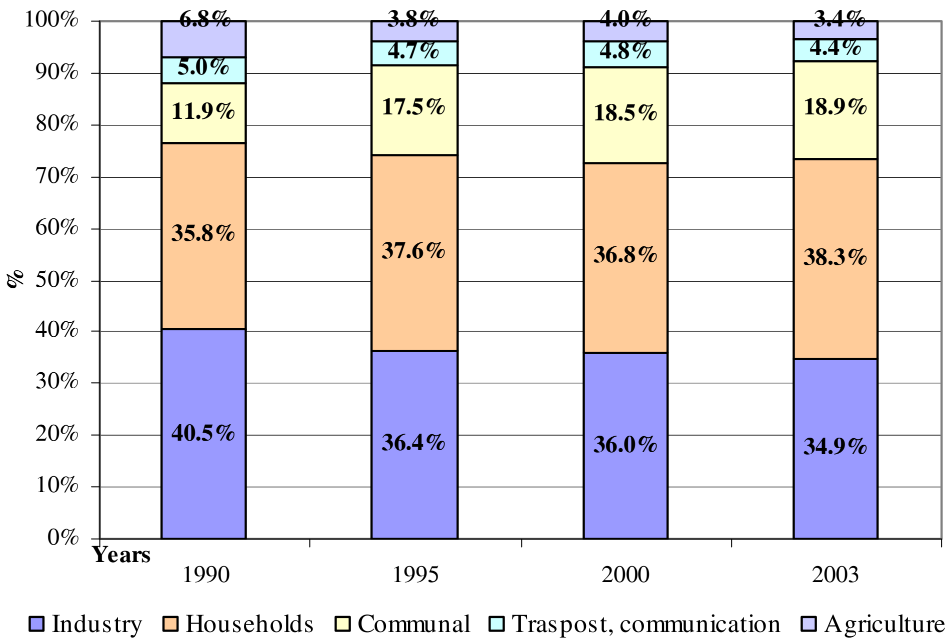

Figure 2 The share of consumers in the energy consumption (1990-2003)

BIOMASS POTENTIAL

According to surveys there is a significant biomass potential in Hungary. The total bulk of biomass in the country is up to 350-360 million tons out of which 105-110 million tons (about 30 %) reproduce themselves annually. The energy content of the biomass developing annually is up to 1185 PJ which is 5 % more than the total annual energy consumption of the country (1124 PJ). The fact that quantity of coal generated annually by plants is four times as much as the quantity of fossil coal exploited for energetic purposes in a year – as much as 30.4 million tons.

The biggest biomass producer is the agriculture producing 58 million tons of organic material annually in which primary product is 53 % (30.5 million tons) and by-products 47 %. The biomass utilized for energetic purposes is barely 1.8 million tons, a merely 0.3 % of the total quantity.

The renewable energies gained from part of the biomass produced by the agriculture could cover 10 % of the national energy demand on the short term.

Table 1 The biomass potential in Hungary (average of years 2000-2003)

1	Total bulk of biomass	350-360 mill t	100%
2	Annual self-reproduction included	105-110 mill t	30%
3	The energy content of biomass annually produced	1185 PJ	105%
4	The energy consumption of the country	1124 PJ	100%
5	The quantity of coal generated by plants	30,4 mill t	Four times as much as the fossil coal exploited p.a.
6	The total biomass production of agriculture p.a.	58.0 mill t	100%
	- primary product in it	30.5 mill t	52.6%
	- by-product in it	27.5 mill t	47.4%
7	Biomass of agricultural origin utilized for energetic purposes at present	1.8 mill t	0.3%

BIOMASS FOR ENERGY

In the primary biomass produced by the agriculture first of all the by-products arising in better amount can be reckoned with for energetic purposes. Under common or regular conditions 4.0-4.5 million tons of cereal straw is processed annually of which 1.6-1.7 million tons are utilized for animal breeding and for industrial purposes. The major part of the remaining 2.4-2.8 million tons of cereal straw could be used for energy production and annually 28-34 PJ energy could be produced of it. At present straw is practically not utilized for energetic purposes in Hungary due to the lack of appropriate stokes.

Maize stalk production in Hungary is **8-10 million tons** of which 4-5 million tons could be utilized for energetic purposes which could yield 48-60 PJ energy p.a. Among the by-products of crop growing sunflower stalk and rape straw also arise in big quantities which could be utilized for burning and could supply 5-6 PJ thermal energy annually should the appropriate technologies for harvesting and burning be available.

The quantity of vineyard and orchard pruning residues (branch tendrils and fruit tree loppings) **arising annually is 350-400 thousand tons** which could supply 5-6 PJ energy. There have only been attempts for their burning till now. The harvesting in bales and burning in small stokes of branch tendrils is a viable solution on the vine growing farms. For the chopping, collecting and burning of pruning residues no technology has been developed so far.

Among the plants which can be produced on big areas for energetic purposes first of all the “Szarvasi energiafű” and the energetic tree plantations can come into consideration in Hungary.

The proper machine technology of growing and harvesting the perennial energy-grass which can be grown in huge bulk is available but the fact that it is very rich on minerals – especially silicon – couses difficulties by burning as, therefore, its ash melts at a relatively low temperature (600-700 degrees C). Due to this stokes with special stokehold or a special burning technology would be required which is now under development.

The Szarvas energy-grass as a short rotation herbaceous grasses is able to provide a dry bulk of 10t/ha which can be baled for several years the energy content of which is 110-120 GJ/ha. The energy-grass can easily be pelletized. 6-7 tons of pellets can be produced of the grass yield of one hectare the burning features of which are more auspicious in lower capacity stokes than that of the chopped material in thermal power stations.

Should the final form of firing technology of energy-grass be developed cropping could be started in a short time maybe on 50-60 thousand hectares which would supply a 500-600 thousand ton bulk of biomass annually, of which 6-7 PJ energy can be produced.

Another prospective source of bio-energy is the energetic tree plantation classified in the agricultural plantation management cultivation sector by which dendromass can be produced relatively fast and in big quantity for energetic purposes.

According to experiences hitherto it is expedient to plant the quickly growing tree varieties (poplar, willow) with a number of plants 12000-15000/ha which will be ready for felling in 3-5 years. The re-shooting tree stock can be harvested in another 3-5 years by felling totally 5-7 times assuming a plantation lifespan of 15-25 years. **On the basis of long term-experiments made with different tree varieties yields of 11-20 t/ha/year can be achieved, of which 185-330 GJ/ha energy can be produced.** For the harvesting of energy plantations by self-propelled choppers machines are being developed with promising prospects in Hungary. The tractor pulled heavy duty cutting-chopping machine is first of all in twin-row plantations productive and efficient.

A rapid territorial expansion of the energetic plantations is expected in the near future which **can achieve, or even exceed 100 thousand hectares of which 25-30 PJ energy can be gained**.

For energy production under arable land conditions **triticale in the form of whole plant** cut into windrow and baled can also be taken into account the yield of which may reach 8-10 t/ha with 40 % grain bulk in it. Its energy content is 15-16 GJ/t so 120-160 GJ/ha energy can be produced. It has a favourable feature from the point of view of firing technology, that in baled form it burns more slowly and with a more even heat regress than wheat straw.

These biomasses originating from plants which can be produced on the field and utilized by direct burning are gaining a growing emphasis in our national energy policy in the coming years.

BIOGAS AS A SOURCE OF ENERGY

The bulk of the biomass of agricultural origin – which can be gasified by biological means – is about 8-10 million tons Hungary of which 7-9 PJ energy can be produced. Taking the substrates into consideration the "wet" (by a dry matter content of 8-20 %) resp. the "semi-dry" (by a dry matter content of 20-50 %) technologies are applicable under the circumstances given in Hungary in view of the auspicious gasification and bigger livestock farms can serve as a basis for them. In this case organic matter of agricultural origin added to floating slurry manures of animals form a favourable substrate for anaerobic fermentation. Under ordinary conditions 300-400 litres of biogas with a methane-content of 60 % can be produced of 1 kg dry matter and this quantity can be increased by adding agricultural primary (e.g. mashed whole maize plant) or by-products (e.g. sugar beet chips) of higher energy content and with a heating effect.

After cleaning and enrichment the raw biogas is – 1 m^3 of can which can substitute roughly 0.4 litre diesel oil – in so-called “Greengas” quality apt for propelling engines or for being dosed into the natural gas network.

Besides heating or chilling livestock farms biogas can be utilized first of all for the production of electric energy in Hungary. The waste heat of the electricity producing blocks can in turn be used for the fermenting appliances and for satisfying the own energy demand of the technology.

According to prevailing orders the electricity suppliers are obliged to take over the electricity produced by renewable energies in Hungary as well. In the next years new investments in biogas settlements are expected in Hungary.

BIOMASS AS ENGINE FUEL OR ADDITIVE

In our country – as well as in most of the EU member countries – government order allows that engine fuels of biological origin may be mixed in fuels produced of mineral oil derivatives distributed in the country. It can be expected, therefore, that the production resp. utilization as engine fuel additive of the two engine fuels of biological origin – the **bio-diesel (RME)** and the **bio-ethanol (ETBE)** - will gather space especially as the biggest national fuel producer and distributor the company “MOL Rt.” has turned up on the market as a significant buyer. Naturally the expectations of the EU can be detected in the background of this according to which dealers of the member countries are expected to mix 2 % of fuel of biological origin into the fuel distributed till 2005 and 5.25 % till 2010.

The ecological makings of Hungary are not really favourable for growing rapes. Autumn rape can be grown on about 150 thousand hectares with acceptable yields. On this area 250-270 thousand tons of seeds can be produced of which **100-110 thousand tons of bio-diesel can be produced.** This quantity only partly covers the 120-130 thousand tons annual domestic demand for mixing to the diesel fuels.

Compared to the present diesel oil prices of the petrol stations the bio-diesel (RME) which is free of excise tax is still competitive. For the expansion of the production first of all investment needs to be encouraged.

The conditions of bio-ethanol production are more favourable in Hungary than that of bio-diesel. Part of the domestic maize crop can serve as raw material for bio-ethanol production. The annual maize crop is 6-7 million tons on the average, and in better years as in 2004 it may even exceed 8 million tons.

Due to the declining livestock the quantity of maize used for feeding is decreasing while the proportion of industrially processed resp. exported maize is increasing. Ideally the annual quantity of maize used for industrial procession can equal 2-3 million tons. Besides starch and iso-sugar production most of this quantity can be used for bio-ethanol production. **So the volume of the inland production of maize-based ethanol can be up to 700-800 thousand litres annually** which is six times as much as the ETBE demand of the Hungarian engine fuel producers and dealers expected till 2010.

The producer's price of bio-ethanol which is free of excise tax is at present competitive compared to the retail price of gas at the petrol stations.

THE THRIFT OF THE UTILIZATION OF THE BIOMASS FOR ENERGETIC PURPOSES

Among the obstacles of the transformation into energy and the utilization of biomasses of agricultural origin the financing of investments, matters of thrift, matters of regulation and the lack of appropriate integrations and logistics are the most significant.

The production and utilization of biomass for energetic purposes is effected by two major factors:

1. The price of traditional energy sources and the development of their costs
2. The production costs of bio-energy sources

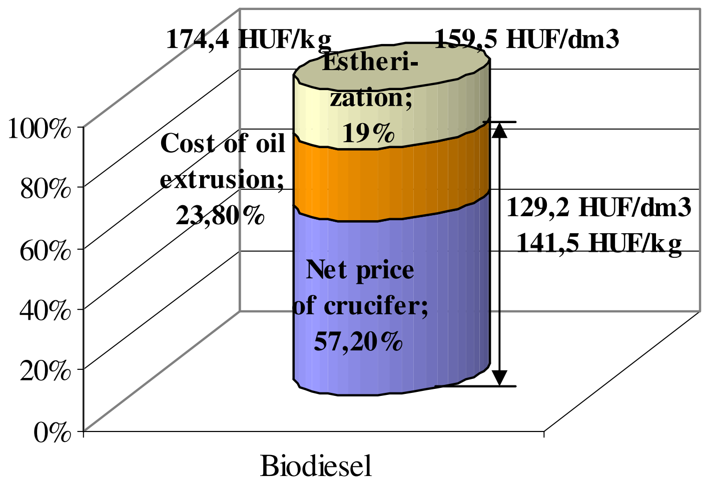

Figure 3 The cost structure of bio-diesel (RME) production in Hungary on 2003 price level (1 EUR = 250 HUF)

The price and costs of the traditional energy sources are highly dependent from price changes in the international market and from the demand-offer relations but they are even more dependent from imposed taxes additional to production costs which are determined by the state. In the case of traditional engine fuels the taxes imposed are higher than the production and distribution costs. The costs of bio-energy production are in turn first of all effected by the costs of raw-material production, the preferences within agricultural production, the transformation costs of biomass and the state aid for bio-energy sources.

The costs of renewable liquid and gaseous fuels in general as well as that of traditional ones could be made competitive freed from taxes but it necessitates the abdication of the state. Besides the two main influencing factors the utilization of biomass for energetic purposes is also effected by the changes in the state of the natural environment and the social sensibility for unfavourable environmental effects.

The two renewable liquid energy sources - the bio-diesel and the bio-ethanol - which are also applicable as alternative engine fuel free of excise tax are competitive with the retail price of the traditional engine fuels – diesel oil and petrol.

In case of implication the spillage of revenues is also decreasing in turn.

The environmental advantages – which play a major part in the limitation of the glasshouse effect – can easily be realized by the application of renewable energy sources.

In the cost of both alternative, environmentally sound engine fuels the cost of raw-material - rape, maize - is dominant (in 57-68 %). Should the costs of raw-material production can be kept on a favourable level the market prices of renewable engine fuels will also be competitive. In case of bio-diesel the costs of oil extrusion and estherization are also significant (43 %), while in case of bio-ethanol besides the costs of technology energy costs are also remarkable with 11 % (**Figure 3 and 4**).

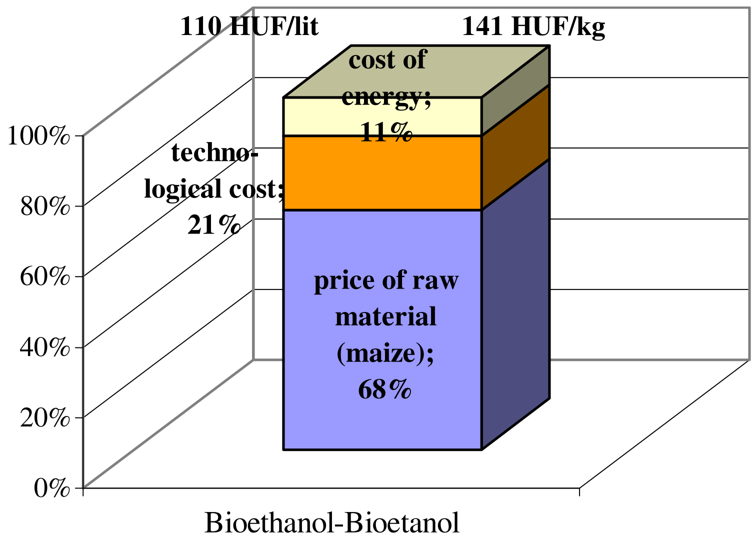

Figure 4 The cost structure of bio-ethanol production in Hungary on 2003 price level (1 EUR = 250 HUF)

The costs of heat produced from the biomass are also highly dependent from the production costs of raw-materials, from the connected logistic costs, and from the construction and size of firing appliances, from the efficiency of firing and last but not least from the servicing and operational costs of the appliances.

The production costs of heat produced of renewable fuels are inversely proportional with the size of firing appliances. Among the renewable energy sources **young trees** can be used for heat energy production at the lowest cost. The price of heat energy produced by young trees can even compete with natural gas. The heat energy produced by burning straw-bales is in case of big size boiler – with a performance of 1-6 MW - **more economical than natural gas.**

Examining the inner cost structure of heat production it can be stated that by renewable energy sources the operational and maintenance costs of the firing appliances are far higher than those of firing appliances operating by traditional fuels. In the latter case the majority of the costs (85-95 %) arisses from the price of fuels.

CONCLUSIONS

It can be stated that bio-ethanol and bio-diesel as fuels for internal combustion engines can be produced in Hungary at a competitive price by the utilization of biomass of agricultural origin as well as chopped wood on energy plantations and baled wheat straw apt for burning for the production of heat energy. The Hungarian agriculture could provide for 10 % of the domestic energy demand to be covered by these renewable energy sources.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

EVALUATION OF SEASONAL SOLAR RADIATION

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SUMMARY

The solar radiation falling on the earth’s surface is influenced by the seasons and seasonal fluctuations form one of its components. Investigating the seasonal fluctuations of solar radiation is of great practical significance for more accurate forecasting and use of electrical energy generated by direct conversion photoelectric systems. The seasonal fluctuation indexes of the average monthly values of solar radiation have been obtained and used to determine the relative changes during each month, due to seasonal influence.

Key words: *total solar radiation, seasonal fluctuations of average monthly solar radiation, photovoltaic system*

INTRODUCTION

Solar radiation is the energy, which the sun emits into space. On passing through the earth’s atmosphere, only about 27 % of the radiation that has crossed its upper boundary reaches the earth’s surface. Despite this fact the quantity of solar energy is enormous [1]. During a clear sunny day the direct solar radiation values take a normal daily course, following the sun’s azimuth with a maximum of 12-13 hours, and a normal yearly course with a maximum in summer. It has been determined that the daily solar radiation values depend greatly on the duration of sunshine and the presence of clouds [3]. Nevertheless, a significant difference in the solar radiation values obtained for a particular day or month of the year has been noticed. This is due to the fact that the solar radiation falling on the earth’s surface is subject to seasonal influences and one of its components is the seasonal fluctuations – these are periodically repeated throughout the year fluctuations with approximately the same amplitude, which are caused by the climatic characteristics of the different seasons and months. The investigation of the seasonal fluctuations of solar radiation will result in taking their influence into account when organising the production of electrical energy from existing or newly-built facilities consisting of photoelectric panels for direct energy conversion.

The aim of the present paper is to determine the seasonal fluctuation indexes for the total solar radiation values and use them to estimate the effect of seasonal influences during a particular month.

MATERIAL

The analysis of the solar energy resource for Rousse is based on measurements of the direct and total solar radiation values in the area of "Angel Kanchev" University of Rousse, located at 43º49'22" northern latitude and 26 º 1'19" eastern longitudes.

The measurements of the solar radiation are accomplished by a specialized measuring system, consisting of piranometer CM 11, integrating block (SOLRAD Integrator) and a personal computer (PC) (Fig. 1) [5]. At the outlet of the piranometer an analogue voltage signal appears, corresponding to the current solar radiation value. On its turn it is fed to the integrating device. The changed solar radiation values are integrated and stored in it for 31 consecutive days. Thus the solar radiation data registered is transferred to a PC under a standard communications interface RS 232.

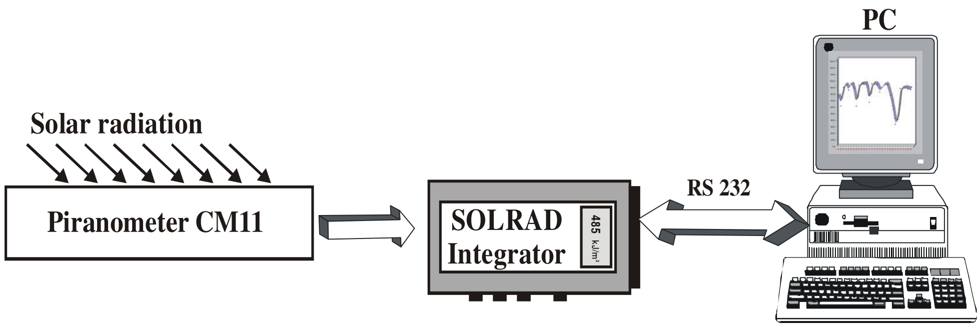

Figure 1 Pyranometer CM 11 and connection of readout integrator SOLRAD with PC

With the help of the specialized software Integrator, the registered values for the solar radiation can be visualised and stored both in real time and after they have been saved in advance (Fig. 2).

Following the approach thus described, the intensity of the direct (every other minute) and integrated (every other day) solar radiation on flat surface in 2005 has been measured in $W.m^{-2}$, and $kJ.m^{-2}$, respectively.

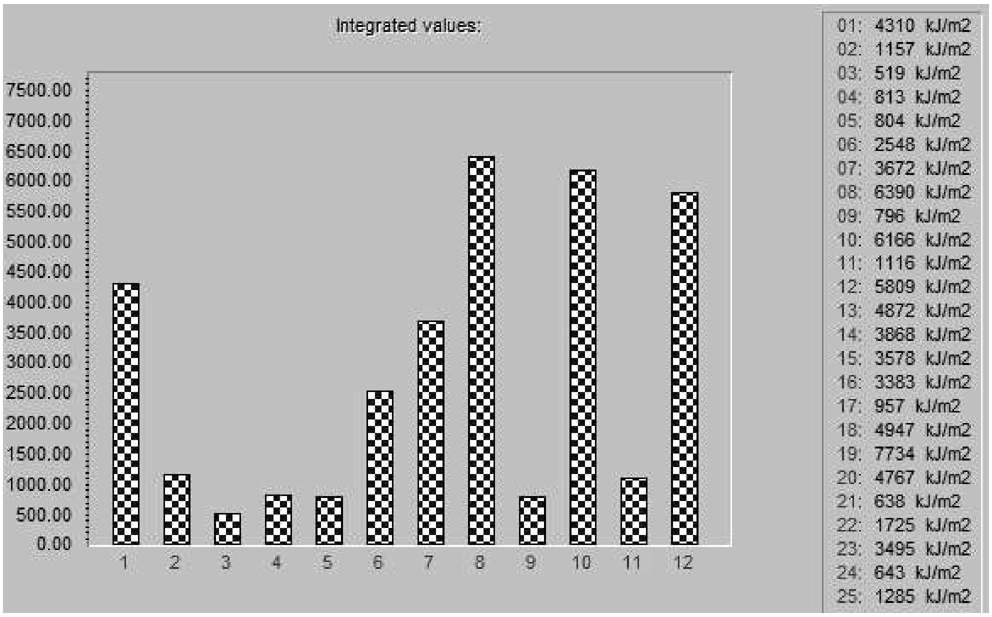

Figure 2 Main windows of the PC software program SOLRAD

METHODS

Preliminary investigations show that the temporary sequence of solar radiation values obtained should be viewed as a random (stochastic) process $H(t)$, which does not contain a development trend [2, 3, 4]. The stochastic process is viewed as a sequence of random variables H_i, depending on the parameter t_i (time). The values of the total solar radiation $H_1, H_2, ..., H_N$, which random variables that form $H(t)$ at $t_1, t_2, ..., t_N$ get, are called stochastic process realisation (Fig. 3). During the investigations the values of the random solar radiation have been registered. Those values that it adopts to determine essential properties of the stochastic process have been taken into account. The stochastic process of solar radiation can be described in a satisfactory way if its main probability characteristics are known, such as expected value $m_h(t) = M[H(t)]$; standard deviation $\sigma_h(t) = \sqrt{D_h(t)}$; autocorrelation function $K_h(t_1, t_2)$ [6, 7]. Expected value and deviation are important but insufficient probability characteristics for describing the statistical properties of the random process. In general, the autocorrelation function $K_h(t_1, t_2)$ is a function of two arguments t_1 and t_2 and reflects the way the random process flows in time [4].

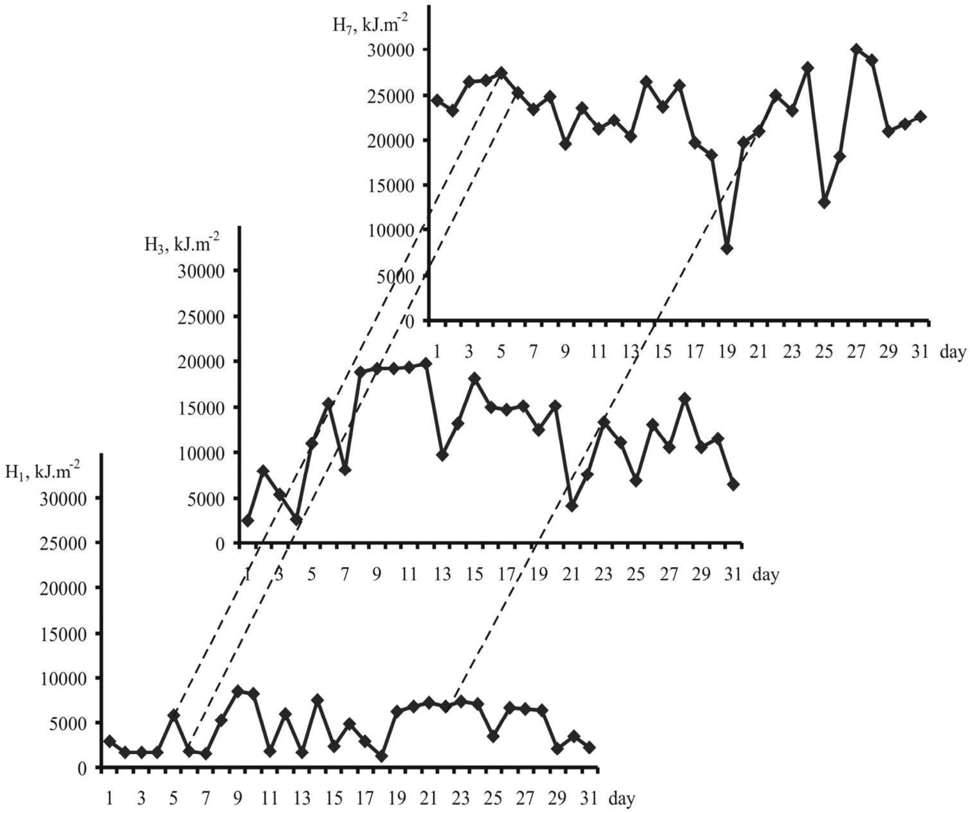

Figure 3 Ensemble from daily realizations of integrated solar radiation

During the investigations it has been determined that the monthly values of solar radiation increase gradually from January to July, in comparison to the rapid decrease observed from July to November (Fig. 4). The maximum of total solar radiation is in July – 703 399 $kJ.m^{-2}$, or 22 690,29 $kJ.m^{-2}.day^{-1}$ on average. This is justified by the fact that July is the warmest month of the year and the total solar radiation is the main source for the heating of the earth's surface and the formation of the regional climate. During the months with a clearly defined winter character, November, December and January, a relatively constant level of the registered total solar radiation is observed, 109 831, 116 445 and 139 450 $kJ.m^{-2}$ respectively. Similar characteristic is observed during the months with a clearly defined summer character – May, June, July and August. They are 620 843, 679 087, 703 399 and 600 890 $kJ.m^{-2}$ respectively. This fact shows that the registered values of total solar energy have a seasonal component.

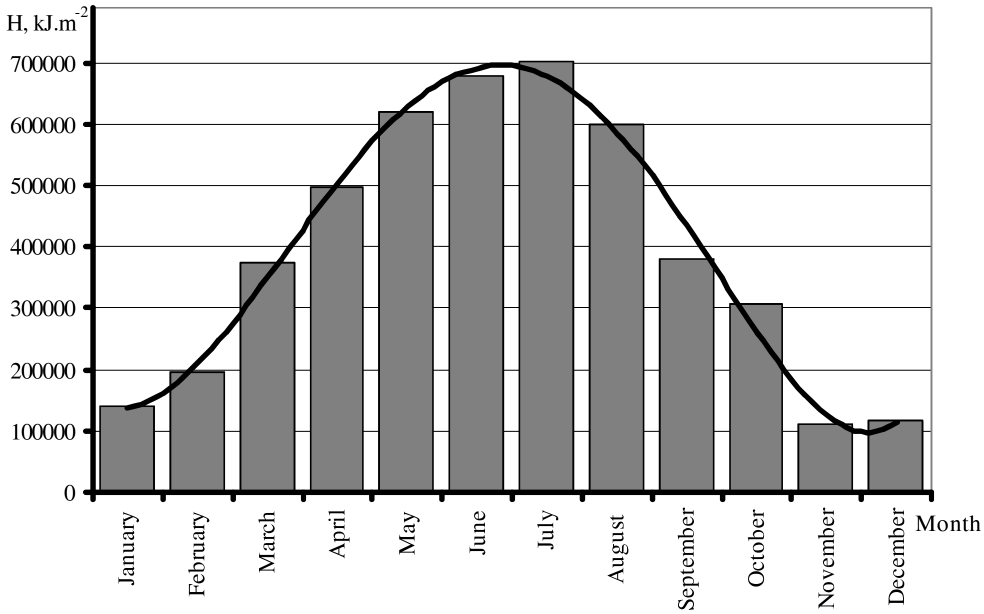

Figure 4 Integrated monthly values of solar radiation for the town of Rousse in 2005 г.

The main objective in studying the seasonal fluctuations for the total solar radiation is to determine the pure impact of the seasons, while eliminating accidental fluctuations and randomly formed trends of development. This is done through determining the seasonal fluctuation indexes for the total solar radiation as a percent ratio of the pure seasonal component for the particular month to the average volume of the studied phenomenon for the whole period of investigation.

The following sequence is observed when determining the seasonal fluctuation indexes (Table 1):

1. Average monthly fluctuations are calculated, for each particular month. This operation makes for accidental fluctuations during a particular year, thus eliminating them completely. Since the temporary sequence under investigation does not contain a tendency for development and the accidental fluctuations have been eliminated, the difference between the average monthly values obtained is influenced only by the seasonal changes. During this operation time equalization is performed, i.e. the different length of calendar months is equalized by dividing the data for the total solar radiation value by the number of days in each month. Further analysis is carried out based on the average monthly values of solar radiation (Table 1, col. 4).
2. The total monthly average is calculated for the whole period, dividing the sum total by the number of months - 12. The figure obtained accounts for the volume of the phenomenon under investigation, provided there was no seasonal influence. The fluctuations of the monthly average from the total monthly average value are due to seasonal changes.

3. The seasonal fluctuation indexes are calculated as a ratio between the monthly average values and the sum total monthly average

$$S_i = \frac{H_i}{\overline{H}} \tag{1}$$

where H_i is the monthly average solar radiation, $kJ.m^{-2}$;

$\overline{H} = 12\,901{,}38$ - the total monthly average solar radiation, $kJ.m^{-2}$.

They show the relative deviation of the total solar radiation during the respective month from the average monthly volume for the whole period due to seasonal changes (Table 1, col. 6).

Table 1 Operating table for determining the seasonal fluctuation index of the sum total solar radiation

Month	Total solar radiation H_i, $kJ.m^{-2}$	Days, no.	Monthly average solar radiation $\overline{H}_i$, $kJ.m^{-2}$	Means square value of solar radiation $\sigma_h(t), kJ.m^{-2}$	Seasonal fluctuation indexes S_i
1	2	3	4	5	6
January	139 450	31	4 498,38	2 457,87	0,348
February	196 245	28	7 008,75	3 620,08	0,543
March	373 374	31	12 044,32	5 073,55	0,933
April	496 194	30	16 539,80	5 597,79	1,282
May	620 843	31	20 027,19	6 260,46	1,552
June	679 087	30	22 636,23	7 360,07	1,754
July	703 399	31	22 690,29	4 496,11	1,758
August	600 890	31	19 383,55	5 070,54	1,502
September	380 857	30	12 695,23	7 364,56	0,984
October	306 138	31	9 875,419	3 274,19	0,765
November	109 831	30	3 661,033	2 048,06	0,284
December	116 445	31	3 756,29	2 173,47	0,291
Total:	4 722 753		154 816,50		12

RESULTS AND DISCUSSION

Based on the methods proposed, the seasonal fluctuation indexes for the total values of solar radiation during each month in 2005 (Table 1) have been determined. The calculation are checked for correctness through the equation

$$\sum_{i=1}^{i=12} S_i = 12 \tag{2}$$

The sum total of the indexes equals 12, that is their average is 1 if the calculations are correct.

For easier understanding and further analysis the seasonal fluctuation indexes are presented in percent (Fig. 5). During the winter months the seasonal fluctuation index is from 28 to 35 %. This shows that as a result from the seasonal change influence the volume of solar radiation obtained is between 72 and 65 % lower than the average monthly solar radiation. This fluctuation is the biggest in November – -71,62 % and the smallest in January - 65,13 %.

In spring, March through April, and autumn, September through October, the seasonal fluctuation indexes are around 100 %. The total solar radiation values in these periods are comparable to the theoretically determined monthly average values.

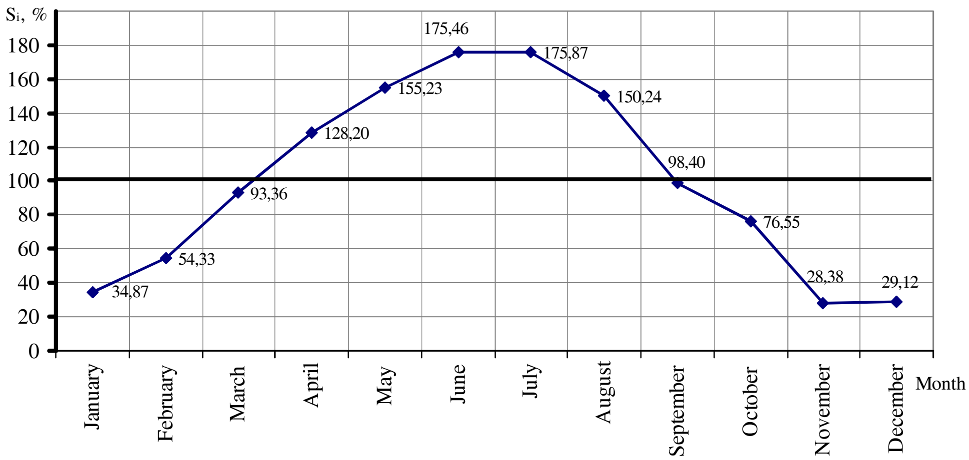

Figure 5 Total solar radiation seasonal fluctuation indexes in months

During the summer months (May, June, July, August) the seasonal fluctuation indexes are 155,23, 175,46, 175,87 and 150,24 %, respectively. This shows that the solar radiation in these cases is between 150 и 170 % higher in comparison with the monthly average value. This is a prerequisite for a more efficient use of the photoelectric converters installed, especially in agriculture, where the seasonal character is most obvious.

CONCLUSIONS

Investigation and recognition of seasonal fluctuations is of great practical significance for the efficient use of photoelectric installations. Taking into account the seasonal fluctuations is a prerequisite for more accurate planning and predicting of the expected amount of solar energy. The seasonal fluctuation indexes provide credible information about the total solar radiation each month. Their analysis shows that for the region of Rousse the monthly average value of solar radiation is $\overline{H} = 12\,901{,}38 \ \ kJ.m^{-2}$ and it is possible to use the photoelectric installations efficiently for 8 months – March through October.

These results could be used when the volume and structure of the electrical energy obtained each month is determined, based on the seasonal consumer demand and the possible utilization of the energy by renewable energy sources.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Izvorni znanstveni rad
Original scientific paper

PROCESS ENGINEERING IN SOLAR DRYING OF BIOGENOUS RESIDUALS

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SUMMARY

By- or end products of many communal, industrial and agricultural processes are biogenous residuals. Drying of these materials before disposal or further processing is advantageous in most cases, since the disposal costs and transport volume are reduced, the calorific value is increased and the biological stability is improved. However, due to the high water content, the energy consumption for drying is high and most of the conventional high temperature drying processes are too expensive for an application in this field. In terms of the energy requirement, solar drying is favourable. However, it is only a realistic alternative to other processes, if the investment costs are competitive and the required standards in terms of process control and automation are met. The objective of this research is therefore the systematic design of a tool for a fully automated operation of solar drying plants. In combination with an intelligent system control the equipment should be able to provide a fully automatic loading, unloading, mixing, transportation and accumulation of the materials within a greenhouse type dryer. The paper describes the different steps required during the development process together with the first results recorded with an appropriate solution.

Key words: *Solar drying, systematic design, sewage sludge, biogenous residuals, mixing device*

INTRODUCTION

By- or end products of many communal, industrial and agricultural processes such as waste water treatment, food processing and biogas-production are biogenous residuals. Removing the water content from these materials before disposal or further processing is beneficial in most cases, since the disposal costs and transport volume are reduced, the calorific value is increased and the biological stability is improved. Furthermore, handling and storage are simplified and new beneficial fields of application such as energy generation are opened. This is important, since the current trend of increased public awareness and government legislation on the agricultural use of biogenous residuals is becoming more significant. However, the energy requirement and drying costs involved are limiting the application of conventional high temperature drying processes. In this respect solar and solar assisted dryers have shown to be an interesting and commercially viable alternative compared to other known drying processes (Bux and Baumann/2003). In different fields of application, investment costs and energy consumption could be reduced significantly. However, most of the known solar-based technologies are only suitable for relatively homogenous wastewater sludge (Bux and Starcevic/2005). To meet additionally the different demands of other biogenous residuals and to improve the standards in terms of process control and automation, the University of Hohenheim was invited to develop a new mixing and transporting robot in cooperation with an industry consortium (Thermo-System, Germany; ACAT, Austria).

The robot is designed to be used for different materials such as sludge, wood chips, effluents from biogas plants and other materials. In combination with an intelligent system control the requirement is to provide a fully automatic loading, unloading, mixing, transportation and accumulation of materials within a climatic controlled greenhouse type dryer. For a fast and efficient development and implementation process new methods of systematic design and evaluation have been applied and tested.

METHODS

For the systematic development of a prototype the methodical development procedure proposed by the VDI-directive 2221 (VDI/1993) was followed. The directive divides the engineering process into seven fundamental working steps or 4 phases. Depending on the problem for each of these steps or phases, several different methods to arrive at a solution are recommended. The steps and the results after each of these are shown in **figure 1**.

For the “clarification and definition of problem“ step, a method proposed by ROTH (Roth/1994) was used (searching matrix). The result of this working step leads to the generation of an “objective requirements list”. The second step “determination of functions and their structures“ was solved by applying the abstraction method of function structure plans (VDI 2222/1997). Based on these lists and definitions generally applicable solutions were developed and combined using the method of engineering morphology (VDI2222/1997). **Figure 2** shows the general procedure for working with the generated morphological chart. The columns SF_i consist of specific functions (defined in the function structure plan and the requirements list). The rows E_{nm} present general solutions for the required functions. By combining several E-fields in different columns it is possible to create independent general options.

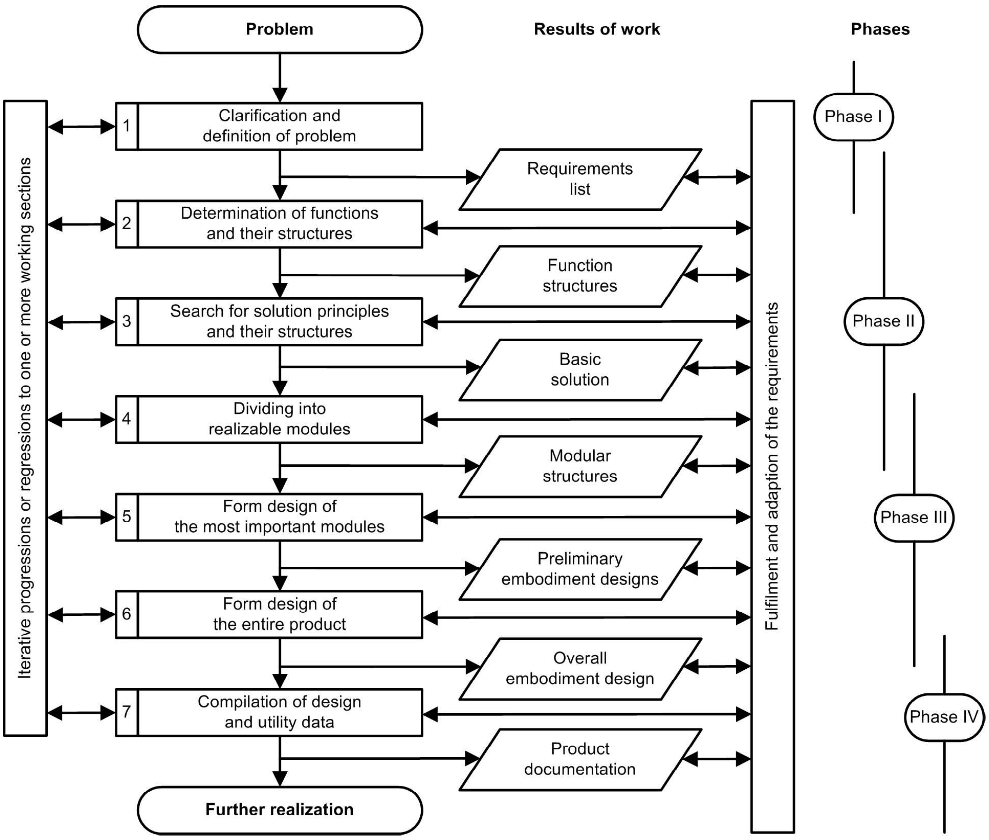

Figure 1 General procedure of systematic development and design according to VDI 2221.

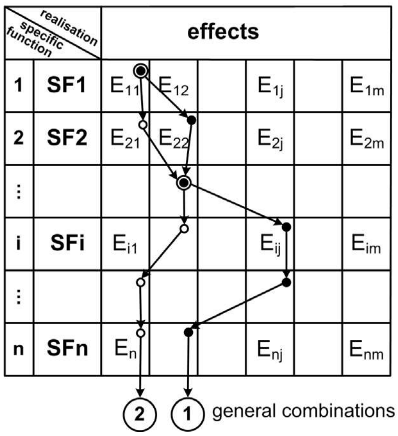

Figure 2 Working principle of morphological charts.

The construction work taking place in the working steps 4 and 5, also under economic viewpoints, were done according to the VDI-directives 2223, 2232, 2222 and 2225 (VDI2223/2004, VDI2232/2004, VDI2222/1982, VDI2225/1998). For the 3D-form assembly design and the construction of the entire product a developing software tool was used (CATIA, Dassault Systems). The meshing of the 3D-models and the mechanical analysis were performed using the FEM-tool ANSYS (Ansys Inc.).

RESULTS

After demonstrating the general methodological working procedure, the development of the lifting device, which is one of 5 main functional components of the machine, will now be described in more detail.

General function structure plan

To describe the states and functions of the final product, a function structure plan of the main system with its sub-systems was created, **figure 3**. The initial and final states of the parameters energy, signal and material are transferred at the boundary of each sub-system. Each single function, which is displayed here as text in white boxes, is represented by an secondary more detailed sub-function structure plan. Hence, the model for the construction of the entire machine is multidimensional.

Requirements list for the lifting device

Working and boundary conditions, technical requirements and economic background during the different product life cycles were reviewed on a basis of a searching matrix and summarized in a requirements list. An excerpt of the results is shown in **table 1**.

On analysing the requirements list it is clear that the most important basic demands on the lifting device are:

- Realisation of the required lift.
- Reliable transmission of the mechanical forces.
- Low production costs.
- Ease of maintenance.

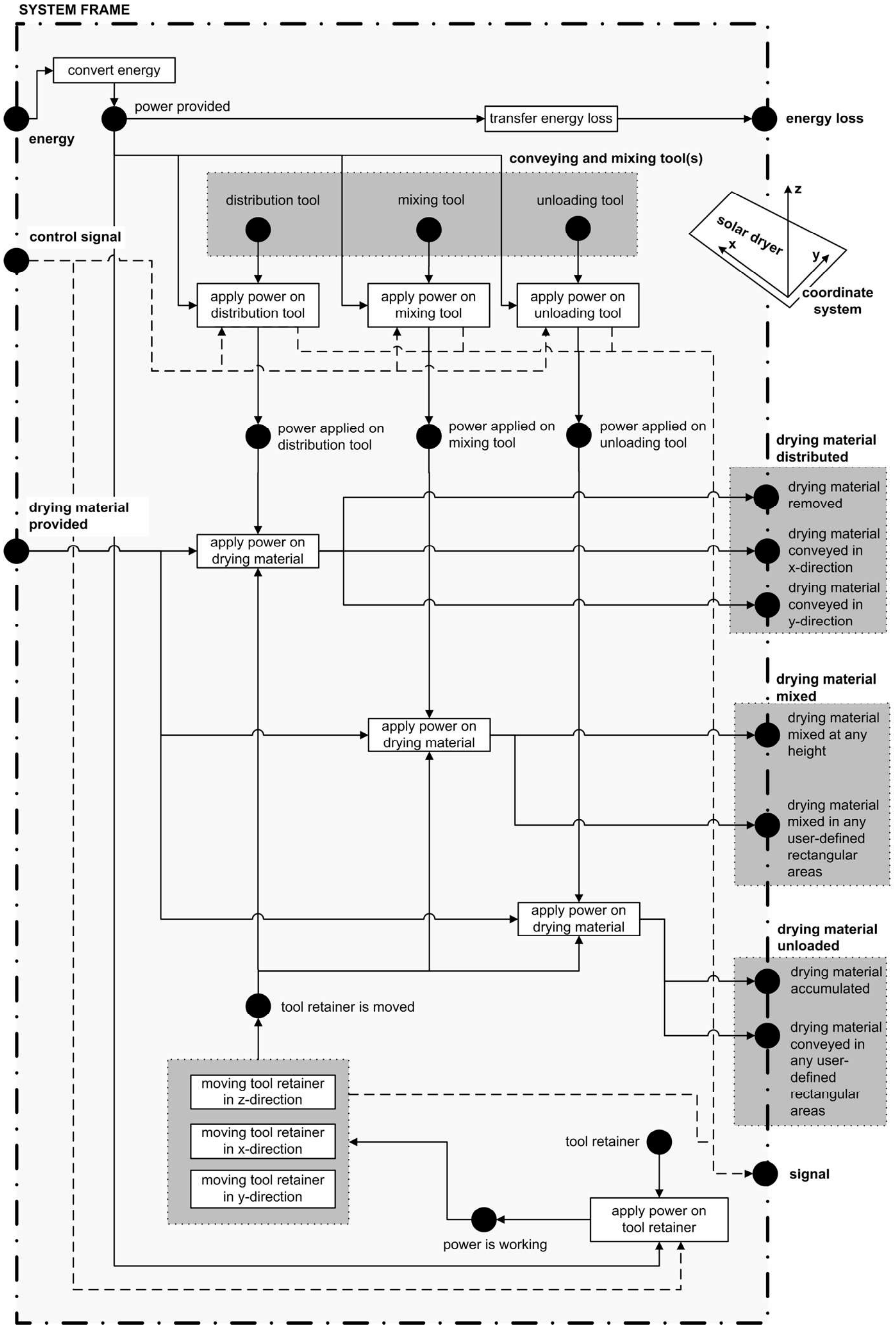

Figure 3 Simplified overall function structure plan of the mixing and conveying robot.

Table 1 Excerpt of the requirements list for the lifting device.

No.	general specificat. / specific request / date						
	Sludge-Manager - LIFTING DEVICE - 11.05.2004						
	requirements	numerical value/ tolerance range			unit	importance	genesis / explanation
		min	request	max	[...]	1-4 1=max	
1	**funcional requirements**						
1.1	lift	500	1000	1700	mm	1	fill < 1 m
1.2	lifting speed	20	25	100	mm/sec	1	see note 20051123-A
1.3	accuracy positioning: measure position	1	1	1	mm	3	
1.4	accuracy positioning: reach position	1	1	3	mm	1	unevenesses of ground!
1.5	torque on x-axis	+/- 0	-	+/- 15 000	Nm	1	see note 20051123-B
1.6	torque on y-axis	+/- 0	-	+/- 37 500	Nm	1	see note 20051123-B
1.7	torque on z-axis	+/- 0	-	+/- 10 000	Nm	1	see note 20051123-B
1.8	secure clamping on a defined position	+/- 0	+/- 2	+/- 2	mm	2	
1.9	on-time	0	3	24	h/d	3	
1.10	system effectiveness	-	high	-	-	4	
...	...	...	...	...	...	...	...
2	**technical requirements**						
2.1	dimensions of lifting device independent from drying plant size	const.	const.	const.	-	1	
2.2	reduced service and maintenence	0	1	3	h/a	2	
2.3	easy service and maintenence	-	accessible	-	-	3	
2.4	reduced abrasion	-	-	-	-	3	
2.5	weight	-	80	300	kg	3	
2.6	robustness	-	-	-	-	2	"robust agritechnology "
2.7	moduls: as few as possible	-	-	-	-	2	MFG complexitiy
2.8	intallation of approved standard components	-	desired	-	-	2	make or buy? Buy!
2.9	dynamic claimable	-	desired	-	-	1	
2.10	stainless steel construction	-	optional	-	-	2	due to customer requirements
2.11	modular construction (removable)	10	30	60	%	1	% of lifting device components
2.12	high automation level	100	100	100	%	1	
2.13	low cubic measure	0,2x0,2x0,1	1,0x0,8x0,3	2,0x1,5x1,0	m	3	height x width x depth
...	...	...	...	...	...	...	...
3	**economic conditions**						
3.1	expected quantitites after launch	xxx	xxx	xxx	pieces / y	4	possibly much more
3.2	material costs	xxx	xxx	xxx	Euro / piece	1	
3.3	manufacturing costs	xxx	xxx	xxx	Euro / piece	1	
3.4	productions costs	xxx	xxx	xxx	Euro / piece	1	
3.5	maintenance costs	xxx	xxx	xxx	Euro / y	1	manpower and material
3.6	sales opening	xxx	xxx	xxx	date	1	
3.7	push construction kit solutions	-	-	-	-	2	
3.8	use cost-efficient standard components	-	-	-	-	2	
3.9	fully load components	-	-	-	-	3	
3.10	reduce ware parts	-	-	-	-	3	
...	...	...	...	...	...	...	...
4	**surrounding conditions**						
	...						
5	**design & ergonomics**						
	...						
6	**safety**						
	...						
7	**others**						
	...						

Function structure plan for the lifting device

Figure 4 shows a simplified function structure plan for the lifting device, providing movement in the z-direction. This function structure plan does not include the positioning function and the displacement measurement function. These functions are included in a higher order signal function structure plan.

On receiving the signal command for a new z-position, energy conversion takes place, resulting in the forces being applied to the lifting device.

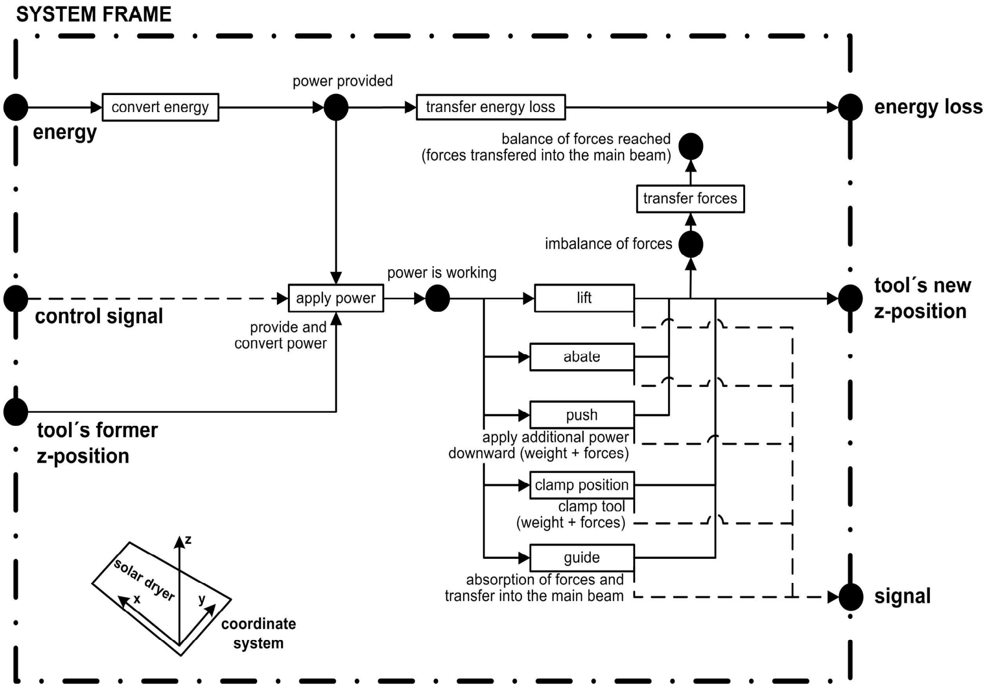

Figure 4 Simplified function structure plan for the retainer movement in the z-direction.

Design of basic solutions for the lifting device

General solutions for the sub-functions were obtained and entered on a morphological chart, **figure 5**. Sub-functions were derived directly from the function structure plan and any additional sub-functions such as “moving sense“ and “transmission of movement“ also had to be added. The morphological chart shows the relevant principles for the sub-functions “energy supply”, “convert energy into power”, “apply power”, “transmission of movement”, “lift”, “abate”, “push”, “moving sense”, “clamp” and “guidance”.

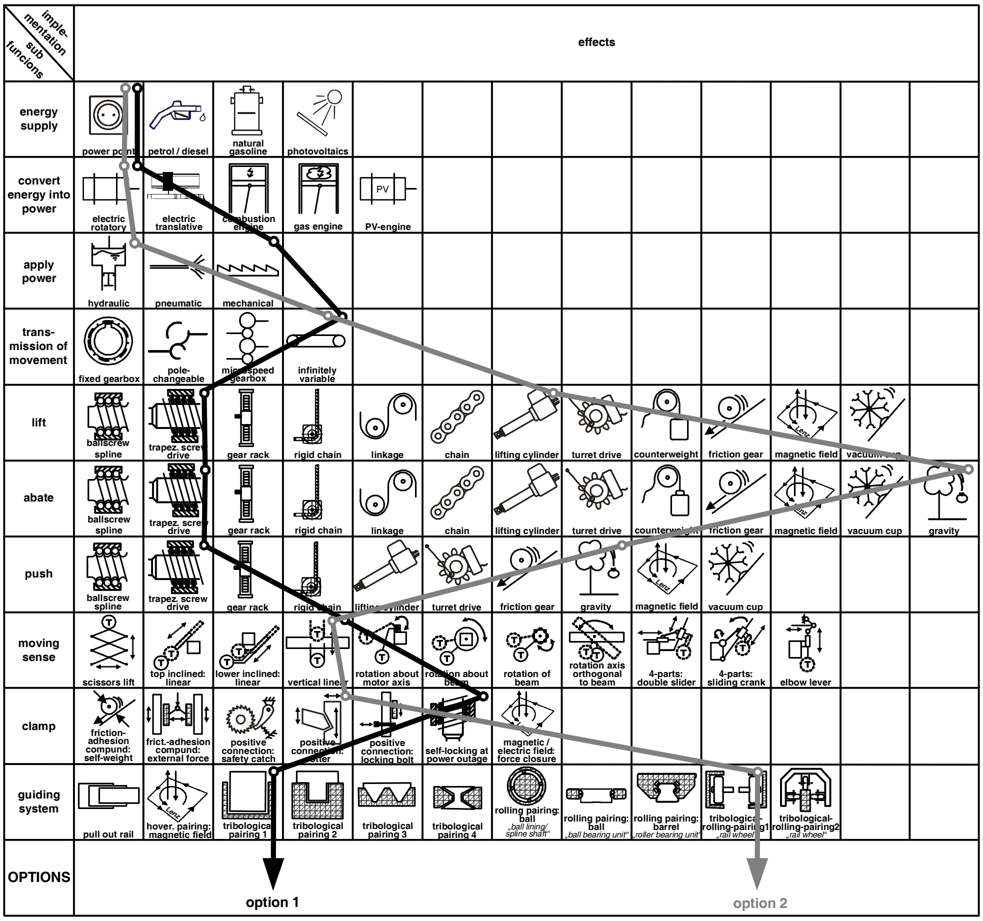

Figure 5 Morphological chart for the lifting device.

The two most suitable combinations of function principles were preselected and evaluated for technical and economic feasibility. The most suitable combination was found to be:

- An electric motor with gearbox.
- A frequency converter for fast and exact positioning and the control of electric current and torque.
- A trapezoid screw drive for lifting, abating, applying thrust and transferring axial forces.
- Vertical movement sense as the most cost- effective solution.
- Tribological pairing with U- and rectangle-profiles as the most cost-effective and robust solution for transferring torque on the x-, y- and z- axes.
- Absolute position encoder for high-precision displacement measurement.

- Inductive proximity sensors for referencing the zero-point.
- A limit switch with a roller plunger for the outer mechanical stop position.

Preliminary embodiment design of the guiding system for the lifting device

Several options for the guiding system of the lifting device and the transmission of forces have been engineered. Two of the results are shown in **figure 6**. The cost analysis shows, that the manufacturing costs of the A-version are 20 % higher than the B-version.

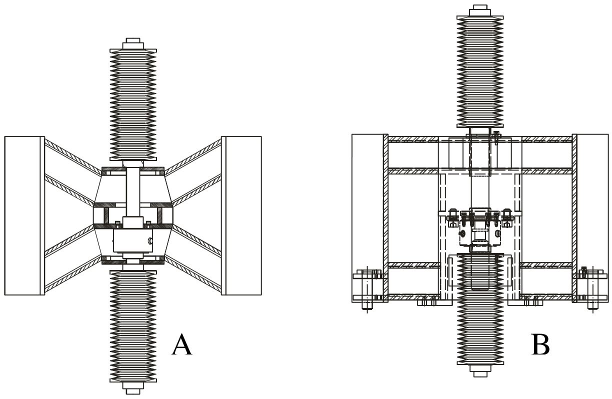

Figure 6 Assembly drawings of two alternative constructions for the guiding system.

Mechanical FEM-analyses shows, that both options had sufficient strength to withstand the expected forces and torque under standard operating conditions of less than 5 000 Nm in x- and 10 000 Nm in the y-direction. Under these conditions the A-version has a more uniform tension profile compared to the B-version and is therefore more evenly stressed. However, under extreme conditions, which would represent a maximum torque of 15 000 Nm in the x-direction and 37 500 Nm in the y-direction, the tension profile for the B-version is advantageous, figure 7. Hence, the more cost-effective B-version was chosen for the final design of the guiding system for the lifting device.

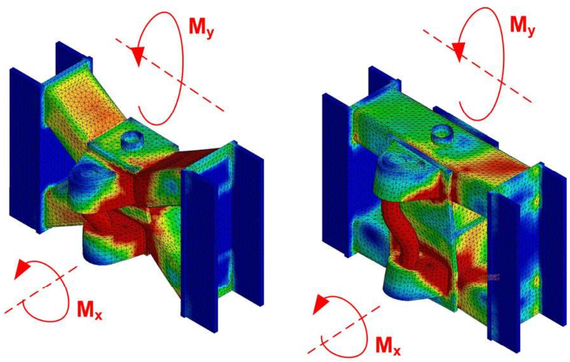

Figure 7 Stress analysis of the two selected options for the guiding system of the lifting device under maximum torque conditions (M_x = 15 000 Nm; M_y = 37 500 Nm).

Overall embodiment design of the mixing and conveying robot

Figure 8 (left) shows the overall embodiment design of the lifting device. For experimental purposes two joint rods were installed. Hence, it is possible to change the pivot angle of the conveying screw's retainer. **Figure 8** (right) shows a first prototype of the robot during an experimental run.

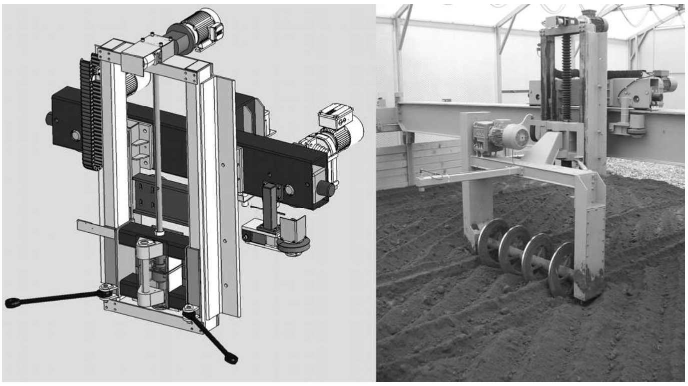

Figure 8 3D-CAD-model of the lifting device (right) and the first prototype of the mixing and conveying robot (left).

The robot is highly flexible in operation and well suited for experiments with different materials. The feed rate of the robot is continuously variable up to 30 m/min. The rotational speed of the mixing and conveying screw is continuously variable to 50 rev/min. Via the Internet, it is possible to observe and change current machine parameters. The high-precision displacement measurement system continuously monitors the x-, y- and z-coordinates of the robot position. The coordinates are sent to the main controller to be computed for the next operations of the robot. The actual status of the control software allows a fully automatic drying process with material mixing in batch and continuous modes. During the process the amount of material over the drying area is continuously monitored by ultrasonic sensors.

CONCLUSIONS

The applied methods of systematic design have proved to facilitate an objective and impartial development of a new robot for loading, unloading, mixing, distributing and collecting biogenous residuals in a solar drying plant. If during the design process the engineering options are applied in the correct sequence, a solution will be reached whereby the relevant sub-functions are equally evaluated. By using tools for 3D-construction and FEM-analysis competing technical solutions can be easily compared and technically evaluated. With additional information on the estimated production costs the decision-making process becomes easy and fast. During the first experiments with the prototype of the developed robot, it proved to be highly flexible and well suited for the intended application. The development of the mixing and conveying robot can increase the competitiveness of solar drying to conventional drying and contribute therefore to the protection of the environment.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 620.95:661.9:662.6
Prethodno priopćenje
Preliminary communication

CHANCES OF A DUAL USE IN BIOGAS PROCESSES: DEACTIVATION OF FUSARIUM SPORES THROUGHOUT FERMENTATION PROCESSES IN BIOGAS PLANTS AND SIMULTANEOUS ENERGY PRODUCTION

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SUMMARY

The Commission Regulation (EC) No 856/2005 [1] sets maximum levels of pollutants in foodstuffs. Consequently Fusarium spores within cereals are defined problematic and to get rid of in future. This inspires current research to create innovative routines of a save disposal. One pressing research approach at the University of Hohenheim is to investigate the prerequisites of a potential deactivation of Fusarium spores in a biogas process. A subsequent reduction of the contained mycotoxin (Deoxynivalenol) throughout the fermentation process is desired.

Varying parameters of temperature, infection rate and time created surrounding conditions which performed a convenient potentiality of spore deactivation. The process is attended by a simultaneous production of biogas. This appears as an alternative way of disposal creating clean high grade energy simultaneously. For Germany an infected quantity of approximately 3.8 Mio. t/a at a sixfold higher annual yield of cereals (FAOstat, 2005) are potential to be decontaminated adapting the promising approach.

***Key words**: Aborticide, Biogas, Deoxynivalenol, Fusarium, Reduction*

INTRODUCTION

As a global dissemination of *Fusarium* toxins has recently been reported for cereals (JECFA, 2000. 2001), a quick contamination within the group of grain containing food is to be expected. The Food and Agricultural Organisation of the United Nations (FAO) has been estimating 25% of the world's crops to be contaminated with intermediate catabolic products. An infected quantity of approximately 3.8 Mio. t/a is listed for Germany (FAOstat, 2005). To prevent these toxins from being spread into the human food chain, the European Community launched a regulation, providing maximum levels of contaminants. One of the chances lies in cereal combustion of contaminated charges, which has to be authorised by regional authorities due to the creation of unfavourable emissions. Additionally this requires a preliminary drying of the contaminated cereal charges which negatively affects the energy balance calculation for combustion. Another productive option is given by using a biogas process for a potential energy saving deactivation of toxic substances. The exhaustive deactivation of all suspicious substances contained is to be granted. That prevents a further distribution of spores and toxins of the contaminant, placing formerly moulded material back in circulation of the food chain.

For this, the design of this research approach was set to modify fermentation in order to gain the aforementioned deactivation of the anti nutritives, named. The most promising approach is based on the decomposition capacity of the rumen. Since years the so called "Hohenheimer Gastest", which determines feed values by using rumen liquid, is the basis of the Biogas yield test. Since the physiological character of the rumen is capable inactivating or transforming defined amounts of *Deoxynivalenol* (DON) by means of the infusoria of the rumen (KING et. al., 1984). Analysis proved rumen liquid causing the transformation of 10mg DON into 3,7,15-trihydroxy-trichotec-9,12-die-8on (DOM-1), which is a far less toxic substance (SCHUH, 1996). A daily ingestion of DON (0.5mg/kg DM feed) causes clinical effects for fatlings. The concentration of DON permitted was reduced by 45% for purified wheat (BUSCHHAUS und ELLNER, 1999). If the microbiological environment of the rumen represents a proper basis for the process of deactivation, the respective micro organisms are as well to be found in manure and faeces.

METHODS

Process

For a potential deactivation of *Fusarium* and the further aborticide of *Fusaria* spores during the fermentation process, a sample of inoculated wheat was set into test conditions. Whereas the inoculated wheat batches were received from cultivation experiments of the *State Institute of Plant Breeding* of the University of Hohenheim. In order to investigate the impact factor of the kernel´s pattern, both physical appearances (ground and entire kernels) were set into the trial.

Inoculation

The inoculation procedure is characterized by conidia, produced on a wheat-grain media. A suspension of $5x10^5$ spores mLm^{-1} was applied in the evening at a rate of $100mLm^{-2}$ at the time of cereals flowering, using a portable sprayer. All genotypes were inoculated simultaneously at different dates to permit a variation of the flowering date (Miedaner et al., 2004).

Midget Batch Trial - Hohenheim Biogas Yield Test (HBT)

For the evaluation of biogas potentials, one option is given determining the available CH_4 yield of standard inoculated manure while the specimen is conducting the HBT. Ground and screened specimen is set into flask samplers with a volume of 100 ml. For the process, the hermetic bins are used as midget biogas fermenter vessels with a charge of standard manure [30 ml] and test substrate [500 mg] (figure 1a). To detect minor differences of the contained nutrients and concentrations of toxins, the physically damaged and highly contaminated kernels were selected by conducting sieve analyses (2.5-3 mm). Determining the dry matter content, a representative sample is taken from the fresh substrate and further treated with 60°C for 48h. The entirety of the samples is further set up in an incubator (37° C for a mesophilic, 53° C for a thermophilic temperature range) which has been amended with an integrated wheel, rotating vertically with a slow and constant speed. This provides an appropriate mélange of the samples without producing a disadvantageous precipitation of the contained dry measure.

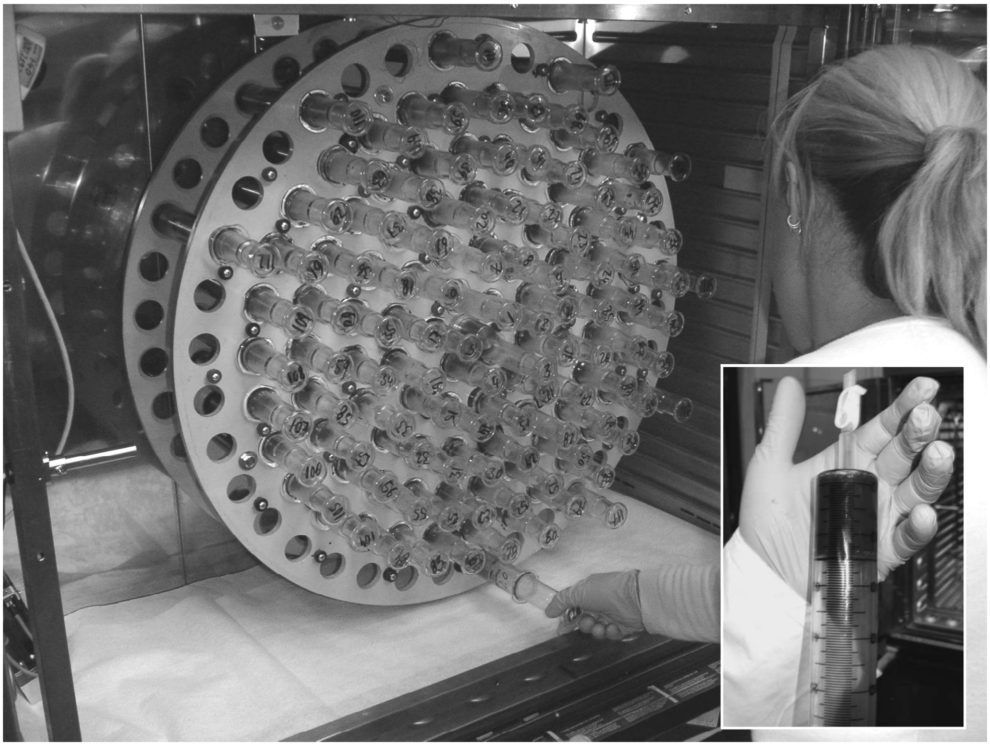


Fig. 1a & 1b Preparation of mini batch fermenter, arrangement of incubator

The applied liquid manure is necessary and imperative to fit defined standards whereas the pattern of a standard range of viable manure is specified by a handbook of manure care for biogas yield tests (HBT handbook, 2001). As the specimen is remaining in the HBT trial, the volume of CH_4 is determined after a minimum gas-production of 20ml. The concentration of CH_4 is measured by means of a infrared sensor (Advanced Gasmitter, Infrared Advanced Gasmitter with implemented barometric pressure compensation).

Fusaria detection by identification

A microbiological reconditioning and the detection of still viable and augmentable *Fusarium* spores after the fermentation is tested with Schmidt agar plates and a subsequent visual appearance as macro or micro conidia. The characteristics of the measurand are documented with the dismounting of flask samplers (retention period 0.5 to 36 days). The quantification of affection by moulds is determined before and after fermentation trials by detection of infection rate and colony-forming units (CFU) on culture media.

Siting of Cultures

At the beginning of the trial an additional colony is applied on Petri dishes in order to verify the rate of the currently contained *Fusarium.*

To determine the infection rate 9 samples are taken from the incubator at specified retention times. The extracted grains are washed in sodium-hyper-chloride before they are exposed on the culture media. This procedure is inevitable to remove the concomitant microbiological flora. Per each discharge, 90 kernels are exposed on 9 Petri dishes, containing Schmidt agar (containing terracyclin).

To determine the CFU, 1 mg of fermented manure including ground substrate is depleted with 9 mg of sodium chloride and exposed on the culture media.

This is accompanied by a dilution series. First dilution grade is derived by preparing 100 µl sodium chloride to 1mg of liquid with the fermented manure. After plating, samples of the two different treatments (temperature) are stored at 28°C and a minimum residence time of 8 days in a micro-aerophile incubator.

Date evaluation

To reveal appearance or rather non-appearance of *Fusarium* in reliance of residence time, an additional micro-visual analysis became necessary. A randomly taken piece of the examined *Mycelium* is positioned on a drop of water. The main criteria of a positive identification is confirmed if the observed test object shows a reddish to yellowish *Mycelium* and appears with crescent-shaped spores.

RESULTS

Microbiological interpretation

The shown results are representing the quantity of colonies with respect to their retention time and applied temperature within the incubators of the HBT. The dataset of the infection rate (numerous) was evaluated for moulds in order to rate the competition of growth among them, deriving an impact factor on the dispersion of *Fusarium*.

Tab. 1: Temperature-time influence on infection rate [microbial count]

mesophile fermentation: 37°C	**before fermentation**	**after 0,5days of fermentation**	**after 12 days of fermentation**	**after 36 days of fermentation**
total moulds	100%	50%	40%	10%
thereof fusarium	100%	0%	0%	0%
thermophile fermentation: 53°C	**before fermentation**	**after 0,5days of fermentation**	**after 12 days of fermentation**	**after 36 days of fermentation**
total moulds	100%	0%	0%	0%
thereof fusarium	100%	0%	0%	0%

The CFU is not displayed, revealing a similar pattern like the above.

The suspicion of an aborticide of *Fusarium* by means of the biogas fermentation could be underlined from first results. The infection of unfermented material comprises a rate of 100 percent, caused by an expeditious domination of Fusarium on the respective inoculated kernels. After a retention time of 0.5 days the extraction and examination showed no proof of *Fusarium spores*. Consequently an inactivation could be achieved after a short period of approved new data. The germination capacity of the mesophile assay shows the affection for a medial temperature range. Per contra it seems as if yeasts are favouring ruggedised ambient temperature.

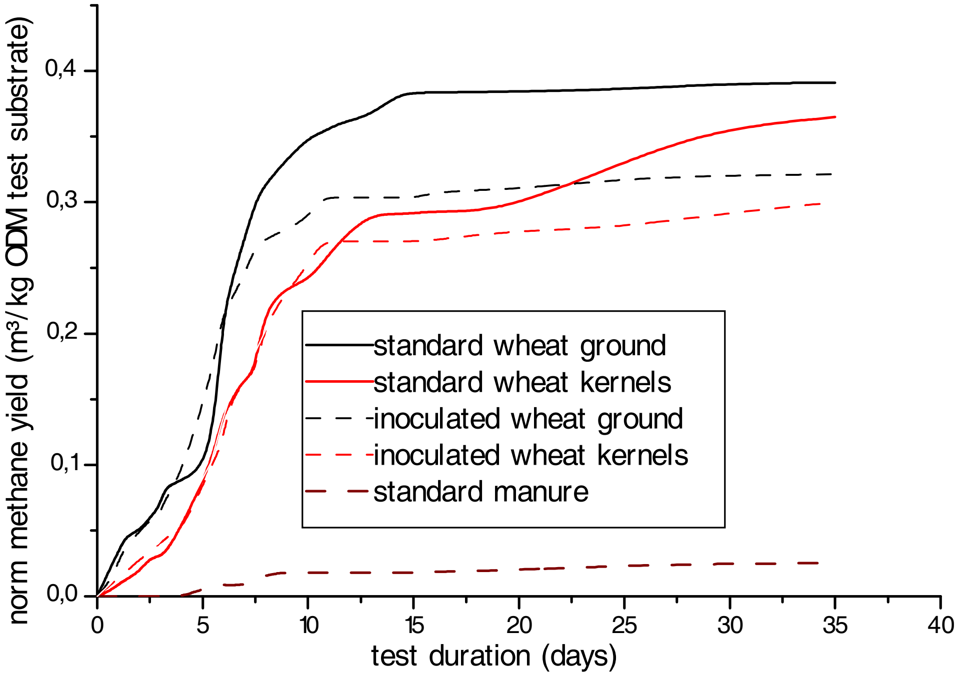
Outlining the aforementioned analysis, it is hypothesis that a growth competition of moulds and yeasts, which were also detected, results from poor conditions throughout the fermentation process. An antagonistic growth competition between moulds and yeasts could be stated. This is emphasized by metabolites which are being formed respectively. The discovered inhibitory effect was found characteristic for numerous agar plates, where colonies of yeasts were predominant and no increase within the formed corona of moulds could be found.

Process interpretation

Regarding the process yield, no significant differences among standard substrate and the contaminated specimen could be found. According to other curve progressions, the set of “standard wheat (ground)” shows a relatively higher yield. One explanation could be the declining of ingredients: thousand-seed weight differs from (mean) 0.043g for normal kernel to (mean) 0.03g for contaminated kernels (LfL, Bayern, 2005).

The Weender/van Soest analysis showed different contents of crude protein within the added wheat. The moulded material showed a medial extent of 4% plus (including the cell components, enriched with micro-protein). Under the impact of a present fungus the decomposition of the kernels showed an easing of the digestion within the biogas process.

Concluding, it might be stated that the biogas forming process (HBT) is not affected adversely by the addition of a microbiological contaminated charge. The addition of this material leads to inhomogeneous samples. Therefore variation of individual cases could be explained.



DISCUSSION

After fermentation of the contaminated grain, neither *Fusarium hyphea* nor their geminable spores could be detected due to terms and conditions prevailing in biogas vessels. Moulds and yeasts find themselves in an inferior position compared to microorganisms, which are inevitable for the biogas process. The conditions of growth and reproduction are differing relative to water activity and the availability of oxygen. The acquired pH value of 8.36 was discovered to high for effective growth. The thermal treatment of temperatures beyond 30° C and a particular absence of oxygen deleted germination capacity.

Fusarium needs a consistent surface in order to grow in hydrogenous ambiance (Kaltwasser, 1980). These requirements were not to be implicated by a media as the liquid manure. The retention time showed no effect on the further appearance of *Fusarium*. The *Mycelium* and the residues of the *hyphea* were found nonviable in the disposing milieu and were probably abolished by hydrolytic bacteria.

Another aspect is given by the negative effect of escharotic substances, emerging from the biogas process, hydrosulphide e.g., which affects the sensitive conidia. Confirmed permanent moulds (like *Ascospores*) are capable to outlast, or even regerminate after exposure on culture media. The mesophile fungus performs its optimum of growth at 22°C - 28°C.

CONCLUSIONS

Primary results of the interdisciplinary approach showed a reasonable potential deactivating *Fusaria* within inoculated cereals. By means of the HBT batch trial it could be stated, that theamined biogas process was found stable in respect to the addition of contaminated charges. The analogy of the currently driven trials to the natural activity of a rumen is to be underlined concerning an effective handling of the contaminants. These first results have to be verified further improving basic process parameters (temperature, dry matter content of the process, fermentation process alternatives). A further analysis of the metabolic procedure, by means of the aforementioned parameters of process control is imperative. Thus the authorized maximum levels of contaminants are expected to be performed due to this innovative alternative of a contaminant disposal under suitable biogas production. For Germany an infected quantity of approximately 3.8 Mio. t/a at a sixfold higher annual yield of cereals (FAOstat, 2005) are potential to be decontaminated adapting the promising approach. In contrast, the preliminary drying for a further energy processing in cereal combustion means a removal of varying water contents off the kernel and therefore a constraint of energy yield.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.171:551.58
Stručni rad
Expert paper

AGRICULTURAL MACHINERY RESEARCH TO REDUCE EXTREME EFFECTS OF CLIMATE CHANGE

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SUMMARY

The extreme changes in climate characteristics experienced in the recent years require the increasing the efficiency of cultivation and the precision of operations, and also require the application of environment, soil, and atmosphere-friendly technologies, renewable energy and materials.

For keeping and increasing the traceability a reliable and high-standard agricultural production is needed which is able to meet the increasing quality challenges even under extreme weather conditions.

To facilitate the sustainable agriculture it is needed to be aware of the conditions and possibilities of soil and machines.

To assure the quality it is necessary to use the capabilities of information technology, new tractor and implement improvements to harmonize the conditions and operations of cultivation.

In our research program we are examining the corn stover harvesting technologies, the relations of soil electric conductivity to soil properties and we had field test to define the advantages of CVT transmissions. In this paper we will introduce the state of our researches.

Keywords: *climate change, renewable materials, CVT transmissions, intelligent implements*

INTRODUCTION

The effect of human action on climate change is not proven yet. But since the mankind produces environment-impairing materials, the change of the environment, such as climate is conspicuous. One of the possibilities of preventing climate change is the use of renewable materials. Agricultural by-products are a great part of these energy resources.

Rice- and cereal straws, corn stover contain cellulose, they can be used in the cellulose- and paper industry, production of bioetanol and biogas, and firing. These materials have the advantage of renewing: the organic matter accumulating in these materials after the utilization gets back in the nature and renews, attaining material circulation, which is necessary for keeping sustainable development.

The last years experiences of the extreme effects of climate change points on the need to find the agricultural technologies of tomorrow to reduce working times by the changed production conditions. Developing intelligent tractors and tillage machines, agricultural production will be able to respond to every change in short time. The mayor requirement of these machine systems is the perfect synchronization of tractor, implement and soil. The synchronization of tractor and implement is now available with the standardized ISOBUS communication system, but till yet the tractors and implements have not reached the technology level to utilize the full range of advantages of this system.

With the research projects of our institute we are searching for solutions to reduce climate destructive greenhouse-gas production, and to increase the efficiency of agricultural production through the research of application possibilities of agricultural by-products and through the development of tractor and implement improvements.

Application of agricultural by products

Classifying residues of agricultural plant-growing worldwide by amount, the order is rice straw (731Mt), wheat straw (529Mt) and corn stover (520Mt), in Europe wheat straw (170Mt), barley straw (76,8Mt) and corn stover (62,4Mt), in Hungary corn stover is the most abundant crop residue (8-10Mt) produced annually. Harvesting and storing of cereal straws are provided, but we can't tell it about corn stover [Seungdo-Bruce, 2004].

With incoming of large-scale corn growing problems of harvesting and storing corn stover didn't come out. There are a lot of researchers, who studied problems of corn stover utilization, but there aren't still widespread technologies and machinery. Therewith we don't have adequate information of characteristics of corn stover, which we need to plan technologies and machinery of the utilization. Typical is referring to the characteristics of other fibrous material [Sokhansanj et al. 2002].

There are essentially two technologies for harvesting and storing corn stover: dry and wet technology. So in the dry technology corn stover is harvested and stored in dry condition, in the wet technology wet material is harvested and stored. Basic operations of corn stover harvest are: cutting, chopping, windrowing, densifying, loading, hauling and storing. The most problematic objectives of this are cutting and windrowing. We run on corn stover as by-product, so we must adjust to the harvest of corn grain as main product.

The most corn is harvested as grain. Between the corn harvesting technologies corn stover is utilized only in the full crop chopping. In the other methods, including grain harvest too, corn is harvested with corn heads, which parts cobs and stalks and leaves stalks on the field half broken or shredded. Combines, tractors and lorries tread this corn stover in the ground. So corn stover can be harvested with low efficiency (max. 25%) and very contaminated in this way. It could be very advantageous, if the harvesting machines didn't tread corn stover in the ground, but cutting and windrowing came off together with cob breaking. Thereto corn head must be modified or with additional machines equip. Thereupon started up different solutions [Nagy et al. 1983].

Rotary knifes below stalk rolls are nowadays frequently solution, too (Claas, Geringhoff, John Deere, Oros corn heads), which can cut and windrow corn stover, when the rotation direction is changed. But rotary knife shredder is not able to harvest clean and great deal of corn stover, because just 30-40% of the stover yield can be picked up from its windrow and that stover is contaminated (not capable to foraging) [Jován-Tóth, 1985].

Another below corn head solution is the RR machine, which includes alternating scythe and stover auger, which can cut and windrow corn stover. The alternating scythe cuts stalks before cob braking and after this auger brings the stalks to the middle and makes a windrow below the swelling of the combine. This machine could cut and windrow 80% of the stover, cleanly, so that is capable to foraging, too. Problems occurred with its trouble proof, because the machine couldn't see it, so couldn't set the cutting height, couldn't see choking, etc., and by the augers this machine had too large height. These problems can be solved with separate hanging and cutting height control or soil control. Size can be reduced with build in of belt conveyor instead of auger [Nagy-Gáts, 1983].

A new corn head is SKB, which cut the whole crop, stalk rolls and breaking laths break cobs as conventional, and a stalk auger brings the stalks to the middle and windrows below the swelling of the combine. This corn head was able to windrowing 80% of the stover and worked very cleanly. Problems are occurring with choking, because entire stalks get in the stalk auger. This could solve with a stalk chopping equipment between the stalk rolls and the stalk auger [Tóth-Mészáros, 1989].

We can copy the cereal harvest, too. Modifying the cereal platform, corn can be cut with low cutting loss. So stover comes over the combine, and thereafter it can be raked in windrows, chopped or baled with endchopper (Case-IH, I-15) or endbaler (Claas Columbus). This solution has the disadvantage, that stover pushes up to demand of the threshing drum, and power requirement of endchopper or endbaler apply load on the engine, too. So the energy consumption of the harvest increases and velocity abates [Shinners-Binversie].

Development of transmission simulation methods

The tractor transmission system has been changed from the single sliding gear type to the electro-hydraulic and power shift and finally to the CVT types. The new system could be a variator or a hydrostatic power selection type, which have a capability to find the best speed value required by the implement in order to work at the optimum drawbar power [Renius-Resch, 2002]. About 30 years ago, nearly all manufacturers have already conducted a series of experiments with step less transmissions as an alternative to the Power Shift transmissions which had come to be standard in practice in tractor constructions [Lober, 2001].

The analysis of a transmission system in a tractor is difficult, time-consuming and expensive task. Nowadays the computer simulation gives a really efficient tool to analyze a new development or an existing machine. The last year executed filed- and bench test this year we extended with the computer simulation of power trains with power shift and continuously variable transmission. The developed simulation program gives a really efficient tool with the real time presentation of the parameters of power train (rpm, speed, ratio, fuel consumption, etc.) to analyze and comparison and interpretation of different power train.

Soil condition mapping for implement control

The development of tillage machines to the way of producing intelligent implements is going slowly. The grounds for the technologies of these machines are not available yet. There is a great need for research projects to improve these developments.

The basic requirement to operate and control these tillage machines a soil condition map has to be created, which gives reliable information about the physical state of soil. To generate these maps we need to create the methods for defining and controlling exactly the properties of soil. Without the calibrated plough, the earlier normalized Sack soil-resistance concept can't be defined. Around the world the researches for new method and instrument, which can be normalized, proceeds in two directions: the measure of tool resistance, and the measure of soil electric or magnetic conductivity.

It's obvious to measure the implement resistance in situ with the tractors hitch controlling system. But we need a calibration for every tool to compare the relative values, if we won't make the mistake like by the Sack-method. The measuring of soil electrical conductivity is a more preferred method for normalization, because we can use a well-defined system, which results a more comparable output. The disadvantage is that we need an expensive system. Because of these arguments, we decided to study the relations between soil electrical conductivity and physical properties to create the theoretical grounds of soil condition maps.

MATERIALS AND METHODS

Tested tractors

The field tests for expecting tractor transmissions were done on CASE CS 150 and CASE CVX 150 type tractors. The CASE CS 150 has a SYNCROMESH 4 range gears electro hydraulic controlled Power Shift transmission, which has 4 range gears with 6 synchronised gears included. The Steyr hydrostatic-mechanic power split, step less transmission is used in the CASE CVX 150 tractors. The investigated tractors – because of the test methods developed by us – have same engine power ($P_{nom.}$=108 kW), tire dimension and pressure, and their axial load was also the same by extra weighting. Due to these specifications the tested tractors were the same only the transmission was different.

Transmission test methods

The investigation of driving systems of tractors is a complex, time-consuming and costly project and can be completed by field or bench tests. Traditionally these tests are based on measurement, but the result of the new development of information technology, the simulation method can be extended to all levels of the driving system examinations. This new method can be cost saving and give a chance to optimize the testing system [Farkas et.al. 2003].

There was a program for the field test developed, which is a first step of the complete comparison. The two basic level of the examination series are the tractor drawbar test and tractor-implement test. The tractor-implement test level was also separated to transport test, high power operation - and PTO operation test.

The transport test was prepared on a special flat field test track (Cegléd Cifrakert). The test track contains wheat stubble section, ground section and concrete section.

Measuring soil EC using Veris system

Conductivity is a measure of the ability of a material to transmit (conduct) an electrical charge. It is an intrinsic property of the material just like other material properties such as density or porosity. The usefulness of soil conductivity systems comes from the fact that sands have a low conductivity, silts have a medium conductivity and clays have a high conductivity. [Lund, et al., 1999] Consequently, conductivity (measured at low frequencies) correlates strongly to soil grain size and texture also. [Williams and Hoey, 1987]

To measure the electric conductivity of soil we decided to obtain the vehicle pulled soil electric conductivity measuring system Veris3100. As the Veris measure cart is pulled through the field, one pair of six coulter-electrodes injects a current into the soil, while the other coulter-electrodes measure the resulting voltage. Although the coulter-electrodes only need to penetrate the soil a few centimeters, the signal arrays penetrate up to 80cm deep into the soil. The Veris3100 gives information about the soil EC, associated with geographic coordinates (obtained from onboard DGPS receiver), in the shallow (0-30cm) and deep (30-80cm) layer of the soil. The system records these conductivity measurements and geo-references them using a GPS. When used on 15 to 20m swaths at speeds up to 12km/h, the system produces between 40 and 100 samples per ha. [Lund, et al., 2000]

Our concept was to create a soil condition map by measuring the soil electrical conductivity together with other soil properties to find relations between these characteristics.

The first study was made in April 2004 before seedbed making, the second in October 2004 after harvesting. Table1 shows the specifications of these studies.

Table 1 Study specifications

No. of study	Date	Weather condition	Studied attributes
1.	2004.04.30	Dry, sunny, 28^{o}C	- electric conductivity - humidity - chemical properties - physical properties
2.	2004.10.03	Dry, windy, 25^{o}C	- electric conductivity - humidity - penetration resistance - physical properties

The study was done on a 20 ha field of Róna Ltd. at Szabadszállás, Hungary. We measured soil electric conductivity with Veris 3100 system, GPS geographic coordinates with Trimble AgGPS system, soil humidity with TDR-300 and soil penetration resistance with Eijkelkamp Penetrologger. We used soil samples made with Eijkelkamp undisturbed soil sampler, to calibrate the humidity measured with TDR-300 and to get information about the density and porosity. Laboratory test was made to study the chemical properties of soil, like PH, humus percentage and mineral composition.

RESULTS AND DISCUSSION

The developed transmission simulation program

To analyze and present the data of transmission field test, simulation software was developed. In the user interface, two diagrams are displaying the engine characteristics, and fuel consumption data is indicated when in operation. The actual values of the measured and calculated data (e.g.: transmission ratio, distance) can be followed also numerically. The speed as a function of rpm or the speed as a function of time or the transmission ratio as a function of time or the rpm as a function of time or the fuel intake as a function of distance can be analyzed by selecting one of these diagrams.

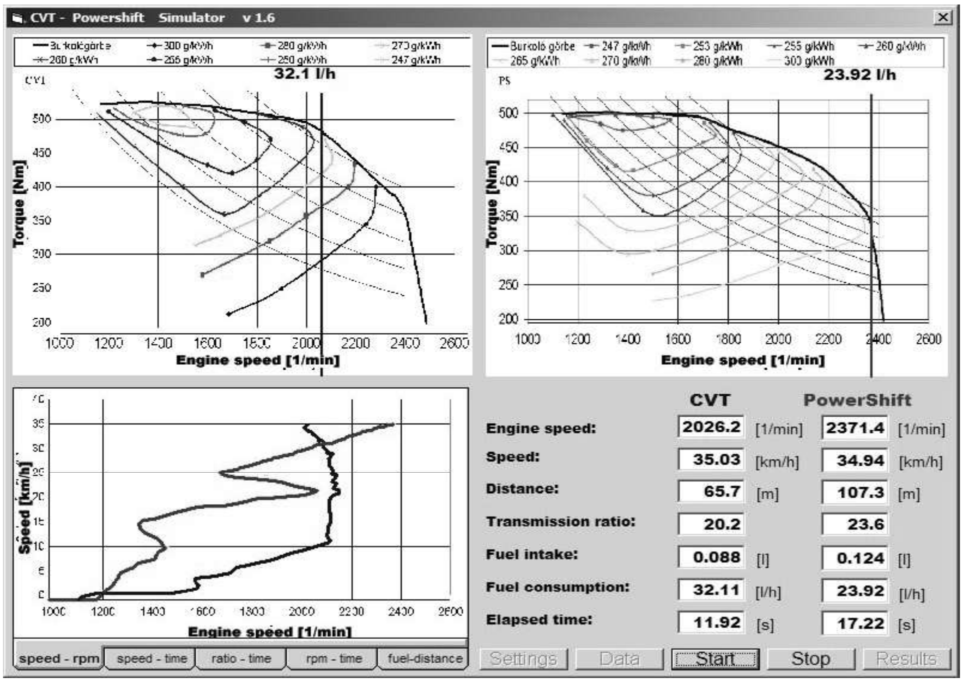

Figure 1 User interface of the developed simulation software

Results of electric conductivity measurements

The first study for measuring electric conductivity of soil was done in April 2004. We inspected the research field before the seedbed making. Because of the high number and geo-coordinate attributes, we processed the data with GIS systems, and represented in thematic map form.

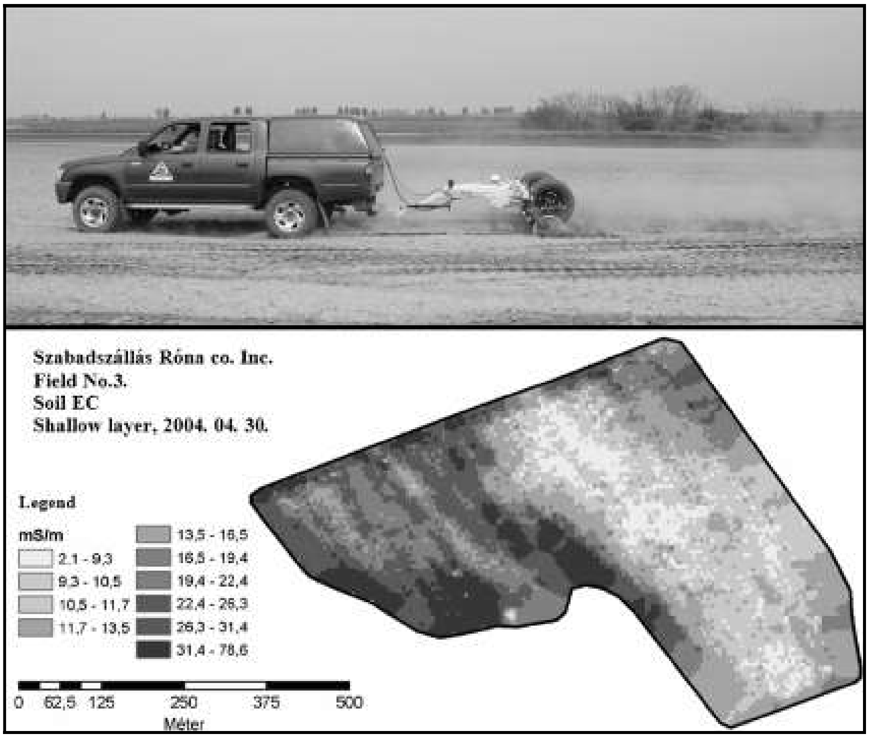

Figure 2 Soil EC measurement and thematic map of results

In comparison between shallow and deep layer data, we realized, that deep layer values are varying between wide limits, possible cause of this could be, that cultivation in the top layer does a homogenization in the soil structure.

We compared the shallow layer soil EC data with soil pH and humus content. This comparison has shown that the soil EC correlates with humus content, but it is not foreseeable how these parameters influence each other. Soil pH and soil EC don't correlate, but we have to take in account, that on this field the pH values were very balanced. The values were within a range from 8,3 to 8,9 in the H_2O suspension. This range is almost the exact range of average alkaline reaction of soil. With the examination of the chemical, physical and EC properties of soil, we studied the possibility of determining the eco-potential of the field. There is a chance for using this advanced property of soil instead of the conventional methods to determine the quality of the fields. With the available GIS systems there is a possibility for making eco-potential maps and with the GPS guided intelligent machines this could be a very efficient way for soil-management. The determining of eco-potential using the Veris system needs an exact definition of the relation between soil EC and other soil properties. Because of this we continued our study with the examination of these relations.

Between the two studies green peas and sunflower were grown on the field, which were harvested before the second measurement. In the first study the whole field was seedbed in the second study the one part of the field was cultivated stubble, the other part non-cultivated stubble.

After the harvesting in October we made another study on the research field. We compared the soil EC data with them of the first study, made in spring. The examination shows, that significant soil EC changes are only in the shallow layer of soil. There was no sub drill cultivation on the field since the first measurement, therefore it can be stated, that electric conductivity is related to cultivation.

Examination of the metered data has shown that on the non cultivated part, where the humidity was 30% lower and related on this, the penetration resistance was 150-200% higher than on the other part, significant decrease of soil EC was observable. This points on the fact that soil EC is related with soil humidity. This gives that soil EC measurement need soil humidity calibration.

To find relations between soil EC and other soil properties needs more examination. We suppose that soil EC is related with the non obvious soil properties, like cohesiveness, porosity etc.

CONCLUSIONS

Summarized the results were getting from the researches the following conclusions can be drawn:

- Corn stover is an abundant feedstock worldwide and in Europe, too. As biomass, the utilization of corn stover can reduce the effects and causes of climate change,
- Information about characteristics of corn stover are awaiting in the literature, they must be determinate before planning the utilization technology and machinery.
- The created method and simulation program for tractor transmissions is applicable to compare the tractors with different transmissions systems, the tractors with CVT have better acceleration behavior and lower fuel consumption,
- the difference between the Power Shift and CVT in the case of loaded test conditions were the most significant,
- By modeling of tractor transmission systems and using experimental parameters the simulation of the transmission types in operation have been achieved. By the application of the experimental results and the simulation model the optimization of the operational parameters can be accomplished for Power Shift and CVT transmissions.
- The methods for exploring the relations between soil electric conductivity and soil physical properties had to be developed. There is a need for studying another soil physical properties, like clod size, water holding capacity etc.,

- It’s required to make further studies to analyze the relations between soil EC and soil homogeneity, but it’s foreseeable, that there is a close coherence between these parameters. Through this it’s observable, that the Veris 3100 system is able to indicate the soil homogeneity,
- The soil humus-content has an influence on soil EC, but from the result getting till now the relations between these parameters can’t be defined,
- Results of the studies suggest that the soil humidity is in coherence with the soil EC. It’s presumable, that soil EC measurements need humidity calibration,
- Results of our study suggest, that the Veris3100 system is able to determine the soil physical properties, but there is a need for another researches to verify this statement.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

ZBRINJAVANJE RABLJENOG ULJA NA OBITELJSKIM GOSPODARSTVIMA

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SAŽETAK

Suvremena poljoprivredna proizvodnja podrazumijeva primjenu visoko sofisticiranih strojeva velikog učinka, visoke uporabne pouzdanosti uz maksimalno očuvanje okoliša. Obiteljska gospodarstva posjeduju veliki broj sredstava poljoprivredne mehanizacije i upravo pravilne mjere servisno-preventivnog održavanja te pravilno zbrinjavanje rabljenog motornog ulja i ostalog otpada značajno utječu na očuvanje okoliša. U radu je predočeno istraživanje provedeno na obiteljskim gospodarstvima u Vukovarsko-srijemskoj županiji i Osječko-baranjskoj županiji glede zbrinjavanja rabljenog ulja i ostalog opasnog otpada. Dobiveni rezultati ukazuju na nekvalitetno zbrinjavanje rabljenog motornog ulja, ulja iz transmisije, plastične ambalaže i ostalog otpada što predstavlja veliki ekološki problem i ukazuju na nužnost primjene postojećih zakonskih normi. Nadalje, istraživanjem je utvrđena visoka prosječna starosna dob poljoprivrednih traktora, velika rascjepkanost proizvodnih površina te mali broj vlasnika obiteljskih gospodarstava s poljoprivredom naobrazbom (svega 23,63% vlasnika).

Ključne riječi: *servisno-preventivno održavanje, rabljena ulja, okoliš*

UVOD

Današnja, intenzivna i tržišno konkurentna poljoprivredna proizvodnja, uz primjenu suvremenih znanstveno-stručnih dostignuća, uporabu sjemenskog materijala koji osigurava vrhunske prinose te veliku mehaniziranost podrazumijeva maksimalno očuvanje okoliša.

Obiteljska gospodarstva posjeduju veliki broj starijih sredstava poljoprivredne mehanizacije (14,5 godina prosječna starost traktora) što uz neodgovarajuće provođenje mjera servisno-preventivnog održavanja dovodi do veće učestalosti kvarova, smanjenja učinka i smanjenja uporabne pouzdanosti, napominju Jurić i dr. (2001), Emert i dr (1996). Stoga bi trebalo posebnu pozornost posvetiti educiranju vlasnika poljoprivrednih strojeva o značaju servisno-preventivnog održavanja kako radi već navedenih razloga tako i zbog povećanja sigurnosti prometa u kojem sudjeluju poljoprivredni strojevi, Jurić i dr. (2001).

Značajan problem glede zaštite okoliša čini problematika zbrinjavanja i postupanja sa rabljenim motornim uljem te drugim otpadom. Iako je postupanje s otpadnim uljem zakonski regulirano («Narodne novine» br. 27/96), na još uvijek neadekvatno zbrinjavanje ulja ukazuju Emert i dr. (1998) navodeći da se prema provedenom istraživanju čak 35% otpadnih ulja iskorištava kao sekundarno gorivo, a ostalih 65% se uglavnom odbacuje. Dobar dio obiteljskih gospodarstava rabljeno motorno ulje upotrebljava pri tehničkoj zaštiti poljoprivrednih strojeva, što nije dozvoljeno, budući da ista imaju određeni sadržaj sumpornih kiselina koje nagrizaju metal i izazivaju koroziju. Ispuštanje ulja na proizvodnim površinama osim onečišćenja tla ima za posljedicu i onečišćenje podzemnih voda. Plastična ambalaža u kojoj je pakirano ulje, zamijenjeni pročistači za ulje, stare traktorske gume i drugi otpad ukoliko nisu zbrinuti na Zakonom propisan način čine vrlo značajan problem glede očuvanja okoliša.

METODIKA I CILJ ISTRAŽIVANJA

Obavljeno istraživanje imalo je za cilj utvrditi postupke zbrinjavanja rabljenog motornog ulja, zamijenjenih pročistača za ulje i plastične ambalaže. Istraživanje je dio kompleksnog istraživanja koje se obavlja na obiteljskim gospodarstvima u različitim županijama Republike Hrvatske.

Istraživanje je obavljeno anketiranjem 20 obiteljskih gospodarstava u selu Dalj u Osječko – baranjskoj županiji te 35 obiteljskih gospodarstava u pet sela Vukovarsko-srijemske županije: Ivankovo, Nuštar, Privlaka, Otok i Cerna. Dobiveni rezultati imaju indikativni karakter budući su dobiveni na temelju subjektivne prosudbe vlasnika obiteljskih gospodarstava. Anketni list je sadržavao 30 pitanja.

REZULTATI ISTRAŽIVANJA

Dvadeset obiteljskih gospodarstava u selu Dalj svoju djelatnost obavlja na ukupno 418,5 ha oraničnih površina podijeljenih u 306 katastarskih čestica, tako da veličina prosječne čestice iznosi 1,36 ha. Veličina obradivih površina pojedinih obiteljskih gospodarstava kreće se od 2 ha do 70 ha. U vlasništvu anketiranih obiteljskih gospodarstava nalazi se ukupno 34 traktora različitih snaga i tipova. Prosječna starost traktora iznosi 20,11 godina, gdje je najnovije nabavljeni traktor proizveden 2003. godine, dok je najstariji traktor proizveden daleke 1967. godine. Nemogućnost kupovine novih traktora vlasnici obiteljskih gospodarstava argumentiraju nepovoljnim stanjem u poljoprivredi te još uvijek teško prihvatljivim uvjetima kreditiranja.

Tehnički pregled učinjen je za sva 34 traktora, a razlog ovome vlasnici obiteljskih gospodarstva navode visoke novčane kazne za neregistrirane traktore. Većinu traktora vlasnici su kupili kao polovne traktore bez potrebite tehničke dokumentacije i bez obuke nužne za rad s novim strojem. Servise izvan jamstvenog roka samostalno obavlja čak 90 % vlasnika obiteljskih gospodarstava.

Zabrinjavajuća je obrazovna struktura vlasnika obiteljskih gospodarstava gdje je svega 15% vlasnika obiteljskih gospodarstava poljoprivredne struke (1 diplomirani inženjer poljoprivrede, jedan inženjer poljoprivrede i jedan vlasnik ima SSS spremu poljoprivredne struke), dok ostali vlasnici imaju neku drugu naobrazbu.

35 anketiranih obiteljskih gospodarstava na području Vukovarsko-srijemske županije svoje djelatnosti obavlja na 1624 ha oraničnih površina koje su raspoređene na 566 katastarskih čestica tako da prosječna veličina čestice iznosi 2,86 ha. Veličina obradivih površina se kreće od 3ha do 400 ha. Obrazovna struktura je nešto povoljnija budući je 28,7% vlasnika obiteljskih gospodarstava poljoprivredne struke. Obiteljska gospodarstva svoje djelatnosti obavljaju s 78 traktora različitih tipova i snage. Prosječna starost traktora iznosi 16,5 godina. Značajan dio traktora (68%) je nabavljen prije 1990. godine, a tehnički pregled je vrijedio za 64% traktora. Kao razloge neobavljanja tehničkih pregleda vlasnici traktora navode starost traktora i nedostatak financijskih sredstava.

Pri kupovini traktora svega je 25,72 % vlasnika prošlo obuku nužnu za sigurno upravljanje i održavanje traktorom. Servise izvan jamstvenog roka samostalno obavlja 69 % anketiranih vlasnika obiteljskih gospodarstava.

Tablica 1. Postupci s rabljenim motornim uljem i uljem iz transmisije
Table 1. Used oil and transmission oil procedures

Uporaba	Rabljeno motorno ulje (%)	Rabljeno ulje iz transmisije (%)
za tehničku zaštitu poljoprivredne mehanizacije	56,36	52,72
kao gorivo u peći	9,09	5,45
za bojanje ograde	9,09	3,63
skladištim u bačvama koje čuvam kod sebe	16,36	12,72
bacam u kanalizaciju	1,82	3,63
bacam u melioracijske kanale	1,82	1,82
dajem ga prijatelju	7,27	–
koristim za spaljivanje drugog otpada	3,63	3.63
skupljam u plastičnoj ambalaži novokupljenog ulja te bacam u otpad	3,63	–
bacam u otpad	1,82	9,09
ovlaštena tvrtka odvozi dio ulja, a dio koristi za tehničku zaštitu	1,82	1,82
ne obavljam zamjenu ulja već samo nadolijevam ulje	–	3,63

Zamjenu ulja u motoru na svim anketiranim obiteljskim gospodarstvima nakon određenog broja sati rada obavlja 83,64% vlasnika obiteljskih gospodarstava, 12,72% ih zamjenu obavlja po vlastitoj procijeni, 1,82 % vlasnika izmjenu obavlja 2 puta godišnje te 1,82% vlasnika ne obavlja zamjenu nego samo nadolijeva novo ulje. Vlasnici koji obavljaju zamjenu ulja nakon određenog broja sati rada čine to dijelom sukladno naputku za rukovanje i održavanje, a dijelom po vlastitoj procijeni.

Rabljeno motorno ulje i ulje iz transmisije vlasnici obiteljskih gospodarstava zbrinjavaju na različite načine, tablica 1.

Zamjenu ulja u transmisiji prema naputku proizvođača obavlja 76,36% vlasnika obiteljskih gospodarstava, a ostali po osobnoj procijeni (izuzev 3,63% vlasnika koji ne zamjenjuju ulje u transmisiji već po potrebi nadolijevaju novo ulje). Većina vlasnika (96,36%) upotrebljava ulje propisane kvalitete.

Plastičnu ambalažu od ulja uglavnom spaljuju ili odbacuju u komunalni otpad, a u manjoj mjeri je koriste za spremanje rabljenog ulja te skladište kod sebe. Zamijenjene pročistače za ulje većina vlasnika baca u komunalni otpad ili ih spaljuje.

RASPRAVA O REZULTATIMA ISTRAŽIVANJA

Rezultati istraživanja ukazuju na visoku prosječnu starosnu dob poljoprivrednih traktora na anketiranim obiteljskim gospodarstvima (20,11 godina u Osječko-baranjskoj županiji i 16,5 godina u Vukovarsko-srijemskoj županiji) i veliki broj katastarskih čestica na kojima se nalaze poljoprivredne obradive površine (prosječna veličina katastarske čestice je 2,34 ha). Svega 23,63% vlasnika ima poljoprivredno obrazovanje. Visok postotni udio traktora za koji nije učinjen tehnički pregled (25% u Vukovarsko-srijemskoj županiji), predstavlja ekološki problem, ali i problem sigurnosti u prometu. Ovakvi rezultati upućuju na kompleksnost problema ostvarivosti tržišno orijentirane i konkurentne poljoprivredne proizvodnje.

Pravilno zbrinjavanje rabljenog motornog ulja, ulja iz transmisije, pročistača za ulje i plastične ambalaže nužno je za očuvanje okoliša što navodi i El-Fadel, M. (2001). Nepravilno zbrinuto rabljeno ulje zagađuje podzemne vode, tlo na kojem je ispušteno ulje nije sposobno za biološku proizvodnju, a nekvalitetno izgaranje ulja dovodi do nastanaka kancerogenih tvari. Navedeno ukazuje na značaj pravilnog upravljanja rabljenim uljem i ostalim otpadom na obiteljskim gospodarstvima.

Sukladno zakonskim normama (N.N. 27/96) vlasnici obiteljskih gospodarstava, budući su proizvođači otpadnih ulja, dužni su skupiti dio otpadnih ulja koji je ekvivalentan umnošku količine upotrijebljenog svježeg ulja i obveznog faktora prikupljanja, koji za motore s unutarnjim izgaranjem iznosi 0,45. Nadalje, proizvođači otpadnih ulja dužni su voditi evidenciju o nabavljenim količinama svježeg ulja te očevidnik o količinama prikupljenog otpadnog ulja kao i postupanja s istim. Nije dozvoljeno miješanje otpadnih ulja različitih kategorija, niti ulja s drugim tvarima, a spremnici za prikupljanje otpadnog ulja moraju na sebi uz zakonom propisane oznake imati i oznaku kategorije otpadnog ulja.

Rezultati istraživanja ukazuju da vlasnici obiteljskih gospodarstava ne zbrinjavaju rabljeno ulje sukladno postojećim zakonskim normama. Svega 1,82% vlasnika obiteljskih gospodarstava rabljeno ulje predaje ovlaštenoj tvrtki za preuzimanje ulja. Veliki broj vlasnika obiteljskih gospodarstava rabljeno motorno ulje koristi za tehničku zaštitu poljoprivrednih strojeva (56,36%).

Pod ambalažnim otpadom se podrazumijeva ambalaža koja ostane poslije otvaranja proizvoda. Ovaj otpad bi se trebao skupljati u spremnike postavljene za tu namjenu. Vlasnici obiteljskih gospodarstava uglavnom spaljuju plastičnu ambalažu ili je odbacuju u komunalni otpad. Jedan dio vlasnika plastičnu ambalažu upotrebljava za zbrinjavanje rabljenog ulja.

Spaljivanjem plastične ambalaže emitiraju se štetni plinovi u atmosferu, a odbačena plastična ambalaža predstavlja ekološki problem obzirom na razgradivost plastike.

ZAKLJUČAK

Na temelju provedenog istraživanja glede zbrinjavanja rabljenog motornog ulja, ulja iz transmisije, pročistača za ulje i plastične ambalaže na obiteljskim gospodarstvima mogu se donijeti slijedeći zaključci:

- svega 23,63% vlasnika obiteljskih gospodarstava ima poljoprivrednu naobrazbu;
- obiteljska gospodarstva raspolažu s poljoprivrednim traktorima visoke prosječne starosne dobi (16,5 godina na području Vukovarsko-srijemske županije i 20,11 godina u Osječko-baranjskoj županiji);
- proizvodne površine se nalaze na velikom broju katastarskih čestica (prosječna veličina čestice je 2,34 ha);
- vlasnici obiteljskih gospodarstava ne postupaju sukladno postojećim zakonskim normama glede zbrinjavanja rabljenog ulja iz motora, ulja iz transmisije, pročistača ulja i plastične ambalaže;
- uporaba rabljenog motornog ulja u tehničkoj zaštiti poljoprivrednih strojeva je neprihvatljiva;
- intenzivno raditi na educiranju vlasnika obiteljskih gospodarstava glede zbrinjavanja otpada sukladno postojećim zakonskim normama
- educirati vlasnike o ispravnim mjerama servisno-preventivnog održavanja i
- početi s primjenom postojećih zakonskih normi.

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USED OIL MANAGEMENT ON FAMILY FARMS

SUMMARY

A modern agriculture involves the use of highly sophisticated, efficient and reliable machinery with a maximum level of environmental friendliness. Family farms use many agricultural machines so that the proper way of their service preventive maintenance and the managament of used oil and other waste has a significant influence on environmental preservation. This paper presents a research into the way of used oil and other hazardous waste management conducted on family farms in Vukovar-Srijem county as well as in Osijek-Baranja county. The results discover a low-quality management of used oil, transmission oil, plastic containers and other waste material, which is a big environmental problem and calls for some necessary changes of the present law. The research found out a high average age of agricultural tractors, there are many small size farms and few family farmers with agricultural education (only 23,63% of farmers).

Key words: *service preventive maintenance, used oil, environment*

34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.42:631.312.631.51
Prethodno priopćenje
Preliminary communication

SIMULATION OF PLOUGH SHEAR MAIN PARAMETERS INFLUENCE ON WORKING PROCESS

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SUMMARY

The plough shear as an important component of the plough is contributing in the working process not only as a drag component but also as a quality one, especially for the hard soils. Using the geometry features of a tetrahedron, based on real ploughshares, a model with imposed geometry and construction parameters was created. The parametric study made reveled the behavior of the tool within the working process as well as the state of stress and strain in the ploughshare, making possible to optimize the tool geometry.

Key words: *ploughshare geometry, parametric study, tillage tool simulation*

INTRODUCTION

Tillage operation is the primary step in agricultural production systems, and consumes energy and time. Energy consumed within agricultural field operation represents a fifth from the energy consumed in agricultural production and is the second after energy for fertilizers in importance. Tool characteristics and the interaction between soil and tool under different operational conditions are very important. For a proper tillage operation, knowledge of soil characteristics is also essential.

In the field of soil-tool interaction modeling, experimental and analytical models appeared during the 1940's. Finite element method (FEM), which originated in aviation engineering in the 1950's, was developed for the soil cutting processes by Yong and Hanna in 1977. This method has received much attention as a strong tool to investigate soil-tool interaction. Primary models looked only the static aspects of soil-tool interaction since dynamic aspects of the process remained a complicated issue in spite of accessibility to basic theories and powerful computers.

The objective of this paper is to make possible for agriculture engineers to improve the performance of the tillage tools, to model an optimum tool for their necessities.

BACKGROUND

The analysis was made for a trapezoidal plough share according to SR ISO 8910 which represent one of the simplest construction of a plough share and it was modeled on a face of an tetrahedron to use the specific parameters of it as shown in the figure 1. The values used correspond to a usual new sharp ploughshare and it's working position. For other tools, the analysis process is similar and can be as evolved as the users want that.

A finite element model (fig. 2), using I-DEAS 8, was created using geometry based linear static analysis conditions. The boundary conditions where imposed for the model according to it's assembly condition with the moldboard and the others elements, respectively there were imposed displacement restraints for five plough share model surfaces and a uniform distributed pressure on the frontal face of the plough share model aligned with Ox movement axle of the plough. Pressure value (0.7 N/mm^2) was chosen according to literature review values and it corresponds to higher pressure obtained for the ploughshare tip.

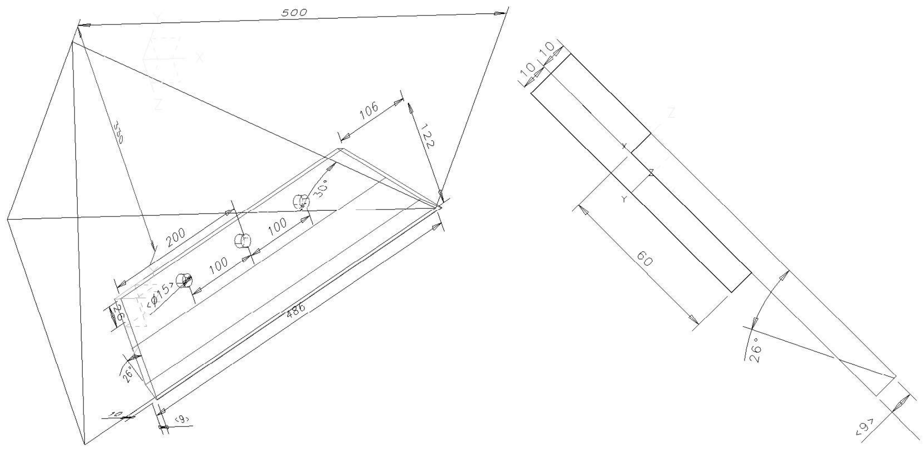

Fig. 1 Plough share and tetrahedron model

The mesh applied on four volumes use solid parabolic tetrahedral elements with a length of 5 and 15 mm with the properties of isotropic steel generated a number of 5126 nodes and 1614 elements.

The imposed boundary conditions have showed within the obtained solution, a high stress in the median zone of the model that indicates the deformation zone if an overload higher then elasticity limit appears (rocks, roots etc.). Also, high stress can be seen at the first bolt screw hole. This fact corresponds to the rupture that appear in the mentioned area. Depending on the overload position, direction and amplitude, the tip of the ploughshare can break loose or detached according to its construction, the most probable event.

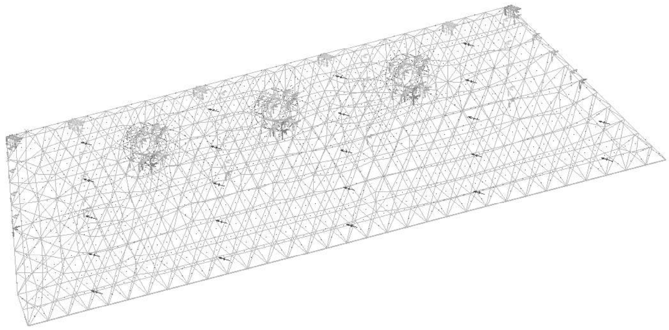

Fig. 2 FE model for plough share

RESULTS AND DISCUSSIONS

Taking into account the presented results, a parametric analysis was made in order to indicate the influence of several constructive ploughshare characteristics.

In the table 1 are presented several ploughshare characteristics with their respective values.

Table 1 Plowshare characteristics parametric analysis

Parameter	Initial value	Studied interval	Step	Stress max. (volume)	Stress max. (top face)	Displacement max.	Weight
Thickness	10 mm	7÷13 mm	0.5 mm	164÷100 N/mm^2	164÷31 N/mm^2	-0,196 mm	4,81÷2,67 kg
Width	122 mm	102÷132 mm	5 mm	120÷80 N/mm^2	24÷82 N/mm^2	-0,111 mm	3,08÷4,14 kg
Sharping angle	26 deg.	10÷42 deg.	2 deg.	≅121 N/mm^2	81÷66 N/mm^2	-0,16 mm	3,23÷3,94 kg
Cutting length	106 mm	56÷156 mm	10 mm	120÷100 N/mm^2	37÷110 N/mm^2	-0,14 mm	4,03÷3,53 kg
Console length	60 mm	40÷90 mm	5 mm	152÷117 N/mm^2	152÷25 N/mm^2	-0.21 mm	-
Ox hole distance	26 mm	16÷36 mm	2 mm	120÷90 N/mm^2	≅67 N/mm^2	-0,068 mm	-
Oy hole length	200 mm	150÷250 mm	10 mm	100÷143 N/mm^2	≅67 N/mm^2	-0,068 mm	-
Hole distance	100 mm	75÷150 mm	5 mm	134÷90 N/mm^2	≅67 N/mm^2	-0,068 mm	-
xOy angle	30 deg.	10÷38 deg.	2 deg.	-	72÷209 N/mm^2	-0.3 mm	-
L_Oz	330 mm	230÷430 mm	10 mm	-	112÷154 N/mm^2	-0.22 mm	-

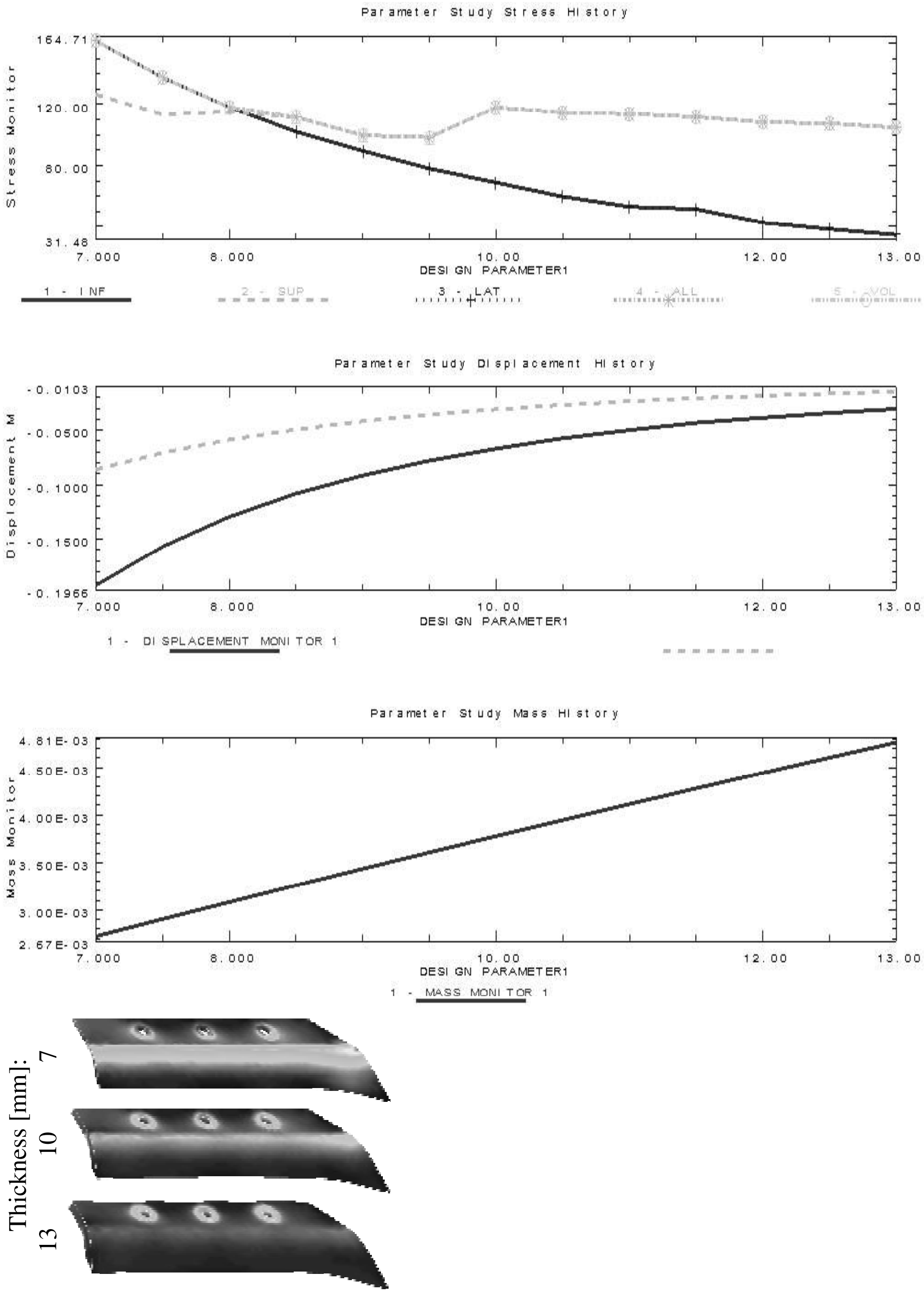

Fig. 3 Thickness variation and top face stress variation with thickness

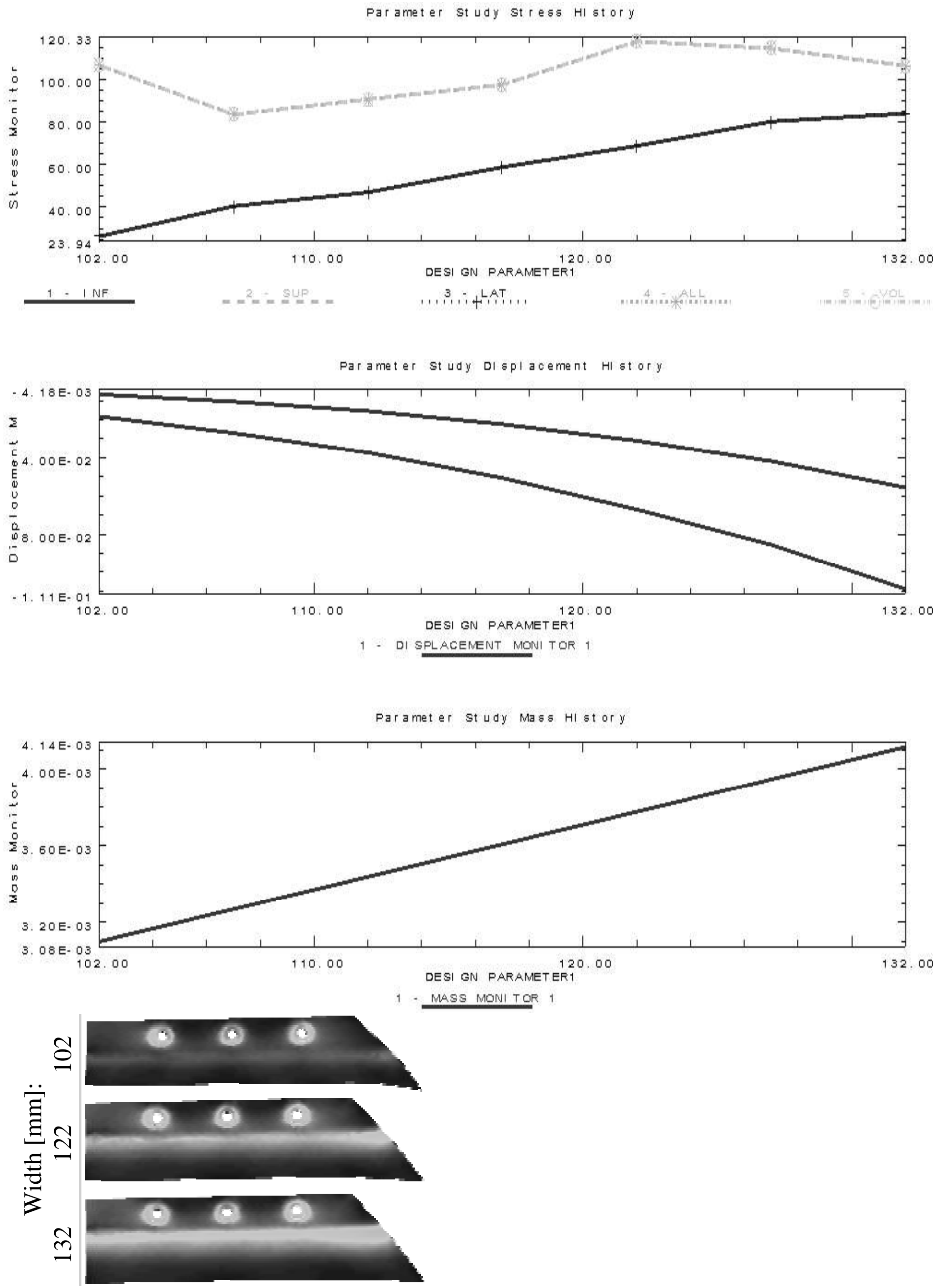

Fig. 4 Width variation and top face stress variation with width

Based on initial values, each parameter from the ones before has been modified within the imposed range with corresponding step. During the parameters modification there were monitored as follows (fig. 3, 4):

1. stress: for top, bottom and one lateral face, all volumes and volume without interference with screw bolt;
2. displacement: for the top cutting edge;
3. weight: for all volumes where there are modifications.

The solutions incompatible with the geometric features or with FE model were eliminated.

Regarding the values presented in table 1 (and for the cases presented in fig. 3 and 4), several specifications must be made. The displacement, for the boundary condition and load case, are considered to be reliable and correct estimated also for the weight. Regarding the stress values, due to imposed displacement restriction (considered as simplified model) the reliable values are considered to be the values for the surfaces (faces) analyzed. The high stress values appear at the interface zone between the volumes used to refine the mesh (the hole areas). Due to a lack of computer performances and the time needed for the analysis, a more complex model was not possible to be used. Anyway, the model presented in a similar form can be used with success to elaborate more reliable tillage tools for the load case considered.

In figures 3 and 4 parametric analysis for thickness and width are presented. As previously precised, from the figures can be seen the correct variation of stress depending to designed parameter for the bottom and lateral face which are not in contact with fully restraint surface. The displacement for top cutting edge is also presented with their varying limits. Also, the deformed model with top face averaged Von Mises stress is presented in for three values of design parameter (lighter colors correspond to higher stress).

Also, it can be see from the values obtained that the loading can be increase, but regarding to the load case used, the pressure applied is almost 7 times higher than the values for a heavy soil.

Taking into consideration the fact presented, an optimum model can be obtained in order to minimize and equalize the stress in the same time by reducing the dimensions and weight of the ploughshare through this minimizing the energy required for field tillage operations.

For the future a more elaborate model will be developed in order to extend the parametric analysis and offer a solid base for ploughshare optimization.

CONCLUSIONS

Many commercial companies are still using inadequate ploughshares that cause problems to the farmers. On one hand, the quality of material used is too low and/or the specific parameters are not respected which could cause reduced lifespan, bad agro-technical conditions for the tilled soil and higher maintenance costs. On the other hand using very good materials or consuming to much energy for a highly elaborated ploughshare will not be economically feasible due to a high tool wear rate in tillage operation.

The parametric analysis presented can contribute as an approach for optimum tool for the very compact soils that presents high resistance and a lower wear component.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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USPOREDNA ISTRAŽIVANJA TROŠENJA MATERIJALA KULTIVATORSKIH MOTIČICA

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SAŽETAK

Istraživanje obuhvaća ispitivanje kvalitete rada i trošenje motičica međurednog kultivatora pri obradi 225 ha šećerne repe i soje u razdoblju od dvije vegetacijske godine. Na antropogenizirano semiglejno plitkom ogleju-nekarbonatnom i djelimično hidromelioriranom tlu kultivator je ostvario prosječnu radnu dubinu od 4,10 cm uz koeficijent varijacije 24,15% pri prosječnoj radnoj brzini od 4,40 km/h uz koeficijent varijacije 28,95%.

Najveći gubitak mase od 34,10% i 37,56% izmjeren je kod motičica oznake M_4 (lijeva i središnja motičica), koje su postavljene iza tragova kotača (pneumatika) traktora. Radom izvan traga kotača pneumatika traktora najmanji gubitak mase od 12,02% utvrđen je kod motičice izrađene iz materijala M3, a najveći od 30,53% kod motičice izrađene iz materijala M2.

Kultiviranjem tla izvan traga kotača traktora najmanje je smanjenje površine oštrice od 11,12% izmjereno kod motičica izrađene iz materijala M3, a najveće od 45,78% kod motičice izrađene iz materijala M1. Motičice izrađene iz materijala M4 i materijala M3, a postavljene iza kotača traktora, izgubile su 29,60%, odnosno 30,66% od početne površine oštrice.

Na sekciji kultivatora bočno (lijeva i desna) postavljene motičice gubile su masu minimalno 13,67% (materijal M2) i površinu oštrice 21,71% (materijal M2), a maksimalno 15,05% (materijal M2) i površinu oštrice 24,06% (materijal M2).

***Ključne riječi**: Kultivator, navarene i ne navarene kultivatorske motičice, trošenje materijala, sabijenost tla*

UVOD

Podizanje razine linije trenda rasta ratarske proizvodnje moguće je samo prihvaćanjem određenih ponašanja te dosljednom primjenom učinkovitih postojećih ili postepenim uvođenjem novih tehnologija. Svjedoci smo da u proteklih nekoliko godina nema bitnih promjena u tehnici i postupcima provođenja međuredne obrade tla.

Međuredna obrada uz istovremenu prihranu usjeva i te kako je značajna, a pogotovo ako je pravovremeno i kvalitetno obavljena. Naročito je to značajno ukoliko je izostavljena osnovna gnojidba. Na razinu kvalitete rada međurednog kultivatora utječu mnogi čimbenici, a jedan od najvažnijih je što duže održanje oštrice i oblika motičice u vrijeme izvođenja radne operacije međuredne kultivacije. Radi značaja ovog problema treba naglasiti da povećanje dugotrajnosti oštrice motičica za izvođenje kultivacije, predstavlja jedan od aktualnih problema njihovog daljnjeg razvoja. Naročito je to značajno u sadašnjim uvjetima proizvodnje kad se na tržištu pojavljuje veliki broj malih proizvođača i dobavljača motičica. Veći broj proizvođača motičica radi snižavanja cijene izrade gotovo ne oblikuje oštricu, a vrlo se rijetko pronalaze motičice s oblikovanom oštricom i mogućnosti izravne ugradnje na međuredni kultivator bez prethodne pripreme.

ZADATAK I CILJ ISPITIVANJA

Zadatak je usporednim ispitivanjem utvrditi intenzitet trošenja materijala i očuvanja geometrijskog oblika oštrice motičica pri radu međurednog kultivatora, s obzirom na cijenu proizvodnje te ostvarenog učinka.

Cilj ispitivanja je dobivanje saznanja o opravdanosti uporabe različitih materijala u izradi, te primjena novih tehnologija i postupaka za poboljšanje oštrice motičica međurednih kultivatora.

METODIKA ISPITIVANJA

Ispitivanje trošenja materijala novih kultivatorskih motičica izrađenih od različitih čeličnih limova provedeno je prema metodici razvijenoj u Zavodu za mehanizaciju Poljoprivrednog fakulteta u Osijeku.

Osnovne mehaničko-kemijske odlike materijala uporabljenog za izradu kultivatorskih motičica prikazano je u tablici 1.

Motičice oznake „M_1" izrađene su od čeličnog lima debljine δ= 4 mm. Iste motičice bile su podvrgnute toplinskoj obradi radi poboljšavanja mehaničkih svojstava. Nakon zagrijavanja u električnoj peći na temperaturi od 780°C, pristupilo se kaljenju (hlađenje) u uljnoj kupelji s temperaturom ulja od 50°C. Upotrebljeno ulje imalo je točku paljenja >160°C i nije sadržavalo vodu. Popuštanje je obavljeno na temperaturi od 300°C radi smanjivanja unutrašnjih naprezanja koja su nastala kao posljedica kaljenja. Pri tome se nastojalo održati predhodnu tvrdoću i otpornost na trošenje.

Motičice pod oznakom M_2 izrađene su od istog čeličnog lima debljine δ = 4 mm kao i predhodne u alatima za prešanje uz prethodno zagrijavanje. Ovim postupkom materijal otvrdne i postaje vrlo otporan prema trošenju i koroziji. Ova skupina motičica nije prošla postupak kaljenja.

Tablica 1 Mehaničko-kemijska svojstva materijala uporabljenih za izradu motičica

Oznaka uzorka	Materijal M_1	Materijal M_2	Materijal M_3	Materijal M_4
Kemijski sastav				
C	0,45	0,45	0,20	0,22
Si	0,40	0,40	-	0,60
Mn	1,50	1,50	-	1,80
P	0,04	0,04	0,05	0,035
S	0,04	0,04	0,05	0,035
N	-	-	0,07	-
V	-	-	-	0,08
Cr	-	-	-	1,50
Mo	-	-	-	0,40
Vlačna čvrstoća (N/mm^2)	1200 – 1400	1200 - 1400	520 - 620	1300
Granica tečenja (N/mm^2)	1050	1050	360	1000
Istezljivost (%)	7,0	7,0	22,0	8,0
Tvrdoća HB	230	230	150	440
Stanje materijala	kaljen	-	metaliziran	metaliziran

Skupina motičice M_3 i M_4 izrađene su od čeličnog lima debljine δ = 4 mm. Motičice su izrađene u alatima za prešanje uz predhodno zagrijavanje od 900°C. Kod ovih motičica provedeno je oplemenjivanja oštrice metodom vruće metalizacije. Metalizirani sloj debljine 1 mm nanešen je na rezne strane motičica gdje se i očekuju najveća trošenja. Širina trake metaliziranog sloja bila je oko 10 mm. Tvrdoća uzorka nakon vruće metalizacije – materijal M_3 i M_4, te kvalitativni prikaz kemijskog sastava upotrijebljenog metalnog praha prikazano je u tablici 2.

Tablica 2 Mehaničko-kemijska svojstva upotrijebljenog metalnog praha

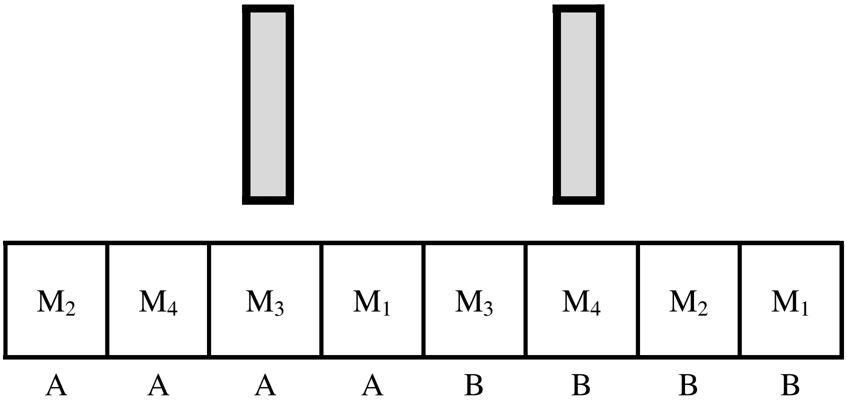
Kemijski sastav (%)							
C	Cr	Ni	Mn	Si	Co	Mo	Fe
3,30	24,32	3,13	0,43	1,49	3,20	0,15	63,98

Tensile strength (N/mm^2)	Yield strength (N/mm^2)	Istezljivost (%)	Toughness (DVM)/J	Tvrdoća (HV)
1730	1400	6	38	571
Temperatura topljenja praha		900 - 1050(°C)		

Osnovna odlika primjene vruče metalizacije je dobijanje tvrde tanke površine na oštrici motičice otporne na trošenje, koja je nanešena na osnovni mekši materijal podložan izrazitijem trošenju i nastajanja tzv. samooštrećeg procesa.

Uporedno ispitivanje kvalitete rada i trošenja materijala motičica provedeno je u prvoj kultivaciji šećerne repe i soje na proizvodnim površinama Belja d.d. i Poljoprivrednog Instituta u Osijeku. Kultivatorske motičice bile su postavljene na 12 rednom kultivatoru tvrtke Rau koji je bio agregatiran s traktorom tvrtke IMT tip 539.

Ispitivanje je obavljeno u razdoblju od dvije vegetacijske godine. U obadvije godine tlo je u prvim danima ispitivanja bilo je povoljne vlažnosti za obavljanje kultivacije, dok je sredinom i krajem ispitivanja bilo nešto suhlje. Položaj i oznake postavljanja motičica kod međurednog kultivatora Rau prikazano je slikom 1.



Slika 1 Položaj i oznake postavljanja motičica kod međurednog kultivatora Rau

STANJE PROBLEMA I DOSADAŠNJA ISTRAŽIVANJA

Jedan od mjerila intenziteta trošenja abrazijom radnih dijelova strojeva i oruđa u poljoprivredi je gubitak mase i promjena geometrije reznih dijelova. Istraživanja trošenja abrazijom ukazuju da intenzitet trošenja radnih dijelova ovisi o sastavu i vlažnosti zemljišta, te o strukturi materijala njihove izrade (udio i tvrdoća strukturnih konstituenata).

Pintarić [8] ukazuje na problem trošenja dijelova poljoprivrednih strojeva na glavnim pozicijama traktorskih priključaka i nepovratnog gubitka mase. Autor ističe da postojeća otpornost trošenju u potpunosti ne zadovoljava, te ukazuje na potrebu kvalitetnog izbora materijala i primjenu tvrdog navarivanja radnih dijelova. Novaković i suradnik [7] u istraživanjima razmatra mogućnost primjene običnih čelika uz nanošenje tvrdih zaštitnih prevlaka na radne dijelove poljoprivrednih strojeva. Isti autor navodi da se zaštitom postiže smanjenje trenja i prijanjanje zemljišta na radne dijelove, te gubitka mase za oko 10 puta. Toth [6] prezentira i ukazuje na mogućnost primjene postupka "Hetill" koji omogućava nanošenje praha i indukciono utaljivanje vrlo tankog ravnomjerno raspoređenog sloja po površini osnovnog materijala. Mihaljević [3] navodi da izbor dodatnog (zaštitnog) materijala ne provodi se samo na osnovi tvrdoće jer ona nije jedino mjerilo otpornosti prema abraziji. To potvrđuje primjerom elektrode EZ-600 T_2 koja ima veću tvrdoću od Cr karbida ali je manje otporna na abraziju. Miloš i suradnici [5] navode da raonik površinske tvrdoće 30 do 35 HRc nakon prosječnog gubitka od 31% svoje mase dotrajava. Isti autori navode da kultivatorske motičice dotrajavaju već pri prosječnom gubitku 21% od početne mase. Banaj i suradnici [1] navode da je u kultivaciji kukuruza na 162 ha došlo do gubitka mase kod standardnih motičica oblika "guščja noga" 182,2 do 396,1 grama ili prosječno 285 grama. Kod poboljšanih motičica istog oblika došlo je do gubitka mase prouzrokovane abrazijom čestica tla u granicama 68,1 do 254,0 s prosjekom od 154,9 grama po motičici ili 8,26% od početne mase. Isti autori ističu da je prosječno trošenje materijala kod standardnih desnih postranih motičica 4,5%, a kod poboljšanih u prosjeku manje za 48,8%. Kod lijevih postranih standardnih motičica utvrđen je prosječni gubitak mase osnovnog materijala 2,0%, a poboljšanih 1,37%. Ercegović i suradnik [2] svoja ispitivanja o opravdanosti zaštite radne površine obavili su na lemešu pluga. Autori ističu da postupkom zaštite oštrice omogućavamo produženje vijeka trajanja lemeša i do nekoliko puta. Mikloš i suradnik [4] navode da se primjenom tehnologije postupka utaljivanja prašaka tvrdog metala visokofrekventnim indukcijskim postupkom postižu uštede do 40% u sačuvanom materijalu i 80% u smanjenju ljudskog rada. Problematika gubitka mase i promjene geometrije radnih dijelova strojeva i oruđa u poljoprivredi razmatra se i u literaturi citirane od [9] do [16], kao i postupci produljenja vijeka trajanja rada, te se navode određena iskustva.

REZULTATI ISPITIVANJA

Nakon obavljenog kultiviranja površine od 225 ha šećerne repe i soje motičicama oznaka M_1, M_2 i M_3 te još narednih 108 ha za motičice oznaka M_4 dobiveni su sljedeći rezultati.

Učinak kultivatora

Učinak ispitivanog međurednog kultivatora po danima rada prikazano je u tablici 3.

Tablica 3 Učinak kultivatora

Materijal izrade	Učinak po sekciji	Ukupna pređena dužina puta motičica sekcije (km)
M_1	20,45 ha	37,01
M_2	20,45 ha	37,01
M_3	20,45 ha	37,01
M_4	30,26 ha	54,78

Fizikalna svojstva tla

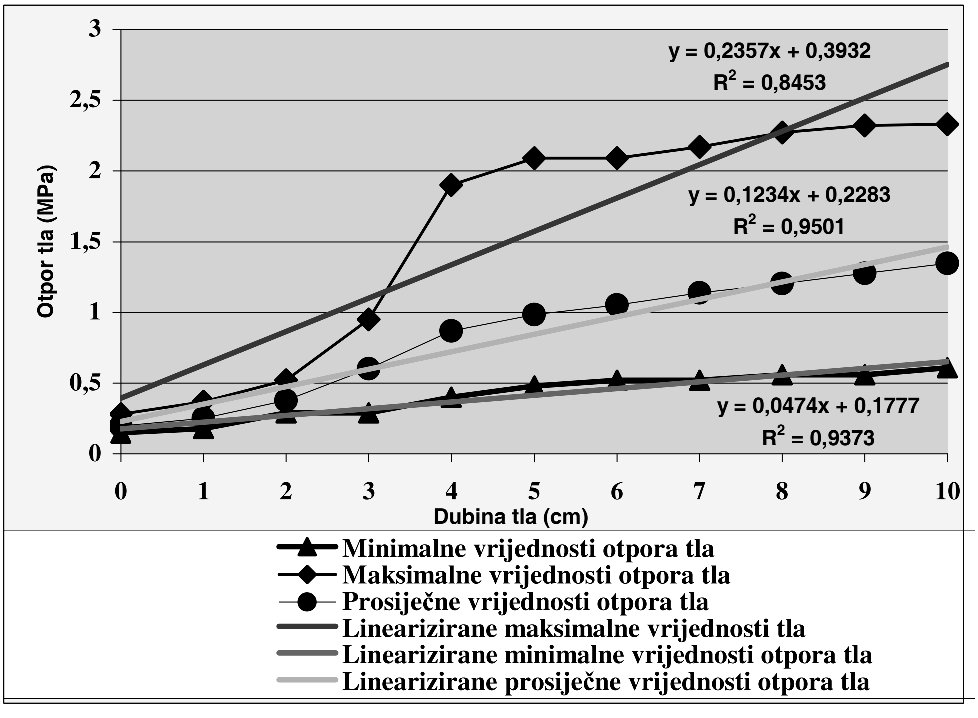
Na području istraživanja šećerna repa i soja zasijane su na više podtipova semigleja. Ispitivanjem je utvrđeno da je površinski najviše kultivacija obavljena na tipu tla antropogenizirani semiglej, plitko oglejen, nekarbonatan, djelomično hidromelioriran. Pedofizikalna svojstva tla prikazana su u narednoj tablici.

Tablica 4. Pedofizikalne značajke i neka svojstva tla

Horizont		Tekstura	Struktura
dubina (cm)	oznaka	horizonta	horizonta
0,0 do 50,0	P	glinasta ilovača	krupno mrvičasta
Dubina (cm)	K_v - % volumni	T_{rv} - % volumni	φ_v – g/cm^3
0,01 do 20,00	42,62	31,28	1,43

gdje je: Kv – retencijski kapacitet tla za vodu, T_{rv} – trenutačna vlaga tla, φ_v – gustoća tla.

Vrijednosti otpora tla na ispitivanim tablama izmjerene po dubini obrade uređajem Eijkelkamp penetrologger SN0 prikazano je grafikonom 1.



Grafikon 1 Izmjerene vrijednosti otpora tla na ispitivanim tablama

Brzina i dubina rada

Tijekom ispitivanja ustanovljene su minimalne i maksimalne radne brzine, te dubine kultivacije, a rezultati ispitivanja prikazani su u tablici 5.

Tablica 5 Statistički pokazatelji kvalitete rada kultivatora

Brzina rada (km/h)				Dubina rada (cm)			
v_{min}	v_{max}	v_{sr}	KV (%)	a_{min}	a_{max}	a_{sr}	KV (%)
2,00	6,30	4,40	28,95	2,20	5,30	4,10	24,15

gdje je KV – koeficijent varijacije

Iz tablice 5. može se zaključiti da je ispitivani kultivator radio u rasponu dozvoljenih granica brzine. Ostvarena dubina rada kultivatora u potpunosti zadovoljava agrotehničke zahtjeve uzgoja šećerne repe i soje.

Gubitak mase i smanjenje površine oštrice motičica

Razlike trošenja materijala dobivene su preciznim vaganjem motičica prije i poslije rada ispitivanih kultivatora. Utvrđivanje smanjenja površina oštrica motičica dobiveno je usporedbom otisaka oštrica prije i poslije rada kultivatora. Obrađeni rezultati ispitivanja gubitka mase i smanjenja početne površine oštrice svih ispitivanih motičica prikazane su u tablici 6.

Iz tablice 6. može se uočiti da je značajnije trošenje materijala utvrđeno kod srednjih (prednjih) motičice u kultivatorskim sekcijama. To je i za očekivati, jer bočne (postrane) motičice intenzivno obrađuju tlo samo s jednom stranom tj. 50 % dijelom oštrice.

Motičice oznake M_1 u ispitivanju su bile postavljene samo izvan traga kotača traktora. Središnje motičice trošile su se prosječno u provedenom ispitivanju 49,08 grama ili 18,27 % uz prosječno smanjenje površine oštrice od 30,27 cm^2. Motičice postavljene na lijevi dio kultivatorskih sekcija izgubile su prosječno 36,77 grama ili prosječno 13,66 % uz prosječno smanjenje površine oštrice od 20,58 cm^2. Kultivatorske motičice postavljene na desnu stranu sekcija izgubile su prosječno 34,78 grama ili 13,20 %. Ove motičice izgubile su abrazijom čestica tla prosječno 16,92 cm^2 površine oštrice.

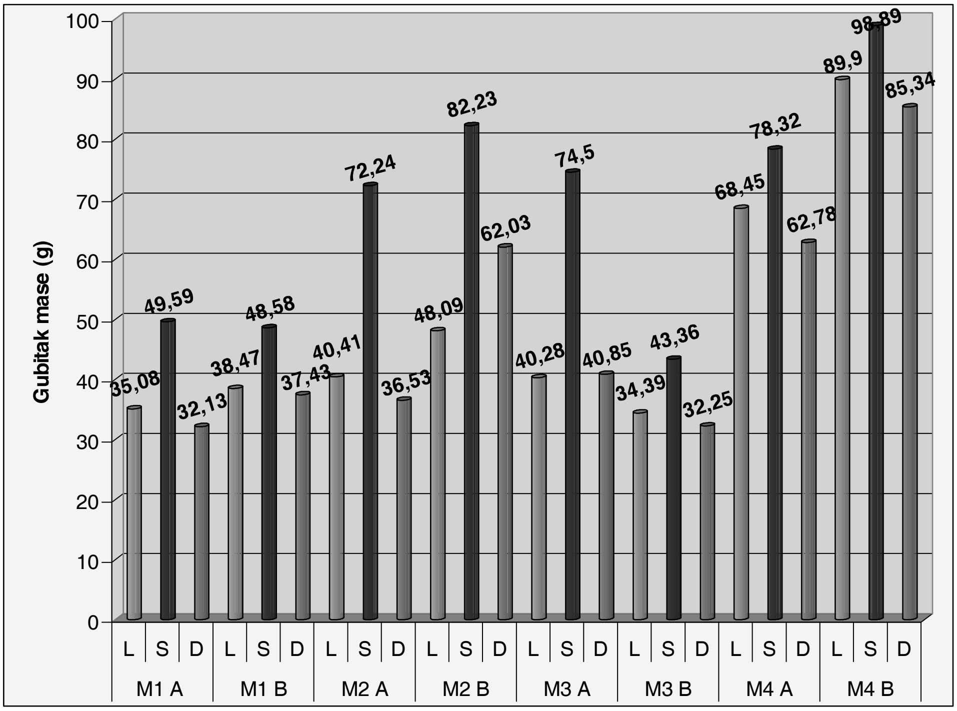
Motičice oznake M_2 prosječno su se nešto više potrošile od predhodnih. Srednje motičice kultivatorskih sekcija potrošile su se prosječno 77,23 grama uz prosječno smanjenje 31,12 cm^2 površine oštrice. Desne motičice kultivatorskih sekcija u ispitivanju izgubile su prosječno 49,28 grama i 18,06 cm^2 površine oštrice. Motičice postavljene na lijevu stranu kultivatorskih sekcija izgubile su prosječno 44,25 grama ili 16,60% od početne mase.

Motičice materijala oznake M_3 postavljen je u dvije kultivatorske sekcije od kojih se jedna nalazila iza kotača traktora (M_3A). U ovoj sekciji srednja motičica izgubila je za vrijeme rada 74,50 grama odnosno 28,45% od početne mase. Središnja motičica oznake M_3 koja je radila izvan traga kotača traktora izgubila je masu od svega 43,36 grama. Kod lijeve i desne motičice oznake M_3 koje su radile na tragu traktora utvrđeno je prosječno trošenje od 40,565 grama. Motičice oznake M_3, lijeva i desna postavljene van traga kotača prosječno su se trošile 33,32 grama.

Motičice izrađene od materijala oznake M_4 postavljene su na tragu i izvan traga kotača traktora. Srednja kultivatorska motičica postavljena u trag traktora izgubila je 98,89 grama mase ili 37,56%. Srednja motičica oznake M_4, a postavljena izvan traga kotača traktora izgubila je 78,32 grama mase odnosno 28,96%. Motičice lijeva i desna oznake M_4 u tragu kotača trošile su se prosječno 87,62 grama, a motičice izvan traga kotača 65,615 grama mase.

Tablica 6 Prikaz gubitak mase i smanjenja površine oštice motičica

Oznaka		Gubitak mase		Smanjenje površine oštrice	
motičice		(g)	%	cm^2	%
	Središnja	49,59	18,50	42,8	45,78
M1 A	Lijeva	35,08	13,10	19,80	21,24
	Desna	32,13	12,10	10,7	11,44
	Središnja	48,58	18,04	13,8	14,76
M1 B	Lijeva	38,47	14,23	21,36	22,5
	Desna	37,43	14,31	21,10	22,4
	Središnja	72,24	27,13	27,25	29,14
M2 A	Lijeva	40,41	15,05	22,5	24,06
	Desna	36,53	13,67	20,3	21,71
	Središnja	82,23	30,53	35	37,43
M2 B	Lijeva	48,09	18,15	14,5	15,51
	Desna	62,03	22,45	19,6	20,27
	Središnja	74,50	28,45	28,8	30,66
M3 A	Lijeva	40,28	15,06	8,4	8,98
	Desna	40,85	15,07	8,9	9,52
	Središnja	43,36	16,36	13,5	14,44
M3 B	Lijeva	34,39	12,90	19,12	20,89
	Desna	32,25	12,02	10,6	11,12
	Središnja	78,32	28,96	29,28	30,82
M4 A	Lijeva	68,45	26,40	27,15	29,01
	Desna	62,78	22,89	20,1	21,49
	Središnja	98,89	37,56	27,7	29,6
M4 B	Lijeva	89,90	34.10	26,6	28,40
	Desna	85,34	28,73	19,1	21,36



Grafikon 2 Prikaz gubitaka masa ispitivanih motičica s naznakom materijala izrade i položaja traga pneumatika kotača traktora

ZAKLJUČCI

Na temelju rezultata ispitivanja trošenja materijala kultivatorskih motičica u kultivaciji šećerne repe i soje može se zaključiti sljedeće:

- kultivacija ratarskih kultura obavljena je s prosječnom radnom dubinom od 4,10 cm uz koeficijent varijacije 24,15%,
- prosječna radna brzina ostvarena u kultivaciji iznosila je 4,40 km/h s koeficijentom varijacije 28,95%,
- prosječne vrijednosti zbijenosti tla na tragu kotača traktora dvostruko je veća (45 N/cm^2 na dubini od 10 cm) nego izvan traga kotača traktora,
- najmanja trošenja materijala na tragu i izvan traga kotača traktora ostvarile su motičice izrađene od materijala oznake $M_{3,}$
- središnje motičice iz materijala M_1 postavljene izvan traga kotača traktora trošile su se u granicama od 48,58 do 49,59 uz prosjek od 49,085 grama, a središnja motičica

iz materijala M_3 izgubila je 43,36 grama mase uz prosječno smanjenje površine oštrice od 13,50 cm^2,

- središnje motičice iz materijala M_2 izgubile su prosječno 77,23 grama mase uz prosječno smanjenje površine oštrice od 31,25 cm^2,
- srednja motičica iz materijala M_4 izgubila je tijekom rada 98,89 grama mase ili 37,56%,
- prema rezultatima trošenja materijala i smanjenja površine oštrice motičica prednost treba dati materijalu M_3, koji je bio podvrgnut postupku vruće metalizacije,
- ispitivane materijale možemo svrstati u naredne grupe:

  M_3 – izvrstan,

  M_1 – vrlo dobar ,

  M_2 – dobar,

  M_4 – prihvatljiv,
- kultivatorske motičice iz materijala M_3 kroz ispitivanje imale su zadovoljavajuću oštricu, što ukazuje na potrebu primjene postupka vruće metalizacije motičica, a naročito za središnji dio sekcije.

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MATERIAL WEAR OF CULTIVATOR SHOVELS

SUMMARY

The investigation comprises shovels quality and wear of one intercultivator at 225 ha of sugar beet and soybean tillage in two vegetation year period. The cultivator accomplished working depth of 4.10 cm with variance coefficient 24.15% at average working speed of 4.40 km per hour with variance coefficient of 28.95% on arable semigley shallow gley-noncalcareous and partially hydroreclamated soil.

The highest mass loss of 34.10% and 37.56% was measured at shovels marked M_4 (left and middle shovel) set behind tractor pneumatic. The lowest mass loss of 12.02% with shovel made from material M3 and highest of 30.53% with shovel made from material M2 was achieved with work beyond the track of tractor pneumatic tyre.

The lowest surface wear of 11.12% was measured with shovels made from material M3 and the highest one of 45.78% with shovels made from material M1 by soil tillage beyond the track of tractor pneumatic tyre. Shovels made from material M4 and material M3 set behind tractor tyres lost 29.60% and 30.66% of the initial surface.

Side set shovels (left and right) on the cultivator section lost minimum mass of 13.67% (material M2) and surface 21.71% (material M2) whereas maximum mass loss amounted to 15.05% (material M2) and surface 24.06% (material M2).

***Key words**: cultivator, hoe culters (welded, unwelded), material wearing out, soil compaction.*

34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.51
Tehnička bilješka
Technical note

NOVE TEHNOLOGIJE I ISKUSTVA U MINIMALIZACIJI OBRADE TLA

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SAŽETAK

Rad prikazuje usporedbu utroška rada strojeva i ljudi u proizvodnji ozime pšenice konvencionalnom, minimalnom i nultom obradom tla. U radu je također naveden i temeljni stručni pristup poljoprivrednoj proizvodnji u uvjetima globalnog tržišta, što je za uvjete u Hrvatskoj nova spoznaja.

***Ključne riječi**: Obrada tla, pšenica, konvencionalna, minimalna, nulta obrada*

UVOD

Živimo u vremenima sveopćeg povećanja proizvodnje i potrošnje hrane na globalnoj razini, tako i velikoj konkurenciji koja svakim danom raste. Ulaskom naše zemlje u EU znatno će se promijeniti uvjeti proizvodnje zbog otvorenog tržišta na kojemu su cijene poljoprivrednih proizvoda značajnije niže nego u našoj zemlji.

Tradicionalan način proizvodnje, je skup i neučinkovit, mora se promijeniti, jer u konkurenciji koja nas očekuje, starim pristupom i načinom rada u proizvodnji smo osuđeni na propast!

U zadnjih desetak godina, uvidjeli smo kako moramo učiniti nešto na racionalizaciji proizvodnje i smanjenju troškova, tako da sam aktivno sudjelovao u traženju načina kako to postići, a zahvaljujući firmi u kojoj radim (HANA – Breznici) i entuzijazmu, spremnosti na promjene, i bio u mogućnosti vidjeti nešto od onoga kako se to radi u Americi, zadnje vrijeme i u Europi. Ta su iskustva od neprocjenjive važnosti, jer sam počeo drugačije gledati na proizvodnju, polako stvarati jedan novi sustav proizvodnje i uz nabavku nove mehanizacije, sa uspjehom je koristiti u našim uvjetima. Radi se o sasvim novom pristupu proizvodnji, novoj filozofiji, koja je sama po sebi logična, naoko jednostavna, ali iziskuje potpuno razumijevanje pristupa, disciplinu i odgovornost, jer ne podrazumijeva ¨pravo¨ na pogrešku. Ako se radi po pravilima struke i znanja, onda višestruko nagrađuje.

Moram napomenuti kako ovim pristupom, uz nužnu opremu koja ide sa njime, je moguća proizvodnja svih ratarskih kultura, na svim tipovima zemljišta, uz uvjet poštivanja njene logike, i pravila struke.

Novi način proizvodnje je sam po sebi daleko jednostavniji, ekonomski isplativiji, ekološki prihvatljiviji. Pored ovih pogodnosti kroz vrijeme se dešavaju nus efekti sa zemljištem, poboljšavaju se njegova fizikalno - kemijsko - biološka svojstva, a što je tradicionalnim načinom godinama uništavano.

BIOLOŠKI EFEKTI KOD PRIMJENA NOVIH TEHNOLOGIJA

Višegodišnjom primjenom ovakvog sustava u proizvodnji dešavaju se pozitivne promjene u tlu! Smanjivanjem prohoda, miješanjem organskih ostataka biljaka u površinskom sloju tla dolazi do promjena u biološkom, i fizikalno - kemijskom sastavu tla.

Jednostavno rečeno, tlu vraćamo život!

Iz godine u godinu se povećava postotak humusa u površinskom sloju tla, odnosno mikrobiološka aktivnost tla, a što je od nemjerljivog značenja kod fiksacije hranjiva.

Smanjuje se ispiranje tla, erozija vodom, tlo dobiva strukturu i biva pogodnije za proizvodnju.

Značajan efekt je u povećanju populacije glista, tako da se već nakon nekoliko godina njihov broj višestruko povećava, a što one u tlu znače nije potrebno posebno naglašavati!

Vrlo je važno napomenuti da se smanjuje i zakorovljenost, sjemenje korova nije u prilici nicati iz dubine tla, a osjemenjeni korovi se ne deponiranju u tlo, kako bi se jednog dana oslobodili i dobili priliku za nicanje, a kako je to slučaj kada se zemlja ore.

Truljenjem korjenovog sistema prethodnih kultura, u tlu ostaju prostori kojima se suvišna voda drenira, pa tako tlo biva propusnije za vodu i ne zadržava se na površini, samim time se smanjuju gubici od gušenja usjeva prekomjernim vodama.

U sušnijim godinama, ovim načinom rada se uspješno konzervira vlaga, što je jako važan preduvjet za jednolično nicanje i normalan razvoj usjeva.

Sve u svemu, proizvodnja dobiva prirodniji tijek, koji je ekološki prihvatljiviji od tradicionalnog!

MEHANIZACIJA NOVIH TEHNOLOGIJA

Kao što je potrebno korak po korak razumijevati suštinu sustava Novih tehnologija, tako je i nemoguće preko noći nabavljati strojeve za nju. Pokazalo se kako je važno da svatko tko primjenjuje i želi primijeniti ovaj način proizvodnje, mora stvarati i sustav koji je prilagođen uvjetima, plodoredu i tlu na kojemu se proizvodnja odvija.

Nabavkom samo nekoliko strojeva: no-till sijačica za širokorednu i uskorednu sjetvu, i stroja za površinsku obradu (miješanje, usitnjavanje i ravnanje) smo došli do potrebne mehanizacije za pripremu i sjetvu, odnosno proizvodnju svih ratarskih kultura.

Oni se upotrebljavaju od trenutka do trenutka, jer je ova tehnologija, tehnologija trenutka!

Strojevi su kapacitirani tako da se u vrlo kratko vrijeme može obaviti jako mnogo posla, tako da se i u najnepovoljnijim godinama može uhvatiti nekoliko optimalnih dana, što se tiče vlažnosti zemljišta i agrotehničkih rokova, izvršiti sjetvu optimalno i kvalitetno!

Cijeli sustav obrade se temelji na strojevima širokog zahvata, koji od sjetve do berbe mogu obaviti posao onda i kada to zemljište kaže, pa se izbjegavaju ekscesne situacije, zapadanja, masakriranja zemljišta i njegovog sabijanja.

Sve u svemu, brojnost se strojeva drastično smanjuje, oni su višenamjenski, jednostavni pa je i potreba za servisiranjem mala.

EKONOMSKI EFEKTI PRIMJENE NOVIH TEHNOLOGIJA

Kada pogledamo strukturu troškova u proizvodnji neke ratarske kulture, vidimo kako se troškovi proizvodnje mogu grupirati u tri grupe:

1. 1 .Troškovi mehanizacije
2. Troškovi materijala
3. Opći troškovi

Za većinu kultura ti troškovi čine oko 1/3 troškova svaka od njih, ali sa naglašenim troškovima u mehanizaciji koji mogu varirati u zavisnosti od godine do godine, pa su ponekada i veći!

Troškovi materijala (sjeme, umjetna gnojiva, zaštitna sredstva...) su uglavnom jednaki te se značajnije ne mijenjaju!

Opći troškovi (zakupa, osiguranja, plaća...) su konstantni i ne mijenjaju se značajnije.

Ako pogledamo gdje bi mogli značajnije utjecati u smanjivanju troškova, tada nam se samo po sebi nameće da su moguće promjene u troškovima mehanizacije, dakle u smanjivanju upotrebe strojeva, odnosno prohoda, a samim time uštedama na gorivu, amortizaciji, rezervnim dijelovima i ljudskom radu koji je vezan uz to.

Kao primjer ušteda na mehanizaciji, u priloženim je tablicama prikazana potrošnja potrebnih radnih sati strojeva u proizvodnji pšenice na Hana Breznici d.o.o. po tehnologijama.

Tablica 1 Tehnološka karta

NO-TILL PROIZVODNJA PŠENICE										
Radna operacija			Sredstvo rada		Vrijeme	RADNIH SATI / ha				
R.br.		ha	Pog. stroj	Priključak		LT	ST	TT	KMB	Ukup.
1.	Izvoz gnojiva+utov.	1	LT	PDU-Prik	5-25.10	0,16				
2.	Gnojidba osn.x2	1	ST	Rasipač	5-25.10		0,32			
3.	Izvoz sjemana	1	LT	Prikolica	5-25.10	0,08				
4.	Sjetva	1	ST	No-till sij.	5-25.10			0,33		
5.	Izvl.vod.brazdi	1	LT	Kanalok.	5-25.10	0,23				
6.	Izvoz gnojiva	1	LT	PDU-Prik	5-15.02	0,08				
7.	Prihrana	1	ST	Rasipač	5-15.02		0,16			
8.	Izvoz vode	1	LT	Cisterna	5-15.04	0,12				
9.	Prskanje G i F	1	LT	Prskalica	5-15.04	0,16				
10.	Izvoz gnojiva	1	LT	PDU-Prik	5-15.04	0,08				
11.	Prihrana	1	ST	Rasipač	5-15.04		0,16			
12.	Izvoz vode	1	LT	Cisterna	10-20.05	0,12				
13.	Prskanje F i I	1	LT	Prskalica	10-20.05	0,16				
14.	Žetva	1	KOMB.		1-15.07				0,4	
15.	Odvoz zrna	1	LT	Prikolice	1-15.07	0,83				
16.	Zaoravanje jaraka	1	LT	Plug	1-15.07	0,1				
17.	PPZ	1	LT	Cisterna	1-15.07	0,04				
	UKUPNO					2,16	0,64	0,33	0,4	3,53

MIN.-TILL PROIZVODNJA PŠENICE - "HORSCH"										
	Radna operacija		Sredstvo rada		Vrijeme	RADNIH SATI / ha				
R.br.		ha	Pog. stroj	Priključak		LT	ST	TT	KMB	Ukup.
1	Izvoz gnojiva	1	LT	PDU-Prik	5-25.10	0,16				
2	Gnojidba osn.x2	1	LT	Rasipač	5-25.10		0,32			
3	Izvoz sjemena	1	LT	Prikolica	5-25.10	0,08				
4	Priprema za sj.x2	1	TT	Terano	5-25.10			0,4		
5	Sjetva	1	TT	Sijačica	5-25.10			0,33		
6	Izvl. Vod. Brazdi	1	LT	Kanalok.	5-25.10	0,23				
7	Izvoz gnojiva	1	LT	PDU-Prik	5-15.02	0,08				
8	Prihrana	1	ST	Prikolica	5-15.02		0,16			
9	Izvoz vode	1	LT	Cisterna	5-25.04	0,12				
10	Prskanje H i F	1	LT	Prikolica	5-25.04	0,16				
11	Izvoz gnojiva	1	LT	PDU-Prik	1-15.04	0,08				
12	Prihrana	1	ST	Rasipač	1-15.04		0,16			
13	Izvoz vode	1	LT	Cisterna	10-20.5	0,12				
14	Prskanje I i F	1	LT	Prskalica	10-20.5	0,16				
15	Žetva	1	KOMB.		1-15.07.				0,4	
16	Odvoz zrna	1	LT	Prikolica	1-15.07.	0,83				
17	Zaoravanje jaraka	1	LT	Plug	1-15.07.	0,1				
18	PPZ	1	LT	Cisterna	1-15.07.	0,04				
	UKUPNO					2,16	0,64	0,77	0,4	3,97

KLASIČAN NAČIN PROIZVODNJE PŠENICE										
Radna operacija			Sredstvo rada		Vrijeme	RADNIH SATI / ha				
R.br.		ha	Pog. stroj	Priključak		LT	ST	TT	KMB	Ukup.
1.	Izvoz gnojiva+utov.	1	[1]LT	PDU-Prik	5-25.10	0,16				
2.	Gnojidba osn.x2	1	[2]ST	Rasipač	5-25.10		0,32			
3.	Oranje 25-30cm	1	[3]TT	Plug	5-25.10			1,4		
4.	Tanjuranje oranja	1	TT	tanjurača	5-25.10			0,32		
5.	Ravnanje	1	ST	ravnjač	5-25.10		0,63			
6.	Izvoz gnojiva+utov.	1	LT	PDU-Prik	5-25.10	0,08				
7.	Gnojidba start.	1	ST	Rasipač	5-25.10		0,16			
8.	Tanjuranje za sj.	1	ST	tanjurača	5-25.10		0,37			
9.	Valjanje 50%	1	ST	multitiler	5-25.10		0,23			
10.	Tanjuranje	1	ST	tanjurača	5-25.10		0,32			
11.	Priprema sjetve	1	ST	sjetvospr.	5-25.10		0,25			
12.	Izvoz sjemana	1	LT	Prikolica	5-25.10	0,08				
13.	Sjetva	1	ST	No-till sij.	5-25.10			0,33		
14.	Zadrljavanje sj.50%	1	ST	drljača	5-25.10		0,15			
15.	Izvl.vod.brazdi	1	LT	Kanalok.	5-25.10	0,23				
16.	Izvoz gnojiva	1	LT	PDU-Prik	5-15.02	0,08				
17.	Prihrana	1	ST	Rasipač	5-15.02		0,16			
18.	Izvoz vode	1	LT	Cisterna	5-15.04	0,12				
19.	Prskanje G i F	1	LT	Prskalica	5-15.04	0,16				
20.	Izvoz gnojiva	1	LT	PDU-Prik	5-15.04	0,08				
21.	Prihrana	1	ST	Rasipač	5-15.04		0,16			
22.	Izvoz vode	1	LT	Cisterna	10-20.05	0,12				
23.	Prskanje F i I	1	LT	Prskalica	10-20.05	0,16				
24.	Žetva	1	[4]KOMB.		1-15.07				0,4	
25.	Odvoz zrna	1	LT	Prikolice	1-15.07	0,83				
26.	Zaoravanje jaraka	1	LT	Plug	1-15.07	0,1				
27.	PPZ	1	LT	Cisterna	1-15.07	0,04				
	UKUPNO					2,32	2,75	2,05	0,4	7,52

[1] Laki traktor [2] Srednji traktor [3] Teški traktor [4] Kombajn

Tablica 2 Radni sati strojeva po tehnologijama - pšenica

		ha	LT	ST	TT	KMB	UKUPNO
1.	**KLASIKA**	1	2,32	2,75	2,05	0,4	**7,52**
2.	**MIN-TILL**	1	2,16	0,64	0,77	0,4	**3,97**
3.	**NO-TILL**	1	2,16	0,64	0,33	0,4	**3,53**
	RAZLIKA 1-2		0,16	2,11	1,28	0,4	**3,55**
	RAZLIKA 1-3		0,16	2,11	1,72	0,4	**3,99**

ZAKLJUČAK

Uvođenjem novih spoznaja, novih tehnologija je neminovnost i naša budućnost! Njima se pojednostavljuje proizvodnja, postaje logičnija, učinkovitija, ekonomičnija i biološki prihvatljivija.

Ona je pametna, jer koristi resurse prirode da radi umjesto nas.

Ovaj pristup je važno razumjeti, jer predstavlja novu filozofiju rada u kojoj sa mora u svakom trenutku razumijevati interakcija čovjeka, tla, biljke i stroja!

Temelji se na zaključcima trenutka, pa je važno da je onaj tko ju primjenjuje i u potpunosti razumije, jer ne podrazumijeva ¨pravo¨na grešku!

Onaj tko ore zemlju, nemilosrdno i nepotrebno gazi po njoj, ima mnogo novaca, ali polako uništava sebe i nju!

NEW TECHNOLOGIES AND EXPERIENCES WITH SOIL TILLAGE REDUCING

Paper shows comparison of winter wheat production machinery and labour requirement under three soil tillage systems: Conventional tillage, Minimum tillage and No-till.

***Key words**: Soil tillage, winter wheat, conventional tillage, minimum tillage, no-till*

34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.314:633.12
Stručni rad
Expert paper

PRIMERJAVA UČINKOVITOSTI VALJARJEV NA VZNIK AJDE

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POVZETEK

V poljskem poskusu je bil proučevan vpliv različnih valjarjev (gumasti, robati in gladki) na vznik treh sort ajde ('Darja', 'Bamby' in 'Gorenjka'). Poskus je bil postavljen na podlagi deljenih parcel v naključnem bloku. Setev in valjanje sta bili opravljeni šestega julija 2003. V tem času je bila prisotna ekstremna suša, ki je povzročila pomanjkanje vlage v tleh. Štetje rastlin je bilo opravljeno desetega in dvanajstega julija, se pravi četrti in šesti dan po setvi. Največ vzniklih rastlinic je bilo pri gumastem valjarju, sledila sta gladki valjar in robati valjar. Najmanj vzniklih rastlinic je bilo na nepovaljanih parcelicah.

Sorta je statistično značilno vplivala na delež vzniklih rastlin četrti in šesti dan po setvi. Največ vzniklih rastlin je imela sorta 'Gorenjka', sledi sorta 'Bamby' in z najmanj vzniklimi rastlinami sorta 'Darja'.

Najboljša kombinacija je gumasti valjar in sorta 'Gorenjka'.

Ključne besede: *obdelava tal, valjarji, ajda, vznik, sklop*

UVOD

Valjanje je postopek sekundarne obdelave tal. Z njim popravljamo napake, ki smo jih storili pri oranju. Po oranju z valjanjem tlačimo in stiskamo zemljo, da se hitreje posede in sklene, se pravi, da pritisnemo zrahljano ornico k neornici, da lahko voda prehaja iz spodnjih v zgornje plasti zemlje. Z valjanjem tudi poravnavamo valovito površje, drobimo kepe in grude. Grude, ki jih valjar ne more zdrobiti, pritisne v zemljo. S tem izboljšamo delovanje talnih herbicidov. Valjamo po setvi, če se zemlja pri spomladanski ali poletni obdelavi strnišča preveč izsuši. Tedaj valjamo, da seme hitreje vzkali, kar je za drobna semena skoraj vedno potrebno.

S tem omogočimo kapilarno vzpenjanje vode in enakomeren vznik, ker poravnamo površje zemlje. Rahlo valjanje zemlje pred setvijo omogoči boljši stik semena z zemljo in enakomernejši vznik posevka. Njive valjamo tudi po zaoravanju hlevskega gnoja ali strnišča z veliko organske mase, če je zemlja preveč rahla, da vlaga ne more krožiti.

Z valjanjem zemljo stisnemo, razbijamo grude, zmanjšamo prostornino nekapilar in s tem povečamo kapilarni vzpon vode. Valjanje je potrebno predvsem po setvi drobnega semena, ki ga sejemo v poletnih mesecih, da privabimo vlago do semena in tako zagotovimo dobre pogoje za čim hitrejši in enakomernejši vznik [2].

OPIS VALJARJEV

Valjarji so orodja, ki pri pripravi zemlje za setev lahko koristijo, lahko pa tudi škodijo. Škodijo zlasti, če valjamo premokro zemljo. Valjarji mrvijo zemljo, jo zgoščujejo, drobijo grude, stisnejo zemljo in seme, da lahko to hitreje kali. Z njimi prav tako podiramo zelene rastline, ki jih bomo podorali. Valjarji mrvijo s svojo težo, obliko in hitrostjo. Razlikujemo gladke in robate (kolutasti, zobati) ter podzemne valjarje [1].

V poskusu smo uporabili gumasti valjar, gladki valjar in robati valjar.

Gumasti valjarji

Gumasti valjarji so sestavljeni iz niza gum, ki so postavljena ena k drugi na skupni osi (slika 1). Povaljana površina ni gladka. Gumasti valjarji se dobro obnesejo za valjanje po setvi, ker je guma prožna in se dobro prilagaja terenu. Uporabljajo se tudi v združenih orodjih, največkrat so agregatirani skupaj z vrtavkasto brano.

Slika 1 Gumasti valjar

Gladki valjarji

Gladki valjarji uspešno delajo na ravnih tleh brez jarkov ali grebenov. Sprva so bili leseni, danes so kovinski, polnjeni z vodo, mivko ali betonom [3].

Sestavljeni so iz enega ali več valjastih teles. Večdelni so pritrjeni na skupni jarem in med seboj povezani z verigami. Gladki valjarji zgostijo zemljo le na površju, zato velikokrat nastane skorja, prav tako slabo strnejo ornico z neornico. Uporabljamo jih za privabljanje vode do semena, sledi jim lahko brananje, da se vlaga po nepotrebnem ne izgublja v ozračje. Gladki valjarji se uporabljajo za vzpostavitev kapilarnega vzpona, ne pa za zgoščevanje zorane zemlje.

Robati valjarji

Robati valjar je imel delovno širino 2,20 m. S svojimi ostrimi robovi dobro drobijo grude in jih pritiskajo v tla. Površina za robatimi valjarji ne ostaja gladka, tako ni nevarnosti, da bi nastala skorja. Dobro se obnesejo tudi na neravnih terenih.

MATERIAL IN METODE

Poskus

Dne 6. 7. 2003 smo začeli poljski poskus na njivi v bližini Bistrice ob Sotli. Poskus je bil zasnovan na podlagi deljenih parcel v naključnem bloku. Vključeni so bili trije tipi valjarjev, kontrola (brez valjanja) in tri sorte. Celoten poskus je bil postavljen v štirih ponovitvah. Preučevan je bil vznik četrti in šesti dan po setvi. Setev in valjanje sta bili opravljeni isti dan 6. 7. 2003. Po šestem dnevu ni bilo novega vznika, zato nadaljnje štetje rastlinic ni bilo smiselno. Split blok shema poskusa je prikazana v preglednici 1.

Preglednica 1 Split blok shema (A_1 - 'Bamby', A_2 - 'Darja', A_3 - 'Gorenjka',V_k - kontrola (brez), V_1 - robati valjar, V_2 - gumasti valjar, V_3 - gladki valjar)

I.	V_k V_3 V_1 V_2	A_1	A_2	A_3
II.	V_2 V_3 V_k V_1	A_2	A_3	A_1
III.	V_1 V_2 V_3 V_k	A_3	A_1	A_2
IV.	V_3 V_k V_1 V_2	A_2	A_3	A_1

Uporabljeni priključki

V poskusu so bili uporabljeni: dvobrazdni obračalni plug (12 col), predsetvenik, sejalnica za strnjeno setev, robati valjar, gumasti valjar in gladki valjar.

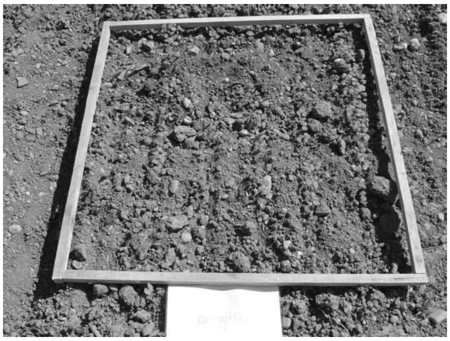
Ugotavljanje gostote posevka pri različnih sortah ajde ('Bamby', 'Darja', 'Gorenjka')

Za uspešen vznik, razraščanje in uspevanje posevka, potrebuje rastlina določen prostor. V prejšnjih poskusih je bilo dokazano, da je pridelek pri 250 semenih na m^2 enak kot pri 700 semenih na m^2. Za poljski poskus je bil izbran sklop 500 semen na m^2. Vznik je dan, ko se opazijo razločno posejane vrstice. Štetje rastlin je način ugotavljanja gostote posevka. Preštejejo se mlade rastlinice na površini m^2. V ta namen je bil izdelan okvir dimenzij 1 m krat 1 m, ki se polaga na posevek in znotraj okvirja se preštejejo rastline.

Na sliki 2 je prikazana sorta 'Gorenjka' v kombinaciji z gumastim, gladkim, robatim valjarjem in kontrolo.

'Gorenjka'; gumasti valjar

'Gorenjka'; gladki valjar



'Gorenjka'; kontrola

'Gorenjka'; robati valjar

Slika 2: Sorta 'Gorenjka' z različnimi valjarji in kontrolo [4]

Iz slike 2 je razvidna tudi najboljša kombinacija in sicer sorta 'Gorenjka' z gumastim valjarjem.

REZULTATI Z RAZPRAVO

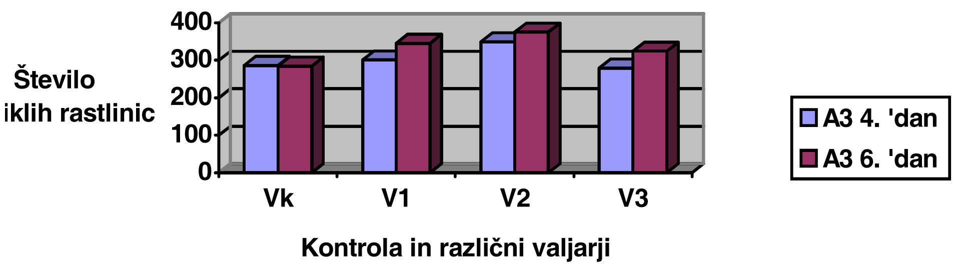
Vpliv različnih valjarjev na različne sorte ajde

S statistično obdelavo podatkov (preglednica 2) smo dokazovali, kako vplivajo različni valjarji (robati, gumasti, gladki) na različne sorte ajde ('Bamby', 'Darja', 'Gorenjka').

Preglednica 2 Statistično značilne razlike vplivov treh tipov valjarjev na tri različne sorte ajde [4]

Dejavnik	n	4. dan	6. dan
Sorte - S	3	**	**
Valjarji - V	3	**	**
S x V		**	**
Sorte			
A_1 - 'Bamby'		278 a	310 a
A_2 - 'Darja'		195 b	235 b
A_3 - 'Gorenjka'		296 a	332 a
Valjarji			
K - kontrola		208 b	235 b
V_1 - robati		276 a	307 a
V_2 - gumasti		293 a	334 a
V_3 - gladki		249 b	292 ab

** - signifikantnost pri $P \leq 0{,}01$
n.s. - ni signifikantno, razlike med obravnavanji ne obstajajo
a, b - sredine, označene z različnimi črkami v stolpcu



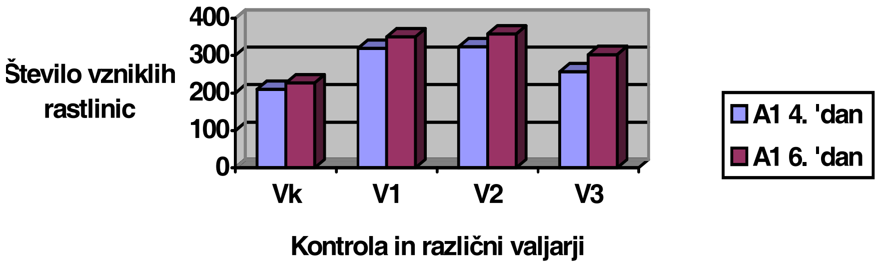
V_k - kontrola, V_1 - robati valjar, V_2 - gumasti valjar, V_3 - gladki valjar

Grafikon 1 Različni valjarji in kontrola pri sorti 'Gorenjka' A_3 (4. in 6. dan) [4]

Analiza variance kaže, da obstajajo signifikantne razlike ($P \leq 0{,}01$) med valjarji in sortami. Sorta (kultivar) je statistično značilno vplivala na delež vzniklih rastlinic, tako četrti kot šesti dan po setvi. Iz statistične obdelave je razvidno, da je sorta 'Gorenjka' imela vseskozi najvišji delež vzniklih rastlinic, pri čemer pa moramo upoštevati, da je imela tudi največjo kalivost v primerjavi z ostalima sortama.

Kalivost je pri 'Gorenjki' znašala 95 %, kar pomeni, da bi naj od 500 posejanih semen na m^2 vzklilo 475. Po statistični obdelavi, jih je vzniknilo 4. dan 296 in 6. dan 332 (grafikon 1). Podatki so navedeni za valjanje z robatim valjarjem V_1. Iz tega sledi, da je vzniknilo slabih 70 % rastlinic.

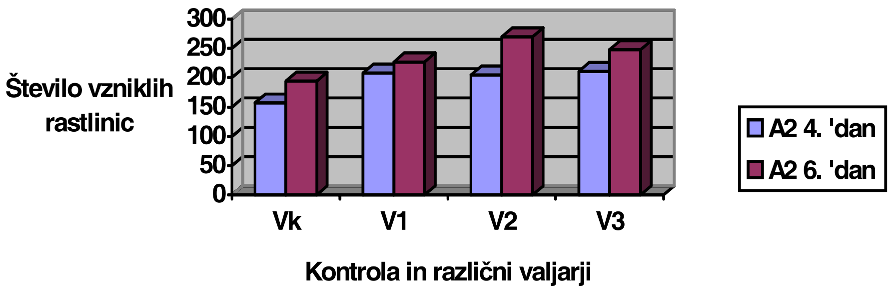
Pri sorti 'Bamby' je znašala kalivost 93 %. Po statistični obdelavi je vzniknilo 4. dan 278 in 6. dan 31 rastlinic (grafikon 2), kar pomeni, da je vzniknilo 66 % rastlinic.



V_k - kontrola, V_1 - robati valjar, V_2 - gumasti valjar, V_3 - gladki valjar

Grafikon 2 Različni valjarji in kontrola pri sorti 'Bamby' (4. in 6. dan) [4]

Sorta 'Darja' je imela najnižjo kalivost (90 %) in tudi vznik je bil najnižji glede na ostali sorti. Od 450 semen, ki naj bi vzklila jih je po statistični obdelavi je 4. dan vzniknilo 195 in 6. dan 235 rastlinic (grafikon 3).



V_k - kontrola, V_1 - robati valjar, V_2 - gumasti valjar, V_3 - gladki valjar

Grafikon 3 Različni valjarji in kontrola pri sorti 'Darja' (4. in 6. dan) [4]

Na število vzniklih rastlinic, ima značilen vpliv ($P \leq 0{,}01$) tudi valjar. Največ vzniklih rastlinic je bilo na parcelicah povaljanih z gumastim valjarjem. Četrti in šesti dan je bil vznik na teh parcelah za 30 % večji, kot na nepovaljanih. Na parcelicah povaljanih z robatim valjarjem je bilo vzniklih rastlinic za 24,5 % več kot na nepovaljanih, šesti dan pa za 23,5 % več. Medtem ko je bil vznik pri gladkem valjarju najnižji in sicer 4. dan 16,5 % in 6. dan 20 % večji kot na nepovaljanih površinah. Iz tega smo zaključili, da sta se v kombinaciji najbolje obnesla gumasti valjar in sorta 'Gorenjka'.

SKLEPI

1. Valjanje vpliva na hitrost in enakomernost vznika (razlika 4. dan – 6. dan in katastrofalni rezultati brez valjanja).
2. Razvidna je velika razlika med valjarji (gumasti V_2, robati V_1, gladki V_3).
3. Valjanje po setvi pride do izraza v poletnih mesecih, ko ponavadi primanjkuje vlage za kalitev. To velja še zlasti v ekstremno sušnem poletju, kot je bilo to v katerem smo delali ta poskus. Tako omogočimo semenu boljše pogoje za kalitev.

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COMPARISON OF EFFICIENCY OF ROLLERS FOR SPROUTING OF BUCKWHEAT

SUMMARY

In a field test the influence of different rollers (rubber, edged and smooth) on sprouting of three sorts of buckwheat ('Darja', 'Bamby' and 'Gorenjka') was compared. The test was carried out on the basis of divided lots of land in a random block. Sowing and rolling were performed on 6 June 2003. During that period there was an extreme drought causing lack of humidity in the ground. The plants were counted on the 10 and 12 July, i.e., on the fourth and sixth day after sowing. There most sprouting plants in case of rubber rollers, followed by smooth and edged rollers. The least plants sprouted on the non-rolled lots of land.

The sort had a statistically characteristics effect on the share of plants sprouting during the fourth and sixth day after sowing. The sort 'Gorenjka' had most sprouting plants, followed by the sort 'Bamby' and the sort 'Darja' with least sprouting plants.

The most favourable combination is the rubber roller and the sort 'Gorenjka'.

Key words: *cultivation of soil, rollers, buckwheat, sprouting, density of sowing*

34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.459:631.61
Tehnička bilješka
Technical note

THE USE OF ^{137}CS TECHNIQUE FOR STUDY SOIL EROSION IN THE SMALL LOESS AGRICULTURAL CATCHMENT

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SUMMARY

In the present study the ^{137}Cs technique was used to measure soil erosion and accumulation on an agricultural field located on the Proboszczowicki tableland near Ujazd village (south Poland). Study area is a small agricultural valley representative to study soil erosion for this area. Three profile across the valley were taken. To assess the rate of soil erosion and deposition the ^{137}Cs measurement was used. The activity of the ^{137}Cs in soil samples was measured by means of high-resolution gamma spectrometry and then the ^{137}Cs inventories for sampling points were calculated. The ^{137}Cs inventories are related to the erosion and deposition rates. The value of soil erosion was calculated by using the proportional model as well as the mass balance model. The ^{137}Cs inventory for study cultivated field ranges from 656 to 10358 Bq/m^2. The smaller of these two values correspond with the erosion rate 92 t/ha·yr whereas the higher with the deposition 46 t/ha·yr. The results obtained from the investigation confirm the potential for using ^{137}Cs measurement in soil erosion investigation and show that the intensity of soil erosion in the study area is considerable.

***Key words**: ^{137}Cs, soil erosion, spatial variability.*

INRODUCTION

Soil degradation by water and wind erosion is a serous problem in most countries. Furthermore, loessial soils are very susceptible to water erosion processes. Even small inclination of few degrees may result in medium to large water erosion of loessial soil (Starkel, 1991). Additionally, an inappropriate soil tillage intensifies the soil erosion. There is an urgent need to obtain reliable quantitative data of the soil erosion for agricultural areas to choose an effective method of soil conservation. ^{137}Cs seems a valuable tracer to study soil erosion and sedimentation because after deposition ^{137}Cs on the land surface is rapidly and strongly adsorbed by soil particles (Schulz et al., 1960). This isotope has been present in the environment since the beginning of nuclear weapon testing and nowadays ^{137}Cs is a part of many ecosystems. The ^{137}Cs method overcomes many limitations of the traditional methods to measure soil erosion as well as the empirical models such as USLE or RUSLE (Stach, 1996). The detailed discussion of the advantages and limitations of the ^{137}Cs method has been presented by Ritchie and McHenry (1990). In few words, this method is based on the comparison of the ^{137}Cs inventories in sampling points with a reference inventory. The reference inventory presents the local input fallout of ^{137}Cs. This means that for a reference site neither erosion nor deposition of soil occurred. The estimation of the local input fallout of ^{137}Cs is problematic especially in regions where undisturbed sites are unusual. The comparison between ^{137}Cs inventory at sampling point and reference ^{137}Cs allows recognising erosion and deposition areas; to obtain quantitative estimation of soil erosion, however, one of the models should be used (Walling *et al*., 1990; Walling *et al*, 1999). Nowadays many relationships to convert ^{137}Cs data into soil erosion exist. All approaches can be divided into two main groups: empirical relationships (Ritchie *et al*., 1974, 1975) and theoretical models (Brown et al., 1981; Kachanowski *et al*., 1984; Quine, 1989; Zhang *et al*., 1999). The results of soil erosion obtained by the mass balance models established by the Kachanowski *et al*. (1984) and improved by Walling et al. (1999) seem to be the most reliable in the group of theoretical models. This approach takes into account the proportion of the freshly deposited ^{137}Cs fallout removed by erosion before mixed into plough layer. It should be mentioned that for cultivated areas, not only water erosion of soil occurs but also a tillage redistribution (Govers *et al*., 1994). A model where the tillage redistribution is incorporated was described by Quine *et al*. (1996) and the refined mass balance model incorporating soil movement by tillage was described by Walling et al. (1999) and thus provides a more realistic values of soil erosion for cultivated than other mass balance models.

This paper describes the measurement of ^{137}Cs activity in cultivated loessial soil. We measured the activities of ^{137}Cs in soil samples in a small agricultural catchment. The study area was contaminated by ^{137}Cs from Chernobyl accident. Cesium-137 method was used as a tool to investigate soil erosion and accumulation for small agricultural catchment. The aim of this study is to evaluate the soil erosion and accumulation rates for the agricultural field located on the slope as well as to evaluate the contribution of tillage effect in soil redistribution for the study area. The value of the erosion rate was obtained by applying the mass balance models as well as the proportional model. Moreover the aspects related to the choice of the model for calculation of erosion rate are discussed.

SITE AND METHODS

The study area selected for the investigation is a small agricultural valley located on the Proboszczowicki tableland near (Ujazd village, South Poland; 50°24´ N, 18°24´ E). The average inclination for the slopes of the study area is 10º. The average annual rainfall for study area is 675 mm, with a range of 277 mm in 1953 to 933 mm in 1981. Generally, the highest intensity of precipitation is in July. The highest daily rainfall was recorded in July

1997 – 257,8 mm. The study area has been cultivated since at least the end of the Second World War. The valley profiles were taken from this area. The scheme of the sampling is presented in figure 1. Soil samples were collected in October 2003. The soil samples were taken by means of the 80 mm diameter borer. Three soil cores were taken at each location and the composite sample for a given depth was formed. Usually soil cores were taken to the depth 80-90 cm on the slope and at the top, but at the slope base soil cores were taken down to a depth of 100cm. Each core was sectioned into 10 cm sections. Soil samples were dried in the dryer until their mass was constant and sieved to remove stones and visible parts of plant roots. A prepared sample was then placed in the Marinelli beaker. The average mass of measured soil samples was 500 g. The activity of ^{137}Cs in samples was measured by high-resolution gamma spectrometry with HPGe detector manufactured by CANBERRA. The resolution was 1.8 keV at 1.33 MeV energy and relative efficiency of 35%. The counting time was usually 80 ksec. The GENIE PC software was used to analyse gamma spectra. The reference material Soil-6 (distributed by IAEA) was used as a standard of ^{137}Cs activity. Finally, activities of ^{137}Cs in soil samples were expressed in Bq/kg of dry mass of soil on the date of collection, corrected for the radioactive decay.

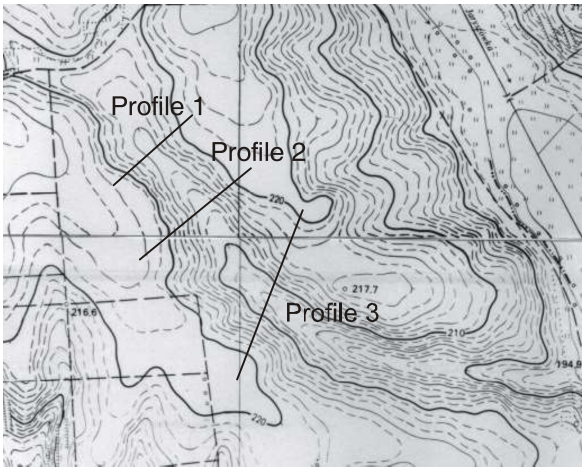

Figure 1 The study area and the scheme of the valley profiles.

There are only few places in the world where deposition of ^{137}Cs has been measured since nuclear weapon tests started. However, the knowledge about the rate of fallout is essential (Ritchie *et al.*, 1990) for a purpose of using ^{137}Cs method to study soil erosion. In Poland the deposition of ^{137}Cs has been measured since 1970 (Stach, 1996). Luckily, the reference value of initial inventory of ^{137}Cs could be done by the measurement of ^{137}Cs in soil on areas where neither erosion nor deposition occurs. This is sometimes quite difficult due to the lack of the undisturbed sites. For presented study area the total baseline inventory of ^{137}Cs was measured in undisturbed soil profiles. The mean value of the total baseline inventory of ^{137}Cs for study area is 5420 Bq/m^2. This value is substantially higher than mean value for Poland (Pietrzak-Flis, 2000; Strzelecki, 1994). That is because the study area is located in the region where larger ^{137}Cs concentration in soil may be expected due to the Chernobyl accident. Concentration of Chernobyl ^{137}Cs varies widely even within one field (Strzelecki *et al.*, 1994; Szewczyk, 1994). Values of Chernobyl ^{137}Cs depend on the trajectories of main radioactivity clouds, and on the precipitation in the area of interest at that time (Stach, 1996; Strzelecki *et al.*, 1994). The increased values of Chernobyl ^{137}Cs concentration are found along the line Warsaw – Opole – the Kłodzko Valley. The largest values of Chernobyl ^{137}Cs fallout were found in Voievodships of Opole and Silesia, and in the Kłodzko Valley in the Sudetes Mts. In these areas values of Chernobyl ^{137}Cs concentration were between 15.6 kBq/m^2 and 19.3 kBq/m^2 (Stach, 1996; Strzelecki *et al.*, 1994). A strong spatial variability of ^{137}Cs concentration from the Chernobyl accident makes the use of ^{137}Cs in soil erosion studies more difficult (Walling et al., 1991). The mean value of ^{137}Cs deposition for the former Voievodships of Opole and Katowice are 11.24 kBq/m^2 and 6.80 kBq/m^2 respectively. The percent of the Chernobyl deposition in global deposition of ^{137}Cs must be known to be able to use the models to calculate soil erosion from ^{137}Cs activity data. Nowadays, there is a problem with separating the Chernobyl fallout from global caesium fallout. The valuable tracer of Chernobyl fallout was another cesium isotope – ^{134}Cs, but this isotope has quite short half-life (approx. 2 yr) and now is not present in the environment. In this work the baseline inventory of ^{137}Cs fallout was separated from the Chernobyl fallout from the global weapon testes fallout by estimating baseline inventory from atmospheric records. Moreover, this method is useful to obtain information about the variability of the ^{137}Cs deposition during the period of the fallout accumulation (Lu et al., 2000). In absence of local records of the ^{137}Cs deposition the model described by the Sarmiento et al. (1986) can be used for this purpose. Figure 2 shows the annual ^{137}Cs fallout estimated from the precipitation data calculated according the model described by Sarmiento et al. (1986).

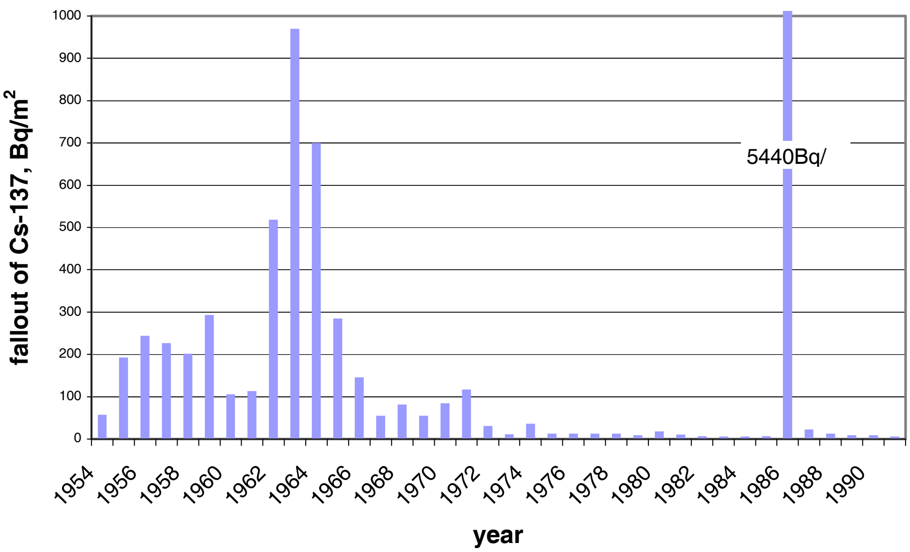

Figure 3 The annual ^{137}Cs fallout for the study area estimated from precipitation data by using Sarmiento's fallout prediction model.

RESULTS AND DISCUSSION

An example of the distribution of ^{137}Cs activity versus depth is presented in Figure 3. The depth distribution of ^{137}Cs activity is similar to the other studies for cultivated soil (Walling et al., 1999). Generally, the thickness of this layer corresponds to the plough depth what probably means that there was no significant accumulation of sediment there. Moreover, the ^{137}Cs concentration is relatively uniformly distributed inside the plough layer. Only for sites where soil accumulation occurs the ^{137}Cs is present below plough depth. For studied locations the plough depth is about 35 cm, within which ^{137}Cs is yearly mixed by agricultural processes.

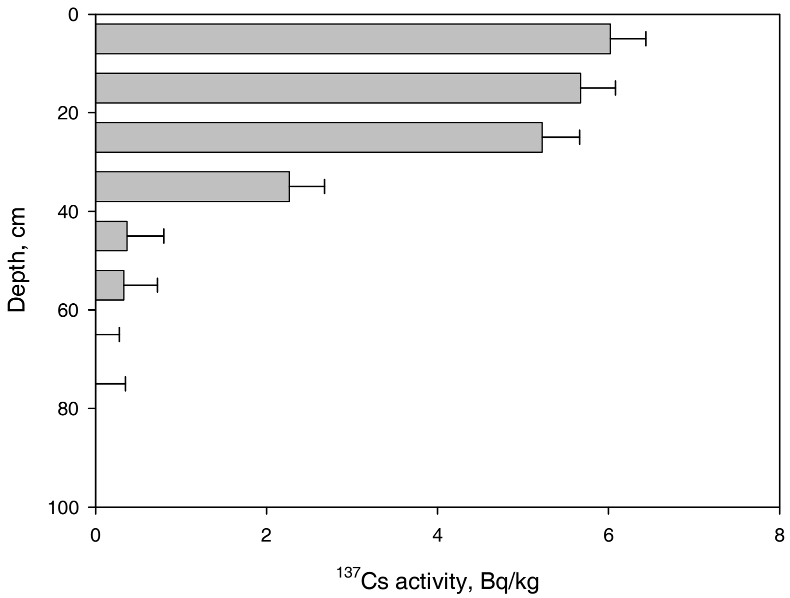

Figure 3 The vertical distribution of ^{137}Cs activity within soil core collected from the cultivated study field.

The results of the ^{137}Cs inventories in soil at studied locations are presented in the Figures 4, 5, and 6. The ^{137}Cs inventory at a sampling point was calculated using the following equation (Sutherland, 1992):

$$C_{inv} = \sum_{i=1}^{n} C_i \cdot BD_i \cdot DI_i \tag{2}$$

where: C_{inv} is the ^{137}Cs inventory (Bq/m^2), i is the sample index, n is the number of the deepest sample with detectable ^{137}Cs, C_i is the activity of ^{137}Cs in i-th soil sample (Bq/kg), BD_i is the bulk density of the dry soil (kg/m^3), DI_i is the thickness of the i-th sample (m).

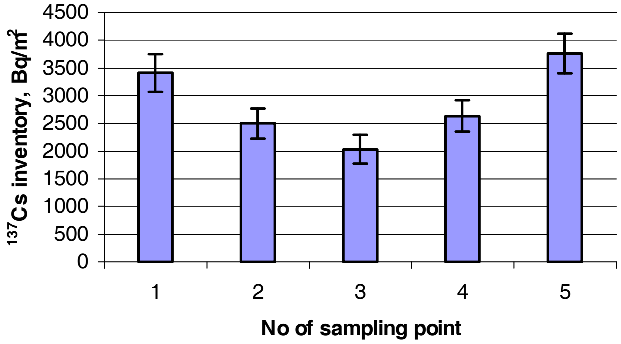

Figure 4 The ^{137}Cs inventory distribution across the valley profile 1.

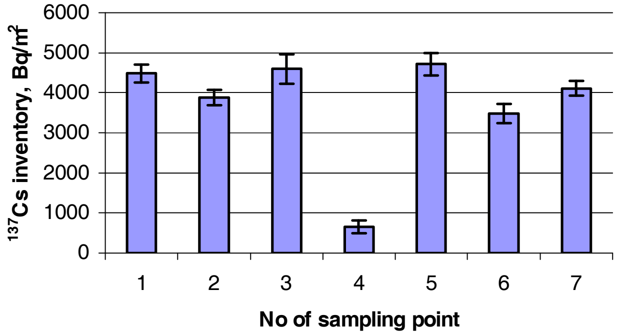

Figure 5 The ^{137}Cs inventory distribution across the valley profile 2

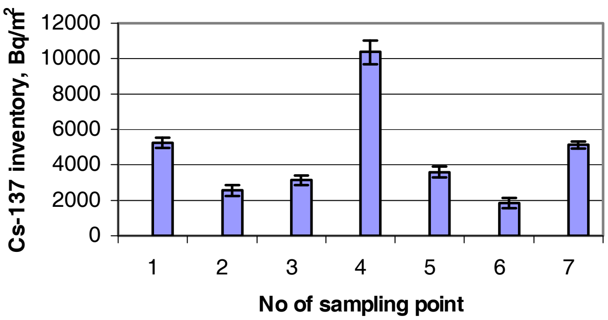

Figure 6 The ^{137}Cs inventory distribution across the valley profile 3.

The spatial variations in the ^{137}Cs inventories in soil could be used to identify the areas of erosion and deposition. It is visible that for almost all sampling points the ^{137}Cs inventory is lower than the reference inventory. The lower values of ^{137}Cs inventories were found on the slopes (10-12^o slope inclination) whereas the lowest ^{137}Cs inventory was found at the valley bottom for valley profile No 2. It might seem surprising but this sampling point is not only the deposition area. This area is rather a transit place. The highest ^{137}Cs inventory was found at the valley bottom for valley profile No 3. By this way the deposition of soil at this site is confirmed and in addition high vale of the ^{137}Cs inventory shows that the rate of this process is rather high. Moreover, the irregular variations of the ^{137}Cs inventories for valley profile 2 and 3 suggest that there is a variation of soil loss and deposition along the slope transect. The simple comparison between reference ^{137}Cs inventory and measured ^{137}Cs inventory allows recognizing erosion and deposition areas; however, to obtain quantitative estimates of soil erosion one of the models should be used (Walling *et al*, 1991). Soil erosion and deposition rates for the study area were calculated by using the proportional model (Walling *et al.*, 1990) as well as the mass balance model (Kachanowski et al., 1984; Zhang et al., 1999; Walling et al., 1999). The main assumption for the proportional model is that ^{137}Cs is completely mixed within the plough layer. If it is true then the soil loss is directly proportional to the ^{137}Cs loss from the soil profile. The equation can be written as follows (Walling *et al.*, 1990):

$$Y = 10\frac{BdX}{100T} \tag{1}$$

where: Y – mean annual soil loss (t·ha^{-1}·yr^{-1}), B – bulk density of the soil (kg m^{-3}), d – depth of the plough layer (m), X – percentage reduction in total ^{137}inventory (defined as $(A_{ref} - A)/A_{ref} \cdot 100$), A_{ref} – local ^{137}Cs reference inventory (Bq m^{-2}), A – measured ^{137}Cs inventory at the sampling point (Bq m^{-2}), T – time elapsed since initiation of ^{137}Cs accumulation (yr).

Although this model is relatively easy to use it has several limitations. For instance, this model assumes that cesium is uniformly distributed in the plough layer. Immediately after the fallout, the surface contained more caesium than lower soil layer due to agricultural mixing, i.e. ploughing. It means that the results of calculation of the soil loss may be overestimated (Walling *et al.*, 1990). Two kinds of mass balance models were also used to calculate soil erosion and deposition. The first mass balance model was described by Zhang et al. (1999). The main assumption of this model is that the total ^{137}Cs fallout occurred in 1963. The mean annual soil loss rate can be expressed as follows:

$$Y = 10dB\left[1-\left(1-\frac{X}{100}\right)^{1/(t-1963)}\right] \tag{2}$$

where: Y – mean annual soil loss (t ha^{-1} yr^{-1}), d – depth of the plough layer (m), B – bulk density of soil (kg m^{-3}), X – the percentage reduction in total ^{137}Cs inventory (defined as $(A_{ref} – A)/A_{ref} \bullet 100$), t – time since the year 1963.

Although this model is very easy to use, the main assumption of this approach that the total ^{137}Cs fallout input occurred in 1963 seems to be an oversimplification. This model does not take into account the value of ^{137}Cs freshly removed from soil surface before incorporation into the plough layer by ploughing. The problem with selective sorption of ^{137}Cs by soil particles could be solved by adding a particle size correction factor (Zhang *et al.*, 1999).

To overcome the problem with removing of the fresh deposition of ^{137}Cs before mixing by ploughing the improved mass balance model was established as follows (He *et al.*, 1997;):

$$\frac{dA(t)}{dt}(1-\Gamma)I(t)-\left(\lambda+P\frac{R}{d}\right)A(t) \tag{3}$$

where: $A(t)$ – cumulative ^{137}Cs activity per unit area (Bq m^{-2}), R – soil erosion rate (kg m^{-2} yr^{-1}), d – the average plough depth (kg m^{-2}), λ - the radioactive decay constant for ^{137}Cs (yr^{-1}), $I(t)$ – annual ^{137}Cs deposition flux (Bq m^{-2} yr^{-1}), Γ - the percent of the fresh deposition of ^{137}Cs removed by erosion before mixing into the plough layer, P – the particle size correction factor.

This model considers the annual fallout ^{137}Cs inputs as well as the losses of ^{137}Cs from the soil due to erosion before mixing with soil by ploughing. To calculate the contributions of the soil movement by tillage into the total soil redistribution the mass balance model described by Walling et al. was used (1999). For the point where soil erosion occurs, the variation of the total ^{137}Cs inventory is expressed as follows:

$$\frac{dA(t)}{dt}=(1-\Gamma)I(t)+R_{t,in}C_{t,in}(t)-R_{t,out}C_{t,out}(t)-R_wC_{w,out}(t)-\lambda A(t) \tag{4}$$

where: $A(t)$ – cumulative ^{137}Cs activity per unit area (Bq m^{-2}), $C_{t,in}$ – the ^{137}Cs concentration of the sediment associated with tillage input (Bq kg^{-1}), $C_{t,out}$ – the ^{137}Cs concentration of the sediment associated with tillage output (Bq kg^{-1}), $C_{w,out}$ – the ^{137}Cs concentration of the sediment associated with water output (Bq kg^{-1}), R_w – the water erosion rate (kg m^{-2} yr^{-1}); R_t – the tillage erosion rate (kg m^{-2} yr^{-1}), Γ – the percentage of the fresh deposit of ^{137}Cs fallout removed by erosion before mixing into the plough layer.

The value of net soil erosion rate could be expressed as follows:

$$R=R_{t,out}-R_{t,in}+R_w \tag{5}$$

where: R – is the net soil redistribution due both tillage and water erosion (kg m^{-2} yr^{-1}).

For the cultivated field this model provides the most realistic values of soil erosion but it is important to mention that this model requires additional information. Moreover, this model like all models described above is sensitive to changing the additional parameters. This is a potential source of uncertainty.

The values for the additional parameters required by the models were estimated using information about local soil and rainfall condition. The results of estimation of soil redistribution rates derived from the ^{137}Cs measurements are summarized in Table 1. The results presented in Table 1 indicate the results of soil erosion are different for different models. The visible difference between results of soil erosion obtained by proportional model and mass balance model are due to limitations of proportional model. The proportional model does not consider the fate of the freshly deposited fallout before its incorporation into the plough layer by cultivation. The mass balance models have not this limitation. Only the simplified mass balance model has this inconvenience. This model provided the results of the soil erosion quite different from the other mass balance model. It should be mentioned that even proportional model provided results of soil erosion in better agreement to mass balance models than simplified mass balance model. That is because the assumption of simplified mass balance model is that the total ^{137}Cs fallout occurred in 1963. It is oversimplification but there is an additional problem for study area. The study area is strongly contaminated by ^{137}Cs from Chernobyl accident. The results of calculation of soil erosion show that the effect of soil redistribution by tillage does not play an important role in global soil redistribution for the study cultivated field. Only for the top of the slope the redistribution of soil by tillage is higher than water erosion. By this way the mass balance model incorporating tillage effect provides the most realistic values of soil redistribution than other models.

Table 1 The results of soil erosion calculation from the ^{137}Cs data by different models

Sample name		Soil erosion and deposition for the study field (t/ha·yr)					
		Proportional model	Mass balance model 1	Mass balance model 2	Mass balance model 3		
					tillage	water	total
valley profile 1	1	-35.1	-53.2	-16.8	-41.4	0.0	-41.4
	2	-51.6	-89.9	-29.0	+0.3	-29.1	-28.8
	3	-59.8	-113.6	-37.3	+0.1	-37.3	-37.2
	4	-49.2	-83.8	-27.0	0.0	-27.0	-27.0
	5	-29.2	-42.5	-13.4	-42.3	0.0	-42.3
valley profile 2	1	-16.6	-22.2	-6.9	-27.0	0.0	-27.0
	2	-27.2	-39.1	-12.3	-0.1	-12.3	-12.4
	3	-14.5	-19.2	-6.0	+0.1	-6.0	-5.9
	4	-84.1	-241.2	-91.6	+0.2	-91.8	-91.6
	5	-12.4	-16.2	-5.0	+0.1	-5.0	-4.9
	6	-34.2	-51.6	-16.3	-0.1	-16.3	-16.4
	7	-23.2	-32.4	-10.1	-44.2	0.0	-44.2
valley profile 3	1	-3.0	-3.8	-1.2	-6.2	0	-6.2
	2	-50.7	-87.6	-28.2	-0.5	-28.2	-28.7
	3	-40.5	-64.0	-20.4	+0.4	-20.4	-20.0
	4	+87.2	+145.8	+45.8	-0.2	-48.9	-49.1
	5	-32.3	-48.0	-15.1	+0.3	-15.1	-14.8
	6	-63.2	-125.0	-41.4	-0.2	-41.5	-41.7
	7	-5.4	-6.7	-2.1	-11.1	0.0	-11.1

CONCLUSIONS

The study of ^{137}Cs measurement of soil in Ujazd area has shown the potential of this method to assess the soil erosion and deposition. The mean estimated erosion for the slopes for study area is about 15.7 t/ha·yr. The highest value of soil erosion was found for the valley bottom for valley profile 2. That is because this area is not only the deposition place but rater the transit place. The results of soil erosion obtained by the proportional model are higher than obtained by the mass balance model 2 and 3. Generally the mass balance models provides more realistic results of soil erosion than other models, but the simplified mass balance model provided probably the most inappropriate results of soil erosion. The main assumption of this model that the total ^{137}Cs fallout occurred in 1963 seems to be an oversimplification, especially for area with high contamination by Chernobyl cesium. Moreover it should be mentioned that the calculated results of soil erosion strongly depend on the model used and also an additional parameters used during calculation. The ^{137}Cs technique permits to obtain medium term-rates of soil erosion. This method allows obtaining both rates and patterns of soil erosion redistribution. The obtained results show that this technique could be used for area where contamination by the cesium from Chernobyl accident was high but with the extreme caution. For this kind of areas only mass balance model, where the annual fallout ^{137}Cs input is consider, provided reliable results of soil erosion estimation.

ACKNOWLEDGEMENTS

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC
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Izvorni znanstveni rad
Original scientific paper

AN ARTIFICIAL NEURAL NETWORK MODEL FOR SOIL MOISTURE PREDICTION RESPONDING TO WEATHER PARAMETERS

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SUMMARY

An artificial neural network model was presented in this paper for soil moisture prediction responding to weather parameters. From January to December, the experimental data of every day were collected in Beijing city in 2004. The model has been established by training a back propagation neural network with 365 samples and tested with other 30 samples. The model consists of 7, 10 and 3 processing units in the input, hidden and output layers. The input layer's variables include intraday daylight time, humidity, rainfall, temperature and other 3 soil moisture value of different depths of burial. The output layer's variables include the next day's 3 soil moisture value of different depths of burial. The step length is 0.1 and the momentum coefficient is 0.05. The training was terminated after 25000 times and the convergence effect was very good. The convergent error value is $8x10^{-4}$*. It shows that this model can predict precisely soil moisture value.*

Key words: *soil; soil moisture; artificial neural network; prediction*

INTRODUCTION

Artificial neural network (ANN) is a computational technique that has the inclination for storing experimental knowledge and making it available for applications. An important feature of neural network is their ability to learn from examples and the learned information is stored across the network weights. Initial research indicates that it appears well suited to problems of classification, as well as pattern recognition, nonlinear feature detection, and nonlinear forecasting [7]. In the last few years, ANN has generated considerable interest across such disciplines as psychology, engineering, business, medicine, and computer science.

It is naturally nonlinear relations between the change of soil moisture and weather parameters. There are most of models structured via nonlinear analysis such as the correlation analysis and regression analysis. But they have many linear assumptions taking simplify research into account. Otherwise, the model may make a biased estimate or an invalid forecast [2] [6]. In this paper, an ANN model for soil moisture responding to weather parameters was established by training a Back Propagation (BP) neural network.

MATERIALS AND METHODS

Experiment

This experiment in measuring soil moisture and weather parameters had been carried out from January 1st of 2004 to December 31st of 2004 in Beijing Tanghekou district. The experiment site locates in 116.37 degrees of east longitude and 39.78 degrees of north latitude. Weather sensors which install in the experiment site measured weather parameters data. Three soil moisture sensors were embedded in three different depths of burial for measuring 10 cm, 20 cm, 40 cm soil moisture (Figure 1). Then the experiment site save these data and send them to the draught monitor center by short-message of GSM. The experiment data are measured once every four hours. At last the experiment data's average value of every day can be obtained in draught monitor center. 365 sets of experiment samples were collected in 2004. The 365 sets of data had been as the training data of BP for acquainting the weights of nodes, which are distributed in the input, hidden and output layers.

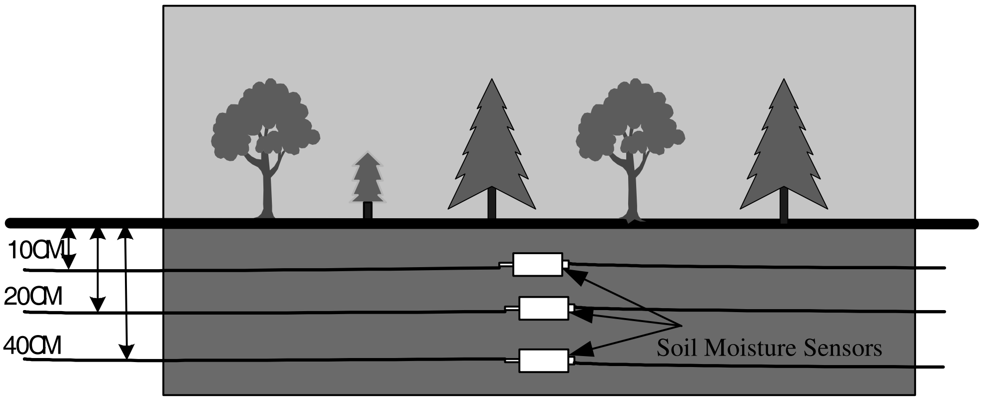

Figure 1 The method for installing soil moisture sensors

The Construction of The ANN

A BP- ANN usually consists of several consecutive layers, i.e. an input layer, a number of hidden layers and an output layer. For producing a nonlinear relationship between input and output, each of nodes in the input layer is connected with other nodes in the subsequent layer by weighted connections. It depends on domain problem requirements there are how many nodes in input and output layers. On the contrary, it is arbitrarily there are how many hidden layers and nodes in them [3] [4] [8].

The proposed ANN model has adopted the structure of three layer BP network and there is only one hidden layer. The input nodes includes seven variables i.e. the intraday 10cm underground soil moisture, 20 cm underground soil moisture, 40 cm underground soil moisture, the intraday average temperature, relative humidity, rainfall, daylight time. The output nodes includes three variables i.e. 10 cm underground soil moisture, 20 cm underground soil moisture and 40 cm underground soil moisture of the next day. All weights and thresholds are assigned random values at the beginning and updated based on the trained results of ANN. Figure 2 illustrates the architecture of the proposed model based on BP ANN.

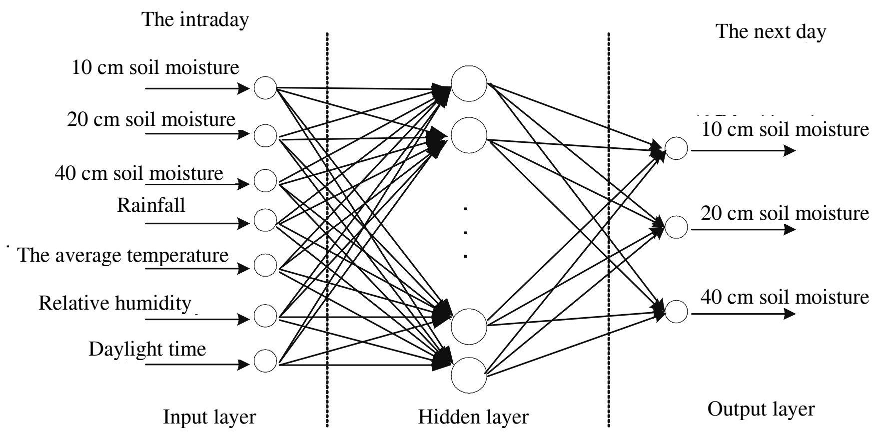

Figure 2 The architecture of the proposed model based on BP ANN

RESULTS AND DISCUSSION

The Analysis of Correlation

Table 1 shows the correlativity between weather parameters and the next day's soil moisture of three different depth of burial. From the table, it is very obvious that the intraday rainfall is the most important factor for changing soil moisture. At the same time, the average temperature and humidity can affect the next day's soil moisture evidently too. On the other hand, the related coefficient between average temperature and soil moisture is negative. It shows the soil moisture will be lower if temperature is higher. It is same that if the daylight time is longer, soil moisture will be lower. At last, it can be found that the correlativity is lower in the deeper depth of burial. This proves that weather parameters will affect soil moisture more and more inconspicuous in the deeper place underground.

Table 1 The correlativity between input variable and output variable

Correlation coefficient	Rainfall	Average temperature	Relative humidity	Daylight time
10cm soil moisture	0.686	-0.333	0.278	-0.153
20cm soil moisture	0.526	-0.293	0.210	-0.167
40cm soil moisture	0.410	-0.288	0.101	-0.114

The Pretreatment of Sample Data

Sigmoid function had adopted in the hidden layer of the proposed BP ANN model, which has the characteristic that the middle part is sensitive to the change of input, but response from both of endpoints is slow. Then the network input sample should be compressed. Furthermore, taking the input samples are from different dimensions and discernment accuracy should be not affected into account. Each of input data needs to be transformed into the format of 0.1-0.9. The process is called normalization. The calculation method lies in equation 1.

$$Z_c = 0.1 + (0.9 - 0.1) \times \frac{Z - 0.95Z_{\min}}{1.05Z_{\max} - 0.95Z_{\min}} \tag{1}$$

where Z represents the raw data, Z_{max} represents the maximum value of the raw data, and Z_{min} represents the minimum value of the raw data, Z_c is the compressed value after the raw data are transformed.

The Ascertainment of The ANN'S Training Parameters

Based on the above analysis, the proposed model is named with BP-ANN (the 7-q-3 structure: seven input nodes - q nodes in the hidden layer – three output nodes), which contains one hidden layer with activated function of logarithm S type and the output layer uses linear function. The node of hidden layer q is related to the concrete problem, and the node of hidden layer q is 10 in this paper.

A software which has been designed specially with VC programming language by the authors was to train the network. The step length is usually within 0.01-0.8 and 0.1 is selected in order to the error value of the neural network going least. The momentum coefficient is usually within 0-1 and 0.05 is selected in order to the neural network having a good stability and a good convergence. The training was terminated after 25000 times of iterative when there had very favorable convergence effect. 30 sets of validation data were used to calculate the prediction error. The result shows the model can precisely predict the next day's soil moisture of different depth of burial.

The Results of Prediction

Because of normalization when the model is trained, the output data must be transformed inversely. The inverse transform formula is as follows

$$Z = \frac{(Z_{out} - 0.1)(1.05Z_{\max} - 0.95Z_{\min})}{0.9 - 0.1} + 0.95Z_{\min} \tag{2}$$

where Z represents the inverse transformed value i.e. the prediction value, Z_{max} is the maximum value of the raw data, and Z_{min} is the minimum value of the raw data, Z_{out} is the network's output value whose range is between 0 and 1

In order to analyze the model further, 30 sets of sample data that were collected from March 1st to March 31th in 2005 were as testing data in this paper. The comparison between forecast value and observed value has been displayed in Figure 3. The forecast value estimated from the proposed ANN model is very close to the actual observed value. 10 cm soil moisture's biggest error between forecast value and observed value is 0.7%. 20 cm soil moisture's biggest error is 1.4%. 40 cm soil moisture's biggest error is 1.3%.

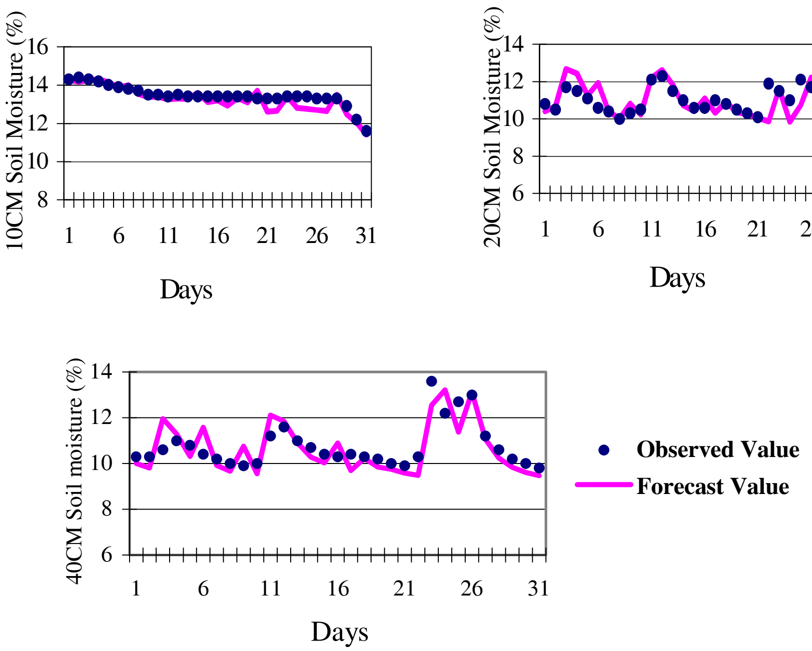

Figure 3 The comparison between forecast value and observed value

CONCLUSIONS

In this paper, the proposed BP ANN model describes the relationship between weather parameters and soil moisture. The former are input factors and the later are output factors. It shows that the proposed model can more effectively describe the nonlinear relationship than the one based on correlation analysis and regression analysis. The impact of weather parameters on soil moisture is analyzed via the proposed model. The order of weather parameters that affect soil moisture is rainfall, average temperature, humidity and daylight time.

It indicates the proposed model is a good supplement to traditional model of soil moisture responding to weather parameters and provides a new method for forecasting soil moisture. Furthermore, the proposed model has certain adaptability range given the model parameters can be obtained easily by experiment under a certain natural condition. On the other hand, just four weather parameters were taken into account in this paper and other weather parameters were neglected. So it is certain that the proposed model can forecast soil moisture more precisely if more weather parameters can be obtained.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

THE INFUENCE OF VANES POSITION ON THE SPREADING DISCS OF THE SPREADER FERTI 2 ON THE DISTRIBUTION OF FERTILIZERS

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SUMMARY

The influence of four vanes position on the working width, coefficient of variability (CV) and border width (Z) of the modern two-disc spreader were tested according to the EN 13739-2 standard. It was established that the position of long vanes (A=8, C=8) significantly effects the maximum spreading width 28 m. Contrary, the position of short vanes (B, D) characterised the Gaussian distribution shape with middle working widths (12-16 m), lower CV (9.65-16.46%) and narrow borders Z (5-5.5 m), whereas the smallest CV (9.65%) and border Z (5m) was measured at the middle position of all four vanes (A=4, B=4, C=4, D=4). Contrary, the less border losses L_{100} (2.83 kg/100m) was calculated when all four vanes were practically closed (A=0, B=0, C=0, D=0).

***Key words**: disc spreader, position of vanes, CV, Z*

INTRODUCTION

The popularity of disc spreaders for application of granular fertilizers and agricultural lime as well as increased interests in variable-rate technology has raised concern about application accuracy and distribution of these spreaders (Fulton et. al 1999). Application accuracy is very important property in evaluating of a disc spreader fertilizer application system. The coefficient of variation (CV) is typically used to characterize the quality of fertiliser distribution by a specific spreader. It is well known the lower is the CV, the more uniform is the distribution pattern. Normally, the CV varies from 5% to 10% for the transverse spread pattern of a disc spreader, but this variation probably doubles under field conditions (Parish, 1991) whenever influenced by a terrain irregularities and wind. It is expected that the CV could increase to 15% to 20% when conducting field tests (Sogaard and Kierkegaard, 1994).

The most significant parameter that influences the CV is with no doubt, disc spreader working pattern. By a two-disc spreader the Gaussian-shaped pattern is prefer most, since it is known to have the smallest CV. Contrary, under unbalanced position of vanes also the uneven 'M' and 'W' pattern may occur, which is characterized with a very high CV.

However, in the case of Gaussian curve tails of pattern should not be too steep, because it results in a large CV for a small deviation of the trajectory of the required swath wide. Contrary, too easy 'ends' produced a large overlapping and the field efficiency is affected adversely (Olieslagers et al., 1996).

For the European conditions, the EN 13739-2: Standard (Agricultural machinery - Solid fertilizer broadcasters and full width distributors - Environmental protection – Part 2: Test methods, 2003) describes a uniform method of determining performance data on broadcast spreaders for granular materials, and provides a basic test procedure to compare spreader distribution patterns. Details, such as test setup, collection devices, testing procedure, determination of application rates, and evenness of transverse distribution, border width and border looses, are given clear definitions in the testing procedure section in the standard.

The main objective of this research was to investigate the influence of four vanes position mounted on both discs on to the working pattern, curve shape and the CV of a specific prototype two-disc spreader.

MATERIALS AND METHODS

A prototype fertilizer speared produced by a Slovenian agricultural machines manufacturer INO was selected for testing. A selected spreader is characterized by two discs with a set of two (one long and on short) adjustable vanes whereby the vane A and C are longer than B and D (Figure 2). Each vane can be set on different position between 0 and 8 by moving the small handle. When placed on 0 the angle between the vanes and the mass flow is very sharp, so that the mass flow is running almost perpendicular to the vane. Contrary, when moved to the position 8, fertilizers kernels are accelerating mainly with the discs rotation.

The fertilizer characteristics of granular NPK fertilizer type INA Kutina NPK, 7:20:30 (ρ=0.95 kg/dm^3). The mass flow was measured prior the field-testing under laboratory conditions to establish the precise flow rate in (kg/min) and omit all negative environmental effects such as wind and terrain unevenness. (Figure 1)

Tests were conducted in-situ at uniform application rate and variable vanes position on both discs. All field tests were conducted on days when sustained wind speeds were less than 2 m/s and humidity 60-80% at a height of 2.5 m above the ground and the slope of the testing site was less than 2 %. All tests were run with the hopper filled to approximately 40% to 50% capacity required at the driving speed of 8 km/h (2.22m/s) and 540 rpm as defined in the standard. Test cases to investigate the application of NPK included:

Figure 1 Measuring the mass flow rate in the laboratory

1. fixed-rate application at a low rate 42.52 NPK kg/min (7:20:30)
2. variable position of long (A and C = 155 mm) and short vanes (B and D = 115 mm), whereby the following combination with different pitch angles (Φ_0) were researched:
   a. A=4 (Φ_0=34°), B=4 (Φ_0=34°), C=4 (Φ_0=34°) D=4 (Φ_0=34°),
   b. A=2, (Φ_0=17°), B=4 , C=2 (Φ_0=17°), D=4,
   c. A=6, (Φ_0=51°), B=4, C=6 (Φ_0=51°), D=4,
   d. A=0, (Φ_0=0°), B=0 (Φ_0=0°), C=0 (Φ_0=0°), D=0 (Φ_0=0°),
   e. A=8 (Φ_0=68°), B=8 (Φ_0=68°), C=8 (Φ_0=68°), D=8 (Φ_0=68°)

Single pass tests were performed for each of vane setting to assess application accuracy and characterize the rate change in kg NPK/ha. The effect of three overlap drives on the transversal evenness was evaluated by using the method for to and fro distribution, superposition by translation of the histogram with its mirror image, so that finally a specific transversal distribution was calculated.

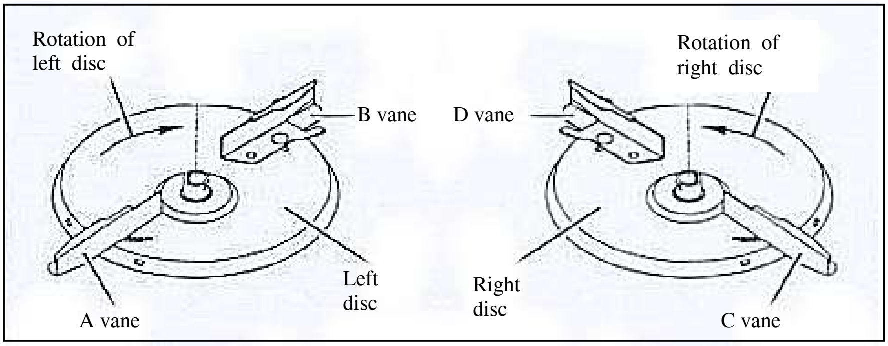

Figure 2 Schematic view on both discs with four vanes

EN 13739-2 was followed to apply collection pans for testing the spreader. The plastic pans measured 50.0 cm wide, 50.0 cm long and 10.0 in height. A divider with a 6.5 cm by 6.5 cm (5.0 cm height) grid was also placed inside each tray to reduce fertilizer ricocheting.

The centre of swath was flagged so that the driver had a visual guide when traversing the test site. The NPK fertilizer kernels were collected within the swath width of the spreader using the trays for each pass by the spreader. Particle samples were collected into measuring glasses and labelled for each of the field tests. All samples were subsequently weighed on the lab balance and recorded. Distribution plots along with surface plots were generated for all tests using the program Excel.

For calculating and representing the required parameters of the single transversal distribution EN 13739-2 standard instructions was followed in all steps of processing. Firstly, the maximum value was first searched from the histogram represented by measuring data, then after divided with two the borders of working width would be found. Then the average amount of collected fertilizer in grams $\bar{x}$, a standard deviation of the working width and the coefficient of variation (*CV*) for the transversal distribution of the working width were calculating according to the well-known equations from statistics.

Beside standard parameters the modern disc spreader must fulfil other requirements, thus the effect of different position of vanes on the border width and longitudinal losses on the border were also studied in our research. The border z was detected from the tables obtained for each test, so that a following formula was applied:

$$z = \frac{\sum_{i=1}^{n} X_{bi}}{n} \tag{1}$$

where x_{bi} is the amount collected in each container outside the border

It was also very important to evaluate the border width and losses in ‰ at each adjustment of vanes properly; therefore the value *Y* outside the border was calculated from the formula:

$$Y = \frac{5 \cdot \sum_{i=1}^{N} x_{bi}}{\bar{x}_b} \tag{2}$$

where N is the number of containers between the border and the first empty container

$\bar{x}_b$ is the average amount of collected fertilizer outside the border

Another parameter showing the working characteristic of spreader represents border width *Z,* which is calculated from the number of containers outside the border and the pan's width according to the following formula:

$$Z = N \cdot 0{,}5 \tag{3}$$

Finally, for calculating the loss per 100m of border length (L_{100}) the given formula was applied:

$$L_{100} = \frac{application\_rate \cdot Y}{1000} \tag{4}$$

RESULTS AND DISCUSSION

The most important measurements from our experiments as measured at five different vanes position by the same flow rate of fertilizer (42,52 NPK kg/min) are represented in the Table 1. It is clearly seen that the spreading width is affected by vanes position (the rising of angle between the mass flow and the vanes), however the working width did not follow it till the very same values, because the spreading pattern changed from Gaussian curve (at 16 m) to the ‘M’ curve at the 22 m respectively. Besides, it was proved that the CV as the most important feature for measuring the quality of fertilizer distribution was better at the position (a) and (b) than on other three. Although, by vanes position (a), (b) and (c) a rather good Gaussian pattern with the exception of a few irregularities, which would be expected from a spinner spreader since they are known for their no uniformity of spread. However, at the position (c) the CV was already over 15%, because the long vanes have influenced very gentle ends with width borders contrary to the very high middle point of the pattern effected by the short vanes, thus a very small working width was produced.

Table 1 Parameters for transversal distribution of the specific spreader as measures at five vanes position

	Vanes position				
Parameter	a	b	c	d	e
Average (3 passes - kg NPK/ha)	197.31	167.28 kg	193.00	187.00	138.43
Standard deviation (3 passes - kg NPK/ha)	19.00	19.86	31.71	26.00	44.14
Coefficient of variability (3 passes) %	9.65	11.89	16.46	13.93	31.96
Working width (m)	16	14	12	12	22
Z (m)	5	5.5	8.5	6	3.5
Y (‰)	49.99	55.00	65.26	16.68	20
L_{100} (kg NPK/ 100m)	8.66	8.93	13.54	2.83	2.94

On the other hand, the pattern surface on the position (d) has much more steep ends than (a) and (b) effecting less working width. The main reason for such distribution shape was the position of both short vanes, which were practically closed and therefore did not accelerate fertiliser particles enough. Contrary to all other distributions, the pattern surface at vanes position (e) looks much like M-shape pattern, whereby less fertilizer at the centre of the pattern is detected. Moreover, the figure of the transverse application rate for the uniform 138.43 kg/ha shows even slight decrease of material in the centre of the pattern. However, on the most part of transversal the spreader does a very unlevelled job at the low rate.

CONCLUSIONS

This investigation was conducted to assess the distribution shape of the specific two spin spreader and its most important working characteristic such as the evenness of transversal distribution expressed in CV and the border width Z. Comparing results of five different adjustment of four vanes at the same fertilizer flow rate of 42.52 NPK kg/min clearly show that the maximum working width with unfavorable 'M' shape is effected significantly by the perpendicular position of long vanes to the kernel flow. On the other hand, the most expected Gaussian shape of distribution is affected in majority by the position of short vanes. Each test further shows that the application of uniform flow rate significantly results in changing of hectare rate (from 138.43 to 197.31 NPK kg/ha) as the working width is varying by the position of vanes from closed to more opened angles.

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PROUČAVANJE UTJECAJA POZICIJE LOPATICA NA DISKOVIMA RASIPAČA FERTI 2 NA DISTRIBUCIJU GNOJIVA

SAŽETAK

U pokusima prema standardu EN 13739-2 kod suvremenog rasipača gnojiva sa dva diska i *četiri lopatice proučavana je njihova pozicija odnosno utjecaj kuta lopatica na radnu širinu, koeficijent distribuciju gnojiva (KV) i širinu ruba (Z). Pozicija dugih lopatica (A=8, C=8) signifikantno utječe na maksimalnu širinu bacanja gnojiva od 28 m. Nasuprot tome položaj kratkih lopatica (B, C) prouzrokuje postanak Gaussova oblika histograma prečane distribucije, sa srednjim radnim širinama (12-16 m), manjim KV (9.65-16.46%) i širinama ruba Z (5-5.5 m) pa su tako najmanji KV (9.65%) i Z (5 m) izmjereni kod pozicija lopatica (A=4, B=4, C=4, D=4) a najmanji gubici gnojiva na rubu L_{100} (2.83 kg/100m) dobiveni su kod pozicije lopatica (A=0, B=0, C=0, D=0).*

Ključne riječi*: centrifugalni rasipač gnojiva, pozicija lopatica, KV, Z*

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MODELLING SPRAY FLOW AND WASTE IN SPRINKLER IRRIGATION PRACTICE: AN OVERVIEW

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ABSTRACT

A thorough understanding of the factors affecting spray flow and waste in sprinkler irrigation is important for developing appropriate water conservation strategies. To properly tackle this problem, relevant theoretical and experimental studies have been carried out during the second half of the last century. Notwithstanding all these efforts, the phenomenon of aerial evaporation of droplets exiting from a nozzle has not been fully understood yet and something new as to be added to the description of the process to reach a better assessment of the events. To this end a mathematical model for irrigation sprinkler droplet ballistics, based on a simplified dynamic approach to the phenomenon, has been presented. The model proves to fully match the kinematic results obtained by more complicated procedures. Moreover, field trials showed the model to reliably estimate spray evaporation losses caused by environmental conditions. Further analytical and experimental activities are needed to gain a better understanding of water flow and waste in sprinkler irrigation practice

***Key words**: irrigation, mathematical modelling, evaporation losses*

INTRODUCTION

Scientific literature concerning irrigation systems (Larry, 1988; Hoffman et al., 1990) is mainly focused on the optimisation of water distribution on the soil, generally neglecting other aspects such as aerial evaporation in sprinkler irrigation. One of the causes of this behaviour is a scarce agreement among scientists for what concerns a clear and univocal definition of the phenomenon causing water losses during irrigation and of the parameters affecting its dynamics. So, spray evaporation of water droplets in sprinkler practice- that is water loss happening in the aerial path covered by a droplet exiting from a nozzle before it reaches the soil surface-was quantified with values ranging from 2 percent or less up to 40 percent or more (James, 1996; Tarjuelo et al., 2000).

Since Christiansen's (1942) now classical work important studies (theoretical and experimental ones) have been carried out to determine sprinkler spray flow and waste under various climatic and operational conditions (Mather 1950; Frost & Schwalen 1955; Wiser 1959; Inoue 1963; and Kraus 1966)

STATISTICAL AND THEORETICAL APPROACHES

Basically there are two approaches (statistical and physical mathematical) available to solve spray flow and waste problems (Seginer et al. 1991). In the first, the measured evaporation losses are related to environmental and operational parameters. The second approach resorts to models which link equations ruling water droplet evaporation with particle dynamics theory.

The statistical approach

The mutual interactions of all the factors affecting the air path and waste of a water droplet (among which are worth mentioning dimension of the droplet, air temperature, air friction, relative humidity, solar radiation, wind velocity) leaving the sprinkler's nozzle make it very hard to work out a proper description and assessment of the phenomena. The problem is particularly acute with respect to drift, where there seems to be very difficult to distinguish between the drift and the distortion of the distribution pattern.

Resorting to statistical (empirical) formulae becomes so often the only way to skip the difficulties, not to say the impossibilities that analytical procedure would imply.

An important work along this line is that of Frost and Schwalen (1955), resulting in a monogram relating spray losses to air relative humidity, air temperature, wind spread, nozzle diameter and nozzle pressure. In that and in other studies, losses were recorded as percent of application, and the results have been statistically analyzed in accordance with the model chosen for the process.

Seginer (1971) worked out a regression model of water loss during sprinkling as a function of various meteorological and operational conditions. Seginer's models, strictly speaking, applies, mainly, to homogeneous areas, where transfer phenomena may be considered one dimensional, in the vertical direction. Nevertheless, it is also useful in dealing with the effect of application rate on the evaporation in field experimental plots.

Yazar (1984), testing with lateral of sprinklers, obtained:

$$\mathrm{E} = 0.389 e^{(0.18W)} \left(e_s - e_a\right)^{0.7}$$

where: E is the percentage of discharged flow lost due to evaporation (%); W is the wind speed (m/s); e_s and e_a are the saturation vapour pressure and the actual vapour pressure of the air (kPa), respectively. Different expressions are available for the assessment of the vapour pressure deficit $(e_s - e_a)$. Murray (1967), defined vapour pressure deficit as:

$$(e_s - e_a) = 0.611\exp\left(\frac{17.27T_a}{237.3 + T_a}\right)\left(1 - \frac{H}{100}\right)$$

where: T_a is the dry bulb temperature (°C) and H the relative humidity (%).

Campbell (1995) proposed the following formula:

$$(e_s - e_a) = 0.00066(1 + 0.00115T_w)(T_a - T_w)P$$

where: T_w is the wet-bulb temperature (°C), while P represents the air pressure (kPa).

Considering the wind as the only factor affecting evaporation losses ,Yazar (1984) obtained, by testing with a lateral of sprinklers, the following equation

$$\mathrm{E} = 1.68e^{0.29W}$$

Tarjuelo et al. (2000), carried out a set of experimental investigations for estimating drift and evaporation losses during sprinkler irrigation events. Various sprinkler-nozzle-riser height combinations were used and the variation of evaporation and weather conditions were measured during the tests which allowed the authors to define the following linear statistical model for water losses prediction in sprinkler practice:

$$Los = aP + b(e_s - e_a)^{0.5} + cW + e$$

where: Los are evaporation and drift losses (%); P is the working pressure (kPa); a, b and c are fit coefficients, e is the experimental error. The model proved to be a useful tool to determine the irrigation timing, as a function of environmental and operational conditions in order to minimise evaporation and drift losses.

The physical-mathematical approach

There are, at least, three important benefits to be gained from mathematical modelling of the spray droplet transport and waste processes, as well as of any physical process. The first of these is that the model development process forces recognition of knowledge gaps. When such gaps occur, research can be initiated to supply the missing pieces. The second benefit arises because a good model must always be experimentally verified. The verification process forces a close examination of any differences between what is predicted and what actually occurs. Finally, a proven model can be a valuable engineering and research tool.

Kinzer and Gunn (1951), modelled evaporation for droplets falling at terminal velocity, just in terms of heat and mass transfer, neglecting the dynamic actions affecting the flight of the droplets. Their results are focused on mass-change effects in a few Reynolds number intervals.

Formally,

$$\frac{dm}{dt} = 4\pi a^2 K \left(\frac{d\rho_v}{dR} \right)_a$$

where: m is the mass of the droplet in Kg; a its constant outer radius in m; K the diffusivity of vapour in air in $m^2 s^{-1}$ and $\left(d\rho_v / dR \right)_a$ is the vapour-density gradient established at the surface of the droplet in Kg m^{-4}; ρ_v is the vapour density in Kg m^{-3} and R the radial coordinate in m.

Ranz and Marshall (1952), studied the evaporation of droplets in connection with spray drying and presented an equation for molecular transfer rate during evaporation along the flight path of the droplet. Goering et al. (1972) , starting from the Marshall's equation, arrived at the following formula for computing the change in droplet diameter D due to evaporation, based on heat and mass transfer analogy:

$$\frac{dD}{dt} = -2 \left(\frac{M_v}{M_m} \right) \left(\frac{K}{D} \right) \left(\frac{\rho}{\rho_d} \right) \left(\frac{\Delta P}{P_f} \right) Nu'$$

where: M_v is the molecular weight of vapour; M_m is the molecular weight of air; K is the diffusivity of vapour in air in $m^2 s^{-1}$; ρ is the density of air in Kgm^{-3}; ρ_d is the density of the droplet in Kg m^{-3}; ΔP is the difference in Pa between the saturation pressure at the wet bulb temperature of air and the vapour pressure at the dry bulb temperature; P_f is the partial pressure of air in Pa and Nu' is a specially defined Nusselt number for mass transfer. This formula was obtained not as the result of an analytical procedure but utilising empirical formulae from different authors for the definition of the parameters involved.. The experimental data of Roth and Porterfield (1965) were used to verify the model. Williamsom and Threadfill (1974) also used the mass diffusion equation in a form similar to the above equation. Williamson and Thereadfill concluded that the results of their model, when compared to measured horizontal and vertical displacements and change in droplet diameter due to evaporation, were accurate under experimental conditions. The study was conducted with droplet diameters from 0.1 to 0.2 mm.

In Seginer (1965) the following differential equation, describing water droplet ballistics in an interesting original way using an empirical drag coefficient C_q in $m^{1-q} s^{q-2}$ and an empirical non-dimensional exponent q, was developed:

$$g - \frac{dV}{dt} = C_q V^q$$

where: g is the acceleration of gravity in ms^{-2}, dV / dt is the resultant acceleration of the droplet in ms^{-2}, *V* the velocity in ms^{-1} and *t* is the time in *s*. This equation can be solved by means of finite difference numerical techniques to predict velocity and travel distance for small time intervals.

Okamura and Nakanishi (1969) used a similar approach based on momentum and drag coefficients to determine the pattern of a sprinkler under wind conditions.

James (1981) adopted the Seginer's model to estimate the kinetic energy of water applied and arrived at the conclusion that the kinetic energy per unit volume of water applied is a sole function of the droplet impact velocity. The same approach was chosen in Hinkle (1991) , where the non dimensional exponent q was defined as a function of droplet size and velocity.

Edling (1985) developed a model, based on the impulse momentum principle, to estimate kinetic energy, evaporation and wind drift of droplet from low pressure irrigation sprinkler. The author's aim was to determine the influence of design and meteorological parameters on droplet behaviour. Droplet size, height, flow rate and deflection plate angle of the nozzle, air temperature and humidity, wind direction and velocity were assumed as input data. The model showed a rapid depletion of evaporation and drift losses when the drop diameter increases, as well as a high dependency of losses on wind speed and riser height. Edling inferred from his experiences that drop evaporation in sprinkler irrigation is almost negligible from a droplet diameter of 1.5-2mm.

The same results arrived at Kohl et al. (1987), on the basis of field measurements and Kincaid and Longley (1989), by means of theoretical investigations. Kincaid and Longley's model combined the heat and mass transfer analogy with the particle dynamics approach to account for the effects of wind drift. The authors' overall objective was to develop a model able to predict droplet waste and assess the role of water temperature in the evaporation process.

Evaporation loss is taken as the difference between the amount of water leaving the sprinkler's nozzle and measured with a grid of catch vessels. When using this concept it must be assumed that the entire difference between the discharged volume and the collected one should not be considered as losses. The reason is that the microclimate generated above the crop during irrigation and the water retention by crop itself imply, among other effects, substantial crop transpiration depletion.

To this end, Thompson et al. (1993, 1997), proposed a model suitable for assessing water losses during sprinkler irrigation of a plant canopy under field conditions. The procedure combines equations governing water droplet evaporation-based on the heat and mass transfer analogy- and droplet ballistics (three-dimensional droplet trajectory equations) with a plant-environment energy model. The latter includes droplet heat and water exchange above the canopy, along with the energy associated with cool water impinging on the canopy and soil.

To skip the difficulties that a univocal analytical procedure would imply, the authors resorted to empirical formulae which were able to give results in reasonable agreement with field measurements carried out in experimental plots equipped, mainly with low pressure sprinkling systems and lysimeters.

The model was used to quantify the partitioning of water losses among droplet evaporation from wetted canopy and soil, and transpiration during irrigation. The model showed that evaporation losses increased rapidly when droplet diameter decreased, as a result of the greater exposed surface area of the smaller drops. Moreover, comparisons between model's outcomes and experimental measurements indicated that canopy evaporation amounted to a great extent (more than 60%) of the total spray waste. Thompson et al's, works are considered by specialist among the most relevant thematic researches ever made in this field.

The effect of sprinkler evaporation on the microclimate and plant species however, was previously investigated by different researchers, among which is worth mentioning: Frost and Schwallen (1960), Kraus (1966), Wiersma (1970), Kohl and Wright (1974), Longley et al. (1983), Silva and James (1988).

Small droplet behaviour (order of magnitude of μm) was analysed by many authors, starting from Ranz and Marshall (1952), who based their investigations on Fröessling's (1938) boundary layer equations and the equation for heat and transfer analogy.

Later on, Mokeba et al. (1997) proposed a procedure accounting for three dimensional effects of turbulence on a spray droplet motion. More recently De Lima et al (2002) worked out a model of a water droplet moving downwards from a rainfall simulator nozzle, which pays particular care to the final mean kinetic energy of small droplets affected in their motion by the action of the wind..

Over the last 25 years, a significant modelling and data collection effort has been undertaken, mainly, by the USDA Forest Service and its co-operators to develop accurate, validated models (spray drift models) to predict the small droplet behaviour (up to 10 μm or less) in both sprinkler irrigation practice and chemical spray aerial applications (Teske et al. , 1998 a, b) . The models are based on both the Lagrangian trajectory analysis of the spray material and Gaussian slanted- plume approach (Teske and Ice, 2002) .Reed (1953) first developed the equations of motion for spray material released from nozzles on an aircraft. Later on, other researchers independently developed their own spray drift models, or contributed essential pieces to the modelling process. These authors include Williamson and Threadgill (1974), Bache and Sayer (1975), Trayford and Welch (1977), Frost and Hang (1981), Saputro and Smith (1990), and Wallace et al. (1995). Lagrangian modelling is now used to simulate other phenomena such as chemical/biological cloud impact on helicopters (Quackenbush 1997) and jettisoning of jet fuel at altitude (Quackenbush et al. 1994). Recent extensive field studies (Hewitt et al. 2002), and model validation efforts (Bird et al., 2002) confirmed the predictive capability of the Lagrangian computational procedure that constitutes the core of the spray drift models. The last versions of the package include atmospheric stability effects, vortical decay, soil characteristics and features, plant canopy and the aerial release of dry materials (Teske, et al., 2003).

Among the different procedures nowadays available, the heat and mass transfer approach offers a sound basis for the assessment of evaporation from falling droplets and the results are in reasonable agreement with experimental data for Reynolds numbers, generally, lower than 1000 obtained, mainly, from field test equipped with low and reduced pressure sprinklers. However, this range covers too small an interval of values to be of a general utility in irrigation practice. Something new has to be added to the description of the phenomenon in order to reach a better understanding of the evaporative effect analysed and to perform an easier description of the processes involved. To fill this gap, Lorenzini

(2004) and Lorenzini and De Wrachien (2003, 2004 a, b; 2005 a, b) proposed a mathematical model for irrigation sprinkler droplet ballistics, which has proved to fully match the kinematics results obtained by more complicated procedures and to work out ready to apply formulae suitable to assess the contribution given to the droplet evaporation by the dynamic phenomena that accompany its aerial path from the sprinkler nozzle down to the ground.

A NEW MODEL FOR SPRINKLING SPRAY FLOW AND EVAPORATION

Droplet dynamics

The flow of a droplet from the sprinkler nozzle down to the ground is described by means of the Second Principle of dynamics: $\vec{F} = m\vec{a}$, where $\vec{F}$ is the total force acting on the droplet and equal to the vector sum of the weight of the droplet of mass m diminished by its buoyancy force and of the friction force acting during the flight on the droplet of acceleration $\vec{a}$. The friction factor f used in the model is that defined by Fanning (Bird et al., 1960). For a fluid flow surrounding a droplet it is given by :

a) for Reynolds number $Re < 0.1$: $f = \dfrac{24}{Re}$

b) for $2 < Re < 500$: $f = \dfrac{18.5}{Re^{\frac{3}{5}}}$

c) for $500 < Re < 200000$: $f = 0.44$

Case (a) expresses the conditions of a Stokes' (laminar) flow law; case (b) of an intermediate flow law, and case (c) of a Newton's (turbulent) flow law. Case (a), statistically speaking, is very unlikely to occurs in sprinkler irrigation practice as, at the usual flow velocities, it would imply droplet diameters of an order of magnitude 0.1×10^{-6} m, which is more typical with chemical spray application rather than with irrigation.

The hypotheses formulated are:

- each droplet is generated exactly in correspondence to the nozzle outlet;
- the forces applied to the system are weight, buoyancy, friction;
- the droplet has a spherical shape;
- the volume of the droplet is invariant during the flight;
- the friction has the same direction of the droplet velocity but opposite sense for all the path;
- there is no wind .

The parameters to be introduced are:

- the nozzle height *h* with respect to ground level;
- the droplet velocity v_0;
- the angle α, with respect to the horizontal direction, of the jet .

If *n* is the weight of the droplet accounting for its buoyancy component and $k = \frac{f\rho A}{2}$ (where ρ is air density, depending on temperature, and *A* is the cross section of the droplet) is the coefficient which defines the action of the friction force, then the final equations in the horizontal and vertical directions are :

$$m\ddot{x} = -k\dot{x}^2$$

$$m\ddot{y} = -k\dot{y}^2 - ng$$

where $\dot{x}$, $\dot{y}$, $\ddot{x}$, $\ddot{y}$ are velocities and accelerations in the horizontal and vertical direction, respectively. The initial conditions are:

$$x(t=0) = 0$$

$$\dot{x}(t=0) = v_{0x}$$

for the first equation and:

$$y(t=0) = h$$

$$\dot{y}(t=0) = v_{0y}$$

for the second one, where *t* is time and v_{0x}, v_{0y} represent the horizontal and vertical velocity components, respectively, at the entrance. Integrating the system of differential equations we obtain the full analytical solution of the problem in the form of parametric equations of position (*x(t), y(t)*), velocity ($\dot{x}(t)$, $\dot{y}(t)$) and flight time.

The model, providing an exact solution, applies to every particular configuration of the system, i. e. for every droplet diameter, flow state, air temperature nozzle geometry, initial flow rate and velocity, in the hypotheses formulated. Attention, though, has to be drawn to the parameter k, as it is strongly affected by the flow state of the droplet. In fact it may happen (and it often does) that a droplet starts its path in a certain flow state modifying it along the way, so requiring a different form of k, to be inserted in the model. In particular, as Re is the parameter highlighting the flow state of the droplet, special care has to be put in computing the value of Re in correspondence of the locations where it reaches its lowest and highest values, so possibly influencing a change in the flow state of the droplet with respect to the initial one. The model treats this problem by determining the Reynolds number at the start and at the top of the trajectory, thereby allowing the proper use of a mean k for computing the final results. At the normal conditions of the experimental tests, the typical range of droplet diameters encountered is between 0.3 and 3mm. (Keller & Bliesner 1990, Lorenzini 2002). Lorenzini (2004) showed that, a part from the smallest diameter droplet, all the cases fall in the Newton's law region in which the value for f is 0.44.

Droplet evaporation

Spray evaporation is assessed on the basis of the analytical procedure previously described (Lorenzini, 2004). The model accounts only the effects of air friction on the droplet evaporation and neglects all other parameters. Despite its limits, the model could improve the understanding of the sprinkler evaporation phenomenon. This approach has not been found elsewhere, probably because air friction was considered as a factor of minor relevance in the process.

Three additional assumptions have been introduced:

- Evaporation is obtained by the total work of the resulting force (sum of weight, buoyancy and friction force) acting on the droplet along its trajectory;
- Droplet evaporation happens just at the end of the flight path;
- The droplet is considered as a material point.

The second hypothesis entails a limitation to the results, as the final kinetic energy of the droplet is calculated by means of the initial mass: this implies that the evaporation losses are somehow over-estimated. A sort of **"upper limit"** (in the proper mathematical meaning) of the "**force-induced**" droplet evaporation is so worked out in the present approach. This does not, anyway, reduce the effectiveness of the model, just aimed at assessing the role of air friction in spray evaporation for sprinkler irrigation systems.

Validation of the dynamic model

The validation of the procedure needs a quantitative approach to check how reliable the predictions are: this can be done introducing other authors' data in the model. The works chosen for these comparison purposes are Edling's (1985) and Thompson et al.'s (1993). Their date set are reported in table 1.

Comparisons of field measurements and theoretical values are presented in Tables 2,3 and 4 in terms of travel distance (Tables 2 and 3 for Edling's and Thompson et al.'s cases respectively), and of time of flight (table 4 for Thompson et al.'s cases only ,since some data required for the computation were missing from Edling (1985)). Table 2 shows reasonable agreement in two cases, but poor agreement with a droplet diameter of 0.5 mm. Tables 3 and 4 present a comparative analysis on the basis of Thompson et al.'s (1993) data in terms of travel distance and time of flight, respectively. A difference can be seen with a droplet diameter of 0.3 mm. This is due to the flow description adopted in Thompson et al. (1993) for smaller droplets, which according to the hypotheses assumed applies to the Stokes' law. The other data, particularly those referring to the range of the intermediate droplet diameters, instead show reasonable agreement both in the values obtained and in the trends determined.

Table 1 Reference data set for comparative analyses.

DATA SET FOR THE COMPARATIVE ANALYSIS OF RESULTS

	Edling (1985)	**Thompson et al. (1993)**
Flow rate exiting from the sprinkler (dm^3/s)	1.4×10^{-4}	5.5×10^{-4}
Nozzle diameter (mm)	3.96	4.76
Jet inclination with respect to horizontal (°)	0 10 -10	25
Nozzle height (m)	1.22 2.44 3.66	4.5
Air temperature (°C)	29.4	38
Wind	NO	NO

Table 2 Travel distance of sprinkler droplets: Edling's (1985) data vs Lorenzini's (2004).

TRAVEL DISTANCE (m)

Nozzle height (m)	**Jet inclin. (deg)**	**Droplet diameter (m)**					
		0.5×10^{-3}		1.5×10^{-3}		2.5×10^{-3}	
		Edling (1985)	**Lorenzini (2004)**	**Edling (1985)**	**Lorenzini (2004)**	**Edling (1985)**	**Lorenzini (2004)**
1.22	10	1.53	2.11	4.04	4.29	5.08	5.22
	0	1.52	1.77	3.55	3.38	4.19	3.98
	-10	1.46	1.35	2.91	2.48	3.22	2.85
2.44	10	1.55	2.20	4.62	4.81	6.00	6.00
	0	1.55	1.92	4.31	4.08	5.37	5.00
	-10	1.50	1.52	3.86	3.27	4.57	3.96
3.66	10	1.55	2.22	4.95	5.11	6.60	6.50
	0	1.55	1.96	4.73	4.47	6.10	5.62
	-10	1.50	1.57	4.36	3.71	5.41	4.64

Facing a comparative approach, it can be stated that the model here defined proves to be kinematically reliable in its predictions from a qualitative and quantitative points of view ,particularly when droplets having a “not too small” diameter are considered. This, being the model defined by neglecting most of the parameter typically introduced in the others, can be considered as a first relevant result .The comparisons performed with Thompson at al.’s data show that when the droplet gets close to a condition of Stokes’ flow law the model provides less accurate results. This is the limit to the model and it somehow defines the field of acceptability of the method. The model becomes weaker when moves away from Newton’s flow law because of the approximation used to define k in the other two flow patterns. The dependence of the results on the flow state criterion can easily explain the different results obtained for the smallest droplets in the present work and in Thompson et al (1993).

Table 3 Travel distance of sprinkler droplets: Thompson et al.’s (1993) data vs Lorenzini’s (2004)

TRAVEL DISTANCE (m)		
Droplet diameter (mm)	Thompson et al. (1993)	Lorenzini (2004)
0.3	1.30	2.73
0.9	5.22	6.77
1.8	10.00	11.56
3.0	13.48	16.66
5.1	17.83	23.59

.

Table 4 Time of flight of sprinkler droplets: Thompson et al.’s (1993) data vs Lorenzini’s (2004)

TIME OF FLIGHT (s)		
Droplet diameter (mm)	Thompson et al. (1993)	Lorenzini (2004)
0.3	2.63	0.84
0.9	1.54	1.35
1.8	1.63	1.73
3.0	1.75	2.00
5.1	1.84	2.26

Validation of the droplet evaporation model

The droplet evaporation model, based on the consideration of the air friction effect only, which applies to the Newton's law, was tested on the basis of the data provided by Edling (1985) and Thompson et al. (1993) reported in table 5. These authors took into account a range of conditions which fall, mainly , under the Stokes' and/or intermediate laws, neglecting, so, the air friction effect. This is why the evaporation results, again reported in table 5, are not directly comparable to ours, even if a check to the order of magnitude can help an analysis. Table 6 presents the upper limits of droplet evaporation obtainable by means of the model presented, starting from the reference data set. The discrepancies between the results in table 5 and table 6 depend on the different nature of the affecting parameters chosen. It has to be stressed, however, that the results here achieved are both qualitatively and quantitatively correct, not of course as descriptive of the whole phenomenon, but just with regard to the maximum role that air friction plays in the process. In fact, the friction force depends on the cross section area of the droplet, and so it is reasonable to expect that larger droplets undergo bigger frictional effects. This is due on the one hand to a longer time of flight, on the other to a more intense action of the friction forces because of the bigger cross-section. It has, also, to be underlined that in some practical applications, like fogging systems or pesticide sprayers, equipments are made to produce very thin droplets to have maximum evaporation. In this cases it is clear that droplet evaporation decreases when its diameter increases due to the fact that, because of the parameters introduced (relative humidity, etc..), evaporation depends on the whole external surface of the droplet, which, augmenting the droplet diameter, has an increase smaller than that of the volume. So it clears why the trends are different.

This could suggest that whenever vapour pressure deficit controls the evaporation process, and the Stokes' law holds, the present model can not be applied, while the hypotheses assumed here are valid when the evaporation is mainly due to friction forces, within the field of the Newton's law.

Table 5 Droplet evaporation without allowing for air friction: Edling's (1985) and Thompson et al.'s (1993) data and results

DROPLET EVAPORATION NEGLECTING AIR FRICTION: LITERATURE DATA						
	Edling (1985)	Thompson et al. (1993)		Droplet diameter (mm)	Edling (1985)	Thompson et al. (1993)
Flow rate exiting from the sprinkler (dm^3/s)	0.73	0.55		1.000	1.19	2.39
Nozzle diameter (mm)	7.14	4.76		1.125	1.08	2.11
Jet inclination with respect to horizontal (°)	0	25		1.250	1.01	1.85
Nozzle height (m)	3.66	4.5		1.375	0.95	1.75
Air temperature (°C)	21.11	38		1.500	0.81	1.41
Air relative humidity (%)	20	20				
Wind	NO	NO				

Table 6 Maximum value possible for droplet evaporation caused by the air friction: Lorenzini & De Wrachien (2003).

DROPLET EVAPORATION DUE TO AIR FRICTION ONLY: UPPER LIMIT		
Droplet diameter (mm)	Lorenzini & De Wrachien (2003) with Edling's (1985) data	Lorenzini & De Wrachien (2003) with Thompson et al.'s (1985) data
1.000	1.12	1.99
1.125	1.52	2.19
1.250	1.70	2.35
1.375	2.29	2.78
1.500	2.69	2.95

On the whole, it is possible to underline the general reliability of the procedure. Furthermore, the model could represent the first step towards a full comprehension of an important issue; i. e. to assess the role played in the evaporation process by the dynamic phenomenon that accompanies the droplet along its trajectory. The approach allows ready-to-apply formulae suitable to assess an **"upper-limit**" of the "**force-induced**" droplet evaporation. Deepening this problem by means of the model here described will be possible by a geometrically and temporally definition of the physical parameters involved.

Further improvements of the droplet evaporation model

One of the main features of this paper is to present an analytical approach suitable to describe the process of a water droplet that, starting from a sprinkler is nozzle, reaches the soil surface at the end of its aerial path. Such an approach has been applied in two directions that, at the moment, lead to two different conclusions: on the one hand the mathematical model, based on few hypotheses and schematisations of the physical process, is able to describe accurately the kinematics of a water droplet and to predict its travel paths and times of flight with a significant precision, when the obtained data are compared to those available in literature; on the other the mathematical model itself, applied to quantify the water droplet aerial evaporation, provides the **"upper limit"** due to the air frictional effect and so it finds a maximum value but does not show an accurate quantitative evidence on the **"true value",** that is on the real evaporative role played by the friction force acting during the flight path of the droplet. This evidently puts the bases for the future research activity and the challenge is to make the mathematical model able to reach, even in an energetic sense, the same reliability up to now obtained just in the dynamic one. The concept of **"upper limit"** is due to the invariance of the droplet diameter along its flight. So the frictional effect, computed as the droplet kinematic energy variation during the time of flight, is maximised because the cross sectional area of the droplet is overestimated, being held equal to the initial value. Just at the end of the aerial path the dynamic phenomenon produces entirely its effect. The passage from the **"upper limit"** to the **"actual value"** entails the discretization of the aerial droplet path in as many intervals as possible, and the application of the same procedure to each interval, using the output of the previous step as input of the next one. Analytically, the improvement will correspond to the minimisation of the **"upper limit"** and to rendering it closer and closer to the true value of the friction induced droplet evaporation. Such a result will allow the achievement of a wide effectiveness, energetic in addition to kinematics and dynamic of the approach presented.

EXPERIMENTAL STUDIES ON SPRAY FLOW AND WASTE

Measurement problems exist when trying to quantify evaporation losses and validate flow and waste models in sprinkler irrigation practice. As previously stated, evaporation loss is taken as the difference between the amount of water leaving the nozzle and measured with a grid network of catch cans. Accurate measurement of water that reaches the ground is very tough with high wind because drift greatly increases the area where measurement is needed. Moreover, evaporation from the collection units is very hard to assess. Investigators have applied corrections to account for these errors, but accurate evaluations are difficult to achieve (Jensen, 1980). Related to this issue, interesting results were obtained by Zanon and Testezlaf (1995) and Zanon et al (2000), who studied problems of experimental techniques for automatic systems of water collection at ground level and the methods of measurement of the water collected, in order to reduce experimental errors.

Pertinent theoretical-experimental results were also obtained by Bilansky and Kidder (1958), who investigated the external and internal factors affecting spatial uniformity of irrigation water, taking into account Christiansen's coefficient of distribution. Salomon (1979) analyzed the beta distribution of individual rotating sprinklers in the presence of external factors.

Tackling the same subject, Le Gat and Molle (2000) devised a model, free from any ballistic assumption, suitable to describe the application pattern of a single rotating sprinkler, and to account for its performance in both windy and zero wind conditions, using a combination of beta functions. The main practical interest of the model lays on the fact that, once the pertinent parameters have been estimated, the depth of water falling on any sufficiently small surface element can be computed using a single ready-to-apply equation. The model can be also easily implemented in a larger module suitable to simulate the water application under centre pivots and moving laterals.

Probability water application curves have been previously analysed by many researches. Seginer et al (1991) using water application measurements for different wind speeds, calculated interpolated maps corrected for evaporation and drift losses. Han et al. (1994) developed a simulation model using water application curves measured in different directions related to the wind under single rotating sprinklers. Generally, in this approach probability distribution curves of water application are determined in different conditions and are identified by the type of distribution function and their mean and standard deviation.

Some investigations focused on radial or square-grid distribution of the catch cans in different environmental conditions. Bilanski and Kidder (1958) studied the effects of various sprinkler components, including pressure and nozzle size, on the pattern shape and radius. Seginer (1963) developed standardized patterns and related the pattern radius to the pressure head for certain nozzle sizes. Solomon et al. (1980) used a clustering algorithm to group pattern test data into typical standards shapes and used pattern radius to define a relative distance from the sprinkler. Kincard (1982) proposed an analytical approach suitable to describe the combined effects of nozzle size, pressure and nozzle discharge on sprinkler pattern radius. The procedure can be used to assess the performance of different sprinklers or nozzles and to determine the effects of the sprinkler characteristics (nozzle height, jet momentum flux and angle) on pattern radius. Tarjuelo et al. (2000) recently carried out an experimental investigation on water losses in sprinkler irrigation due to evaporation and wind drift, without closely examining the effect of the surrounding air temperature.

The sizes of water drops from spray nozzles bear on important areas of irrigations experimental study, including the extent of wind drift and evaporation losses, distortions of spray patterns by the wind and the reduction of the soil's infiltration rate due to drop impact on the soil surface. Moreover, knowing the droplets' distribution within the jet and along a radius could help anticipate their path related to environmental conditions.

To enter into details, research has shown that small droplets lead to distortion of spray patterns by wind as well to water loss due to wind drift and evaporation (Thomspon et al. 1986) . Large droplets may lead to a reduced soil infiltration rate through soil surface disruption caused by droplet impact (Mohammad and Kohl, 1986). Nozzle configuration and water pressure are both important factors in determining droplet size as well as the field distribution pattern (Hills and Gu, 1989).

Few researches have been carried out on irrigation nozzle drop size distributions and even fewer have quantitatively assessed the relationship between nozzles size, operating pressure and distribution characteristics. Generally, at the conditions of the experimental tests the typical range of droplet diameters encountered is between 0.3 and 4 mm (Solomon et al., 1985; Keller and Bliesner, 1990).

Drop size distribution can be investigated by both direct methods (sensitive paper, oil, flour, photography, laser velocity etc..) and indirect ones. Calibrated stain techniques were used by Inoue and Jayasinghe (1962), Inoue (1963) and Seginer (1963). Kohl and De Boer (1983) resorted to the pellet method to measure the size of drops from irrigation nozzles, while Von Bernuth and Gilley estimated drop size distributions from radial curves. Spraying Systems Co (1968) presented volume media drop diameters for their flooding nozzles for various nozzle size and operating pressures. On the whole, complete drop size distributions for irrigation spray nozzles are relatively rare. Tate and Janssen (1965) and Tate (1968 and 1977) presented a total of three distributions for flooding style spray nozzles while Kohl and De Boer (1983) presented fourteen distributions for different types of nozzles.

Concerning probabilistic models, Mugele and Evans (1951) proposed the upper limit log normal (ULLN) distribution function to describe spray droplet data. The distribution is based on the assumption that the drop diameter is related to a pseudo one, log-normally distributed. The peculiarity of the model consists in the fact that the ULLN distribution function can refer to either number or volume frequency (Goering and Smith, 1976). The same authors found that the distribution fits well the drop size distributions from a wide variety of agricultural spray nozzles. Bezdek and Solomon (1983) showed good ULLN fits to both sprinkler and spray nozzle drop size data. Solomon et al. (1985) developed a regression model to predict ULLN parameters as functions of nozzle style, size and operating pressure.

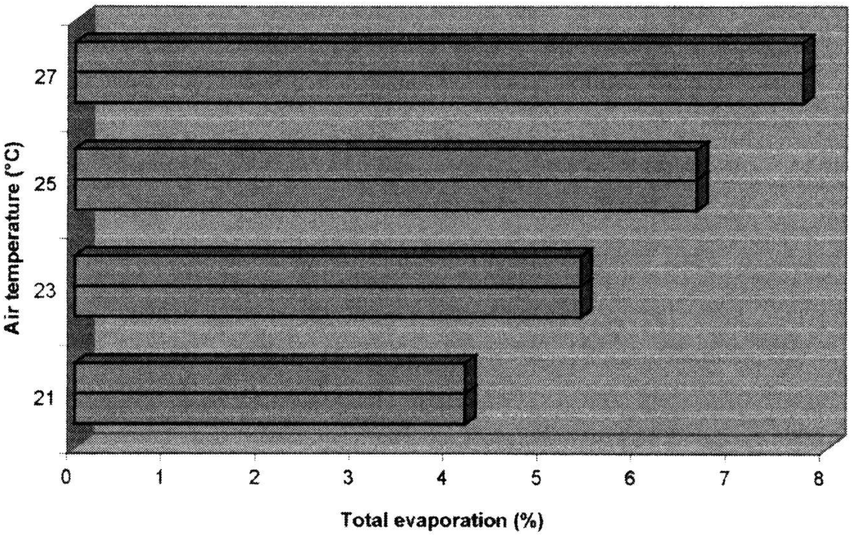

Figure 1 Total evaporation of sprinkler water droplets in the experimental tests (Lorenzini 2002)

All these studies share the awareness of the difficulty of being able to comprehend clearly the process of spray evaporation in sprinkler irrigation. The problem is due to the very many parameters that mutually affect each other. To this end Lorenzini (2002) carried out an experimental study (following the relevant standards) in the field on sprinkler irrigation evaporation. This study only treated the influence of the environmental air temperature, keeping all the other variables constant and minimizing the experimental error. A single sprinkler was tested in-field and this, obviously, led to higher evaporation with respect to the many adjacent sprinklers. The results, expressed as the mean values of at least 12 tests under the same conditions, are shown in Figure 1 for a constant relative air humidity of 94% and a water temperature of 15.0°C. Each irrigation test was performed with sprinklers working in steady-state for a time interval of 360 seconds, and the flow rate delivered by the sprinklers was always equal to 18.15dm^3 sec^{-1}. These results are significantly higher compared to those of Thompson et al. (1997), but it should be noted that the climatic conditions during the experimental tests of Lorenzini (2002) were far more homogeneous, and therefore more suitable for singling out each parametrical contribution than those considered in the paper quoted above. In fact, the Thompson et al.'s evaporation measurements, each of which was carried out for a whole day, were obviously affected by the usual daily thermal rushes, and are therefore difficult to interpret. The air temperature effect has been proved here to significantly affect sprinkler spray evaporation, something that up to now has generally been neglected.

CONCLUDING REMARKS

- A thorough understanding of the factors affecting spray flow and waste in sprinkler irrigation practice is important for developing appropriate water conservation strategies. To properly tackle this problem relevant theoretical and experimental studies have been carried out during the second half of the 20^{th} century.
- Among the analytical studies, the heat and mass transfer analogy, linked with particle ballistics offers a well – established approach to assess jet flow and waste. The procedure describes the event of a droplet travelling from the sprinkler nozzle to the ground as a combination of environment parameters such as pressure gradient, vapour concentration, air relative humidity, resulting in very elaborate formulae and strongly condition-dependent. Something new has to add to the description of the phenomenon, in order to reach a better understanding of the processes involved.
- A mathematical model for irrigation sprinkler droplet ballistics and evaporation, based on a simplified dynamic approach to the phenomenon, has been presented and validated. The tool can be considered as an indicator of the system performance and has proved to fully match the kinematic results obtained by more complicated procedures. Furthermore, the model made it possible to work out ready-to-apply formulae suitable to assess the **"upper limit**" of the contribution given to the droplet evaporation by the friction force during the droplet's aerial flight. Results showed that air friction is of relevance in spray waste in the Newton's law region. This approach has not been found elsewhere, probably because air friction was considered as a factor of minor relevance in affecting spray evaporation.
- A deepening of both the analytical and experimental activities, will allow the authors to assess the **"actual value**" of the "**force-induced**" droplet evaporation and further steps towards a thorough understanding of the phenomenon.

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NOTATION

a	constant outer droplet radious, m
A	cross sectional area of the droplet, m^2
C_q	empirical drag coefficient in Seginer (1965), $m^{1-q} s^{q-2}$
D	droplet diameter, mm
E	percentage of discharge flow lost because of the evaporation (%)
e_a	actual vapour pressure (kP_a)
e_s	saturation vapour pressure (kP_a)
f	friction factor according to Fanning
$\vec{F}$	total force acting on the system, N
g	acceleration of gravity, m s^{-2}
h	nozzle height with respect to ground level, m
H	relative humidity (%)
k	friction parameter, kg m^{-1}
K	diffusivity of vapour in air, $m^2 s^{-1}$
Los	evaporation and drift losses (%)
m	mass of the droplet, kg
M_m	molecular weight of air, g
M_v	molecular weight of vapour, g
n	actual mass of the droplet because of the presence of buoyancy in air, kg
Nu'	Nusselt number
P	working pressure (kP_a)
P_a	air pressure (kP_a)
P_f	partial pressure of air, P_a
q	empirical non-dimensional exponent in Seginer (1965)
R	radial co-ordinate, m
Re	Reynolds number
t	time, s
T_a	dry bulb temperature (°C)
T_w	wet bulb temperature (°C)

v droplet velocity, m s^{-1}

v_{0x} inlet horizontal velocity, m s^{-1}

v_{0y} inlet vertical velocity, m s^{-1}

v_0 velocity vector of the droplet exiting from the nozzle, m s^{-1}

V variable droplet velocity, m s^{-1}

W wind speed (m/s)

$\dot{x}$, $\ddot{x}$ velocities and accelerations in the horizontal direction, m s^{-1}, m s^{-2}

$\dot{y}$, $\ddot{y}$ velocities and accelerations in the vertical direction, m s^{-1}, m s^{-2}

α angle of the exiting droplet trajectory with respect to the horizontal direction, deg

ΔP difference between saturation pressure at the wet bulb temperature of air and vapour pressure at the dry bulb temperature, P_a

ρ air density, kg m^{-3}

ρ_d density of the droplet, kg m^{-3}

ρ_v vapour density, kg m^{-3}

34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.42/.43
Izvorni znanstveni rad
Original scientific paper

THE DYNAMIC MEASUREMENT OF WATER CONTENT AS A SIMPLE APPROXIMATION OF HYDROLOGICAL PROPERTIES

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SUMMARY

The spatial distribution of varying water contents cause varying specific soil-physical properties for each type of soil. Current practice limits hydrological site evaluation to a particular geo-physical evaluation method for agricultural sites. Depletion and saturation is to be predicted from available additional information of soil type.

The development of an online TDR-field moisture probe (Jantschke, 2004), which is capable measuring shallow layers of soil on a high resolution scale, brings a clear moisture documentation into the range of potentiality for empirical field evaluation. The documentation of precipitation events and quantities is providing basic data for field water status calculations. An online assessment of prevailing water status is capable defining areas of defined water holding capacities relative to time, respectively. The trial setup consists of the recently developed dynamic online TDR-probe, an additional field moisture gauge and a GPS device for a clear spatial allocation of the field data gained. First results showed a promising capability.

Key words: *Dynamic, Hydrological Evaluation, Soil Moisture, TDR, TRIME*

INTRODUCTION

The present data set which is usually collected in applications of advanced farming includes a vast range of data which is to improve agricultural production. At present date this basic data does not consider the site specific data acquisition of current water contents. Therefore it does not support field moisture - based considerations of operations. Field specific hydrological properties have to be derived from geo-physical analysis. By means of an innovative dynamic measurement system, which was derived from Time Domain

Reflectometry (TDR), this subject moves towards realizable proximity in order to fit the observed value of prevailing actual water content to the information pool of site specific farming and to consequently overcome the aforementioned information gap. Applications of relative machine-control are conceivable to be established in order to regulate machinery during field operations. These aims are most obvious for the application fields of soil cultivation, drilling, irrigation and the decision of field trafficability and bearing capacity of top soils.

In order to use the gained data for pure analytical purposes it is necessary to allocate the data spatially. Which leads to a mapping of soil moisture. In reverse the collected dataset allows to outline concrete conclusions on simple hydrological properties of sites, considering additional data, as electrical conductivity, climatic data and appearing draft force documentation these values are to be consolidated further.

METHODS

For stationary measurements as well as moreover for dynamic TDR practice, air filled gaps and water filled gaps are interfering a correct reading. These disturbances of the test values are not represented with soil´s average porosity. The appearance of large pores might be explained by root tracks and earth worm tracks. Especially for fork probes stones play another important role as a factor of disturbance (Jacobsen & Schjonning, 1993; Malicki, 1994; Roth, 1992). The disadvantageous effects on TDR readings have been exemplarily investigated for the task of stationary measurements. The abstract kind of influence (deviation of waves, appearing of pores etc.) on the dynamic measurements stay the same, while the number of readings per square unit raises up and therefore causes a higher failure potential. By modifications of progression angle, probe geometry and a further evolutionary stage of TRIME (Time Domain Reflectometry with Intelligent Microelements) as the mean of data collection algorithm (Jantschke, 2004), failure reading potential could be lowered significantly (figure 1). The implemented device generate a surge of 200 mV in a time of 20 ps (1 ps = 10^{-12} s). The voltage surge causes the propagation of an electromagnetic wave, whose reflection is determined in time and therefore the assigned volumetric water equivalent (Becker, 2004). Working with the momentary probe design, the resolution of a shallow horizontal layer (3 cm) is measured accurately with a temporal resolution of 1 Hz. The probe generates a measuring field of +/- 190 cm³, dependant on prevailing conditions. The waveguide was set under an eggshell ceramic plate of exceptional anti abrasive characteristics. The massive plate (4 x 30 x 250 mm) was arranged to show a hollow of 10 x 200 mm for the high frequency waveguide of the modified TRIME device. Field size has been modelled by means of ´Maxwell2D´**.** The appearing energy of the electric field was simulated and further analysed by ´Matlab´ in order to describe the quantiles of energy. Thus, lines of equal energy, representing a certain percentage of the total field energy (here: 95%) were determined. Consequently the major part of the measuring field is characterized. The line of 95% field energy at an electrical permittivity of 20 creates a sharp suggestion of the measuring field´s active volume at an equal soil moisture content of 34 Vol. % (figure 2) (compare Topp, 1980). With that, any change of the measuring field, caused by the humidity of soil or the shape of the sensor can be simulated and compared.

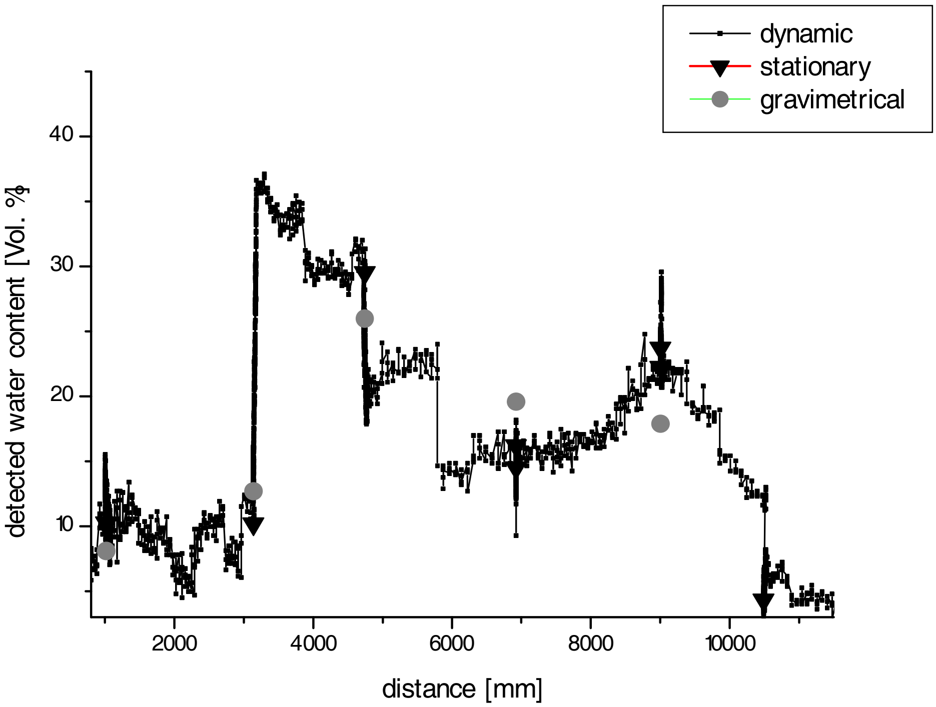

Figure 1 Dynamic acquisition of water content, using dynamic TRIME, reference values: TRIME P2G and gravimetrical validation

An additional detection of electrical conductivity by means of an geo-electrical measurement device (EM 38) is provided to the dataset. The EM 38 originates from geo engineering and gives an actual value of apparent electrical conductivity (dS/m) on a varying penetration depth of about 1-1,5 m. This supplements the data collection by one more evaluation value of prevailing average depth water content. Therefore conditions of drainage or saturation can be identified. With the increase of measurements at different specific precipitation events over the years course, a prediction of field water status on the basis of topsoil water content and actual weather conditions is potential. Areas of high drainage or areas of high water holding capacity (reverse) are potential to be outlined.

RESULTS

The moisture acquisition of a shallow soil layer supplies a simple mathematical model with a first assumption of prevailing conditions in the observed top soil layer. This is prepared by an automatic transfer of derived moisture data to a database. Technically it is realized, using the analogue measuring signal of the novel dynamic moisture probe. The interface provides a signal of 0-1V. This is further amplified and transmitted over *DAQCard* interface [6024E] to DASYLab. The basic data set momentary contains measuring duration, position of the carriage, penetration depth of the dynamic probe, a triaxial force documentation at the measuring probe and the current soil moisture. First trials showed a high regression coefficient of stationary TDR-readings, dynamic TDR readings and gravimetrical validation of the collected data (figure 1). This forms the initial potential of reverse estimation of past precipitation events and therefore the evaluation of varying hydrological capacities.

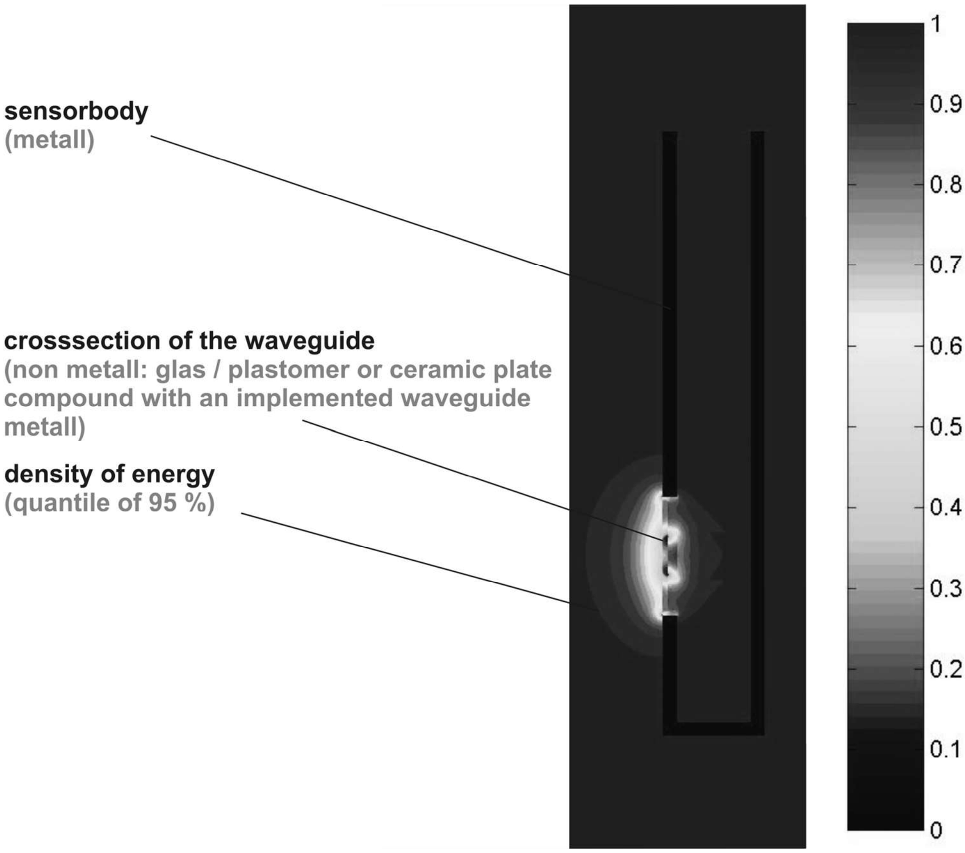

Figure 2 Display of field density at the dynamic sensor for a value of defined dielectrical permittivity of 20

Preliminary experiments of a stationary validation of this approach showed excellent results, predicting depletion of the root zone following defined irrigation events. The trial was conducted for lychee fruit trees on slope position at a sub tropic location. Prediction models of plant water requirement as the basic Penman-Monteith approach (Penman, 1963; Monteith, 1985) and CROPWAT (FAO 1990 & 1998; Spohrer, 2005) were rated. For the first step of validation various spots were equipped with TDR and Tensiometer moisture detection probes at soil depths of 12, 25, 45, 70 and 100 cm. Therefore a basic hypothesis of actual irrigation quantities was possible using additional actual climatic data, which was collected on field scale. The subsequent validation process lead to a further adjustment of preset plant water requirements, which are derived from crop coefficients for lychee, known from literature (Ooshuizen, 1993). Using xylem-flow documentation (Granier, 1985) and the determination of apparent photosynthesis rate, the gained data was further trimed by modifying the coefficient. First assumptions from soil moisture balance calculation were further refined (Spohrer, 2005; Jantschke, 2005; Spreer 2002). Figure 3 shows a comparison of CROPWAT computed irrigation quantities, actual calculated irrigation quantities and the advanced irrigation strategy, using a combined model of depletion prediction and optimal xylem flow properties.

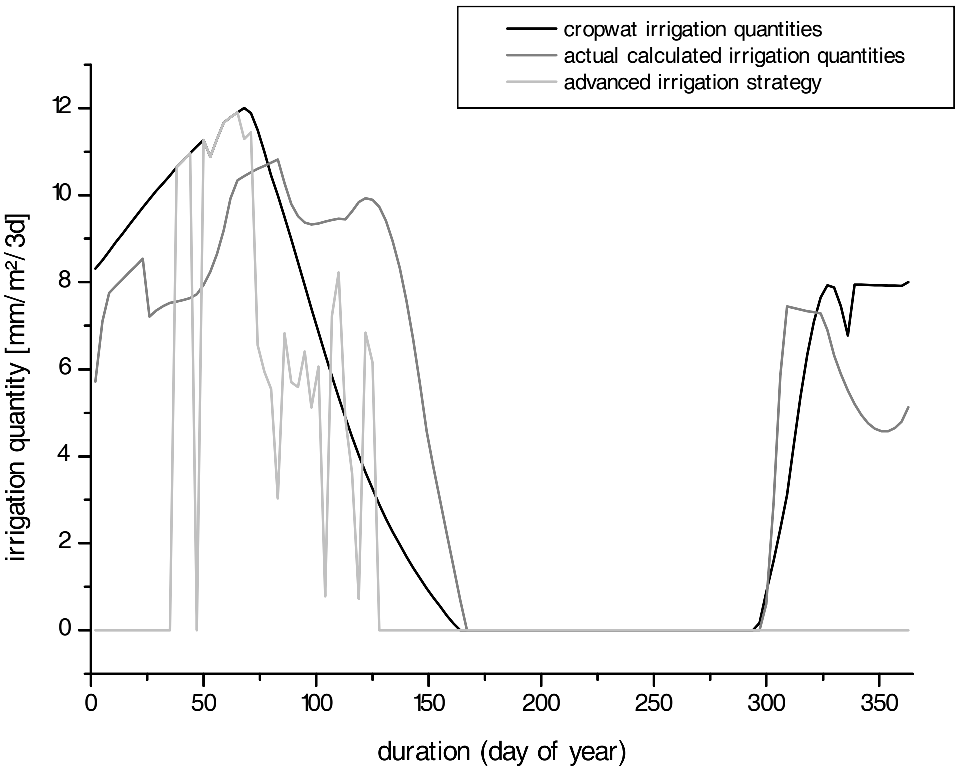

Figure 3 comparison of different irrigation strategies due to variation of decisive data

First results of a dynamic approach showed coherent data for the determination of shallow layer soil moisture information. The apparent properties of layers underneath the documented shallow line are recorded by a dynamic non-contact measurements of electrical conductivity. The measurement is producing a sigma value of electrical conductivity containing a selection of affecting measurands (water content, salinity, pore size, texture) (Zimmermann, 2004; Gebbers, 2005). Therefore a clear reading of solitary water content is impossible. The fusion of the two regarding datasets allows a validation of field water depletion or saturation status. First results have to be verified in a further trial setup, sizing impact families down to the very basic limiting factors.

CONCLUSION

First stationary results showed excellent results, predicting field water status after defined precipitation or irrigation events. The novel development of a dynamic soil moisture sensor enables a data acquisition on the go at a resolution of 1 Hz. Therefore the evaluation of field characterising hydrological potential seems potential. But penetration depth of the dynamic TDR evidence is limiting the simple prediction model to a shallow top soil layer. The combination of two datasets is promising, whereas the underlying soil fraction is documented in sigma values of electrical conductivity, which is contrasting the solitary acquisition of volumetric water content in the top soil layer.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

INFLUENCE FACTORS ON TIME DOMAIN REFLECTOMETRY - UNDER- AND OVERESTIMATION OF WATER SAVING POTENTIALS FOR IRRIGATION FARMING

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SUMMARY

The detection of soil moisture represents an essential parameter, assessing irrigation quantities. It serves as a decisive data base for irrigation management. Thus it is generating a substitute value to determine actual plant water requirements and consecutively adjust current irrigation means. Leaching can be detected by sensors at root zones bottom. Optimal water conditions within the root zone can be achieved by simultaneous placing of moisture quantification sensors. For the purpose of irrigation scheduling further information of air temperature, soil temperature, solar radiation, wind speed and relative air humidity is required (Allen et al., 1998).

For suitable devices, there are still difficulties being reported, concerning the accuracy and reliance of TDR (Time Domain Reflectometry) equipment. This finding is due to the undefined negative impact of salinity (Auerswald et al., 2001) and the potentiality of a probe distortion while the probes are penetrated to the soil profile. Consequently these problematic situations were set into trial in order to resume a quantification of the prevailing effects.

Distortion lead to a minor influence on TDR level (visual quoting of the gained curve). Whereas TRIME (Time Domain Reflectometry with Intelligent Microelements) showed a significant effect, concurrent with a distortion of 10° at each rod. Soil-to-sensor contact appeared to be essential. Salinity showed no impact on the measurement, until the threshold value was not reached.

Key words: *Probe distortion, Salinity, TDR, TRIME, Water Saving Potentials*

INTRODUCTION

The water saving potential of a moisture detection system is appearing obvious for different irrigation means, as sprinkler irrigation, micro-irrigation, drip-irrigation and subsurface irrigation. Under arid and tropic conditions, irrigation farming is simultaneously facing a relentless conflict of water use interests. So the subject of irrigation efficiency is emerging as one of the most pressing of intensive farming. Contradictory, irrigation water is essential for food security but it is bitterly requested by urban basic supply, as well.

The adjustment of irrigation quantities represents an almost obvious application for a soil moisture quantification, which has already been in practice for stationary measurements at micro irrigated sites. An application of a dynamic system could serve as a reference tool for a spatial variation of irrigation quantities of linear or centre pivot irrrigation. Regarding the measurement value of soil moisture it contains a great potential of saving precious irrigation water. Additionally the dynamic moisture detection provides a characterization for symptomatic locations with regard to their basic hydrological properties. A timeline data-acquisition enables feeding a basic input/output model which is capable providing basic hydrological information about prevailing drainage rates, e.g.. The disparity of expected water content, detected water content at actual evapotranspiration rates (Allen et al., 1998) basically results in an approximation of hydrological properties of top soils (Spohrer et al., 2005).

METHODS

TDR: The measurement of soil moisture by means of the Time Domain Reflectometry underlies the differing permittivity of soil. Thereby soil is to be characterized as a mélange of dry and porous material, water and air in varying portions. The actual permittivity of air ($\varepsilon r=1$) and soil ($\varepsilon r < 5$) is significantly lower than the one of water ($\varepsilon r = 81$). The correlation of specific runtime for a reflected electromagnetic pulse provides a determination of the actual moisture of the substrate. Molecules of water are strong dipoles, which are aligning up within a given electromagnetic field. A medium characterised by that is called a dielectric. Dielectrics are slowing down the propagation speed of electromagnetic waves. This goes along with the finding that a TDR pulse propagates slower within a moist soil (Stacheder, 1996) Disturbances within the high frequency field cause faulty measurements due to part-reflection of the emerging pulse. So far the electronic detection of soil moisture is conducted, setting up stationary measurements in situ. This integrated electronic measuring device is using the TDR-approach, which consists of a signal generator, sampler and the sensor plate itself. The signal generator is capable of producing a rapidly escalating voltage surge. Commonly used TDR instruments like the TRIME-EZ (IMKO) or the laboratory TDR instrument Tektronix Cabletester 1502 B generate a surge of 200 mV in a time of 20 ps (1 ps = 10^{-12} s). The voltage surge causes the propagation of an electromagnetic wave. First this pulse (0,6-1,2 GHz) propagates through a high frequency (HF) cable to the uncovered waveguide which provides the contact to the surrounding substrate. At the end of the waveguide, the pulse is being reflected in the soil and returns to the electronic measuring implements, where the interference of emitted and reflected pulse is recorded by a sampler. In that way the implemented electronic equipment is capable, reading the runtime of the electromagnetic pulse which is to be displayed in a TDR trace. The visually quoted value has to be translated to the respective volumetric water content of soil. Roth (Roth et al., 1990) gives an equation, regarding soil physical properties (porosity and bulk density), while Topp (Topp et al., 2000) formulates an empirical equation in order to derive the volumetric water content. The most common TDR instruments are scanning the TDR curve point by point, detecting a current voltage past a defined time **Δ t**, which is altered until the expressive part of the TDR signal has been scanned.

The common shape of a sensors-waveguide is a two or three prong fork, whose prongs are set up parallel. The created size of the measuring field depends on substrate and surrounding moisture, and varies by a proportion of 10%. Typically it covers a size of $\mathbf{V_m = \pi\, d^2 * l}$ (*empirical approximation*), whereas **d** defines the distance between prongs and **l** gives the length of prongs. The accuracy of the TDR reading correlates positive with an increase of the measured volume, which is based on a clearer resolution due to an extension of the pulse reflection runtime. TRIME (Time Domain Reflectometry with Intelligent Microelements, IMKO) provides in contrast to regular TDR readings, a direct system integrated interpretation of the measured reflection grade [water content in Vol. %]. In practice both systems are facing the same basic kinds of problems: high salinity (Dalton, 1981; Dasberg, 1985; Nadler, 1991), air filled large pores proportions (Jacobsen & Schjonning, 1993; Malicki, 1994; Roth, 1992) water filled gaps and stones which are bending the prongs while installing them. High salinity leads to a non reflecting of the pulse. Thus the interpretation range of the reflectance curve does not appear and a subsequent reading is impossible. Further disturbances are not represented with soils average reflecting behaviour and porosity and lead to miss-interpretations of the actual water content.

RESULTS

DISTORTION: The effect of large pores on the accuracy of the TDR reading was investigated following. Experiments were conducted, using screened silt (0,5 mm) with an appearing field capacity of 50 %. Preparatory moisture for the experiments was set to 25 % and moved up by steps of 5 % to gain field capacity. The applied probe performed a 3 prong setup (l = 8 cm), which was used with an oscilloscope (Tektronix cable tester 1502 C). The measured volume was set to 0.9 litre. The impact of a possibly appearing deformation on its accuracy was investigated simultaneously due to changes of the measurement value expected. Therefore different contents of moisture were established on sandy clay. Three compositions of gravel proportions were set up complementary (25, 50, 75 % of gravel within sandy clay substrate). Reference values were produced, determining the consequence of deformed probes (TDR and TRIME) within a solution of water saturated bead (Dragonit bead Ø 0,45 mm and a reference value of 43,8 % Vol., water content) in order to avoid diminishing effects on measurements quality. The measured volume showed 8 - 10 litres.

The first experiment was set up, creating a maximum array of three artificial large pores (Ø 3 mm) in the field of the measured volume. This trial setup showed no significant results. Neither while saturation process, nor at attained water contents. Therefore it might be stated, large pores are not interfering the TDR measurement, regarding a questionable field measurement set up. A different picture could be noticed with an incomplete contact of the sensor to the substrate. If the signal was tracked, while the sensors movement caused a cavity of about 1 mm an underrating of 5 to 7% water content could be recorded. This was consequently evoking a shared reflection due to a fast change of impedance for the regarded wave pulse. A second sequence of experiments was conducted using a larger volume size of substrate to provide evidence effects on the accuracy of the measurement after geometrical defined probe deformation. The grade of deformation reached from 0° to 90° with common TDR probes and 0° to 20° with TRIME probes. Deformation was carried out both, lengthwise and crosswise (figure 1) at all three prongs. TDR readings showed decent values despite a massive deformation. Straddling the two outer prongs led to a > 5 % underestimation comparing the referenced value. The contradictory effect could be reported using TRIME. It results in overestimating the value about 10 %. The other kinds of deformation lead to an equal distribution of the measured values (+/- 5%) of uniformly distribution of the reference value (figure 2).

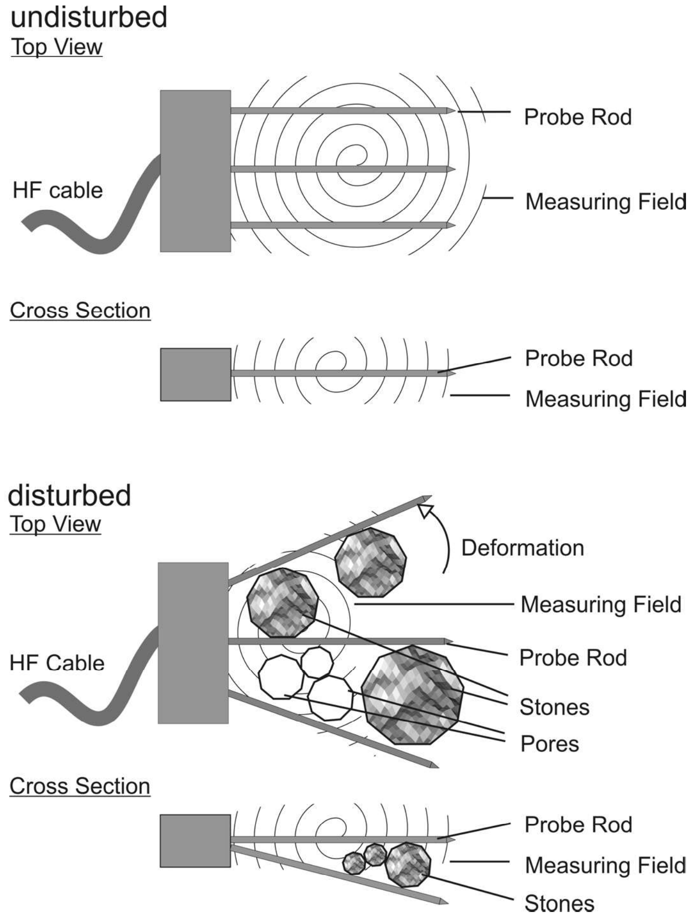


Figure 1 undisturbed and disturbed measuring field and field propagation at a 3 prong sensor

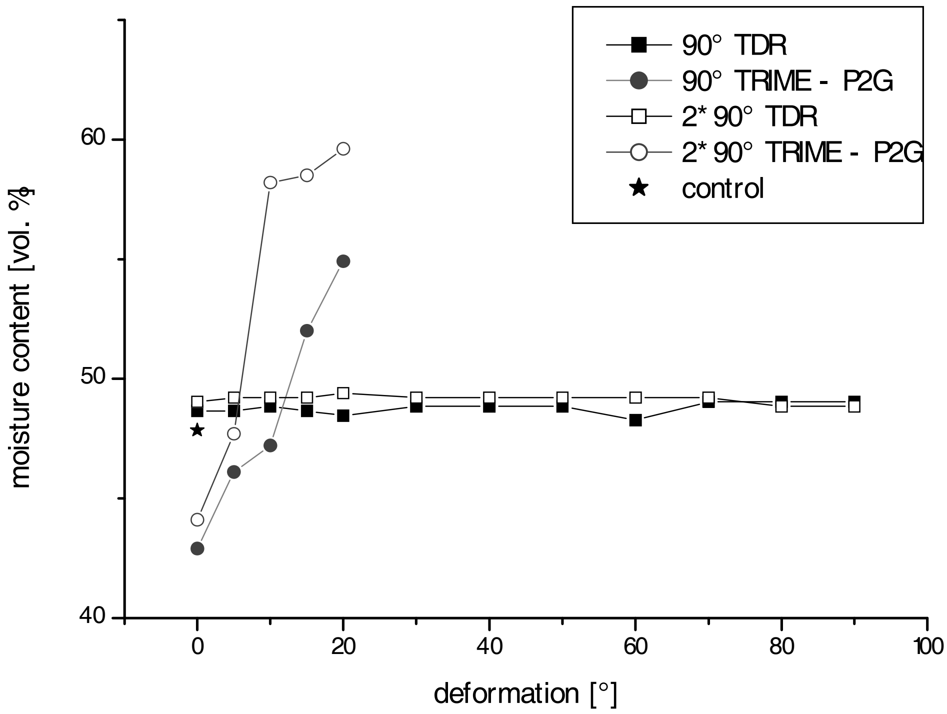
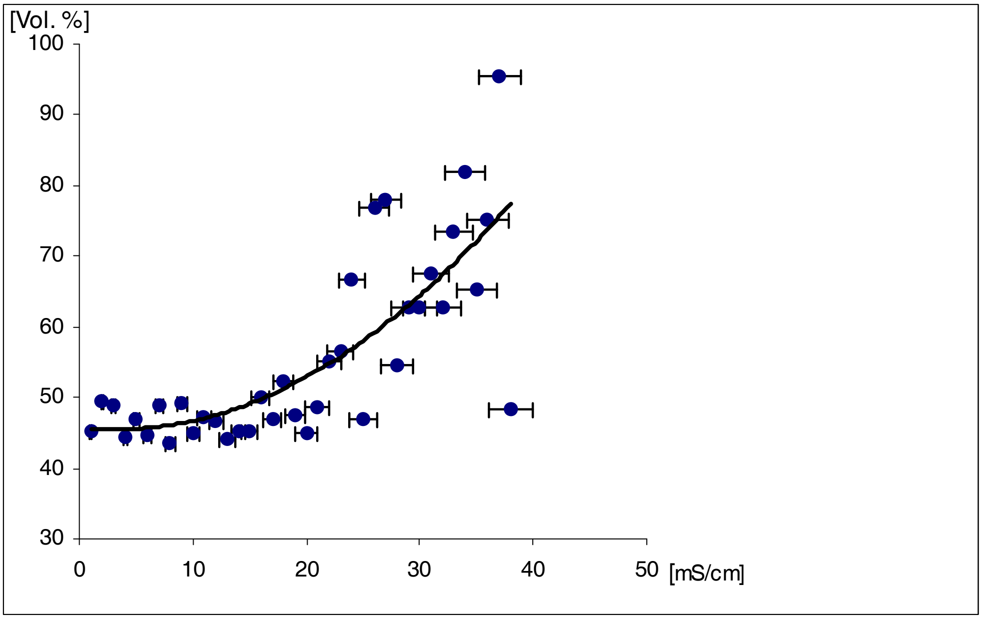


Figure 2 Distortion of the 3 prong probes: one side to the outside {90°}; two-side-simultaneous: to the front and to the outside {2*90°)

SALINITY: To determine the potential disturbance of a saline ambience, the calibration setup of TRIME probes, using saturated and unsaturated glass beads in order to give a reference value of 2,8 and 43,8 Vol.% was modified. Saturated glass beads (Ø 0,45mm) were used as the basic matter for test series of a linear increase of salinity due to the addition of universal NPK fertilizer in steps of 1g/test vessel (V_t=8 litres). The trial setup was completed by documentation of impedance change by an electrical conductivity probe set for soil conductivity measurements (Eijkelkamp 14.01). The linear addition of fertilizer was leading to a nonlinear increase of salinity within the saturated glass beads. The test series started at 824 Ω (= 2,81 mS/cm) and ended at 27,1 Ω (48,9 mS/cm) (figure 3). With 74,5Ω the reading of TDR level started to scatter. This was calculated equal to 31,44 mS/cm. From this threshold point the reflected part of the TDR trace curve started to flatten too much for a consequent interpretation of the curve (figure 4). Therefore the automatic detection algorithm of TRIME generated faulty readings in a range of > + 20% total. The correlation factor was calculated r^2= 0,58 in total (polynomical), whereas the standard deviation was calculated 14,77 in total. For TRIME the first and undisturbed part of the curve a standard deviation of 10,85 could be described. Consequently the setup of both kinds of TDR probes is limited with an electrical conductivity of 30 mS/cm.

DISCUSSION

Basic impacts on the TDR measurement were derived from several setups, underlining the accuracy of the method itself. Methodical self immanent limitations lead to a deviation threshold starting with 31,44 mS/cm. The basic and calculable limitation factor of salinity is accompanied by the altering impact from probe distortion which could be eliminated by careful handling of probe penetration to soil. For irrigation purposes a clear reading of the signal is substantial, whereas a documentation of salinity is substantial deriving proper results. The further documentation of salinity progress over a defined period of time provides further possibilities to manage a controlled leaching (over irrigation) to prevent an over proportional increase of salinity on problematic sites. For a future dynamic control of driven irrigation tools (Jantschke, 2004), a dynamic TDR sensor is planned to provide the requested data for top soil layers. An additional input parameter could be provided, finding an appropriate measurement tool, additionally displaying average moisture content of the root zone. A future project is already on schedule.



F*igure 3* salinity influence on TRIME P2G 3 prong sensor

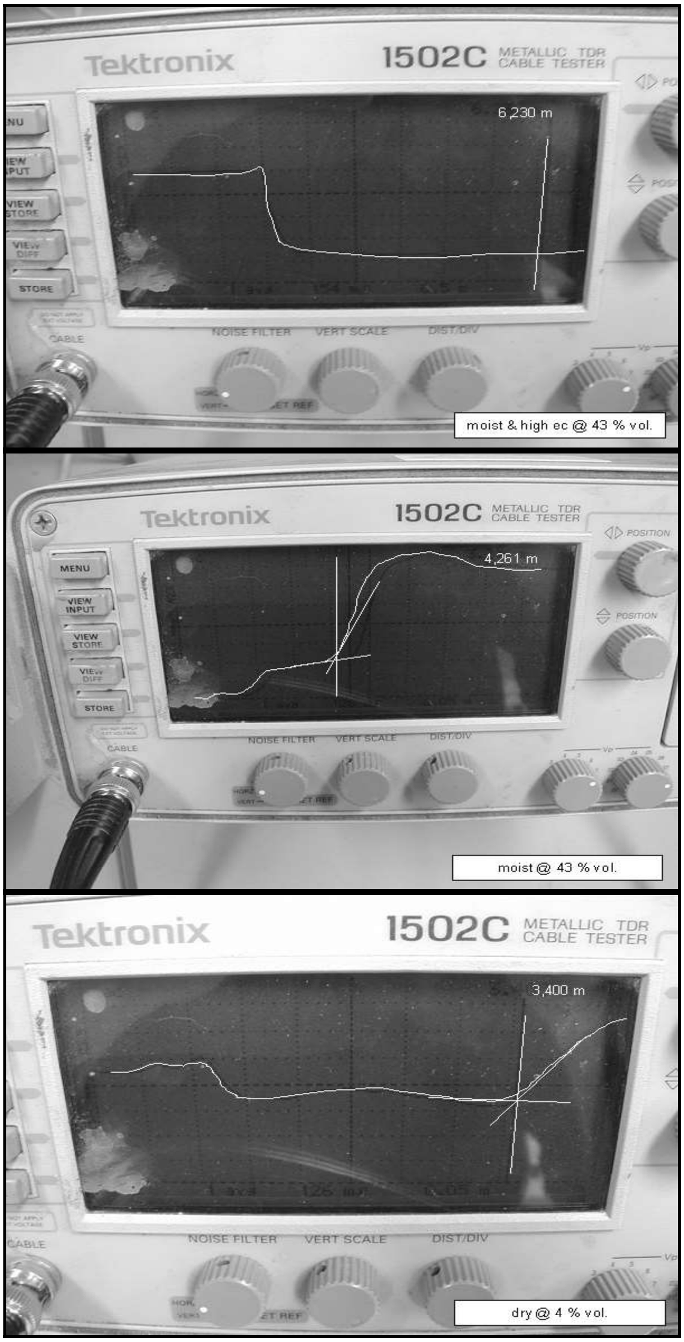


Figure 4 Tektronix reading: dry at 4 % Vol. water content, moist @ 43 % Vol. water content, moist @ 43 % Vol.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Preliminary communication

THE RESEARCH ON THE DISTRIBUTION OF DRAUGHT MONITOR SITES

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SUMMARY

In the end of August 2003, the authors organized a soil moisture content experiment in Beijing TongZhou district whose area is about 907 sq.km. Soil moisture data that are measured have been analyzed by clustering method. At the same time, the reasonable amounts of draught monitor sites and position in the district has been researched by Davies Bouldin's index criterion in the paper. According to the research, 7 draught monitor sites should be built in the district. The final result has been displayed on GIS map and proves that clustering method is fit for draught survey. It will provide theoretical foundation for draught monitor in the future.

Key words: *Draught monitor; Soil moisture; Clustering-analysis; Davies-Bouldin index; GIS*

INTRODUCTION

Recently building draught monitor system has attracted more and more attention in many provinces of China for example Chongqing province, Anhwei province, ShanDong province and so on. So China Agriculture University is cooperating with Beijing water resource Bureau and putting up Beijing's Draught monitor system. The project plans to build 80 draught fixed monitor sites and 120 mobile draught monitor sites in five years. So how to analyze these data we got from draught monitor system and how to locate these draught monitor sites rationally are in need of solution urgently.

In the paper, the author studied on Beijing TongZhou district's draught distribution trend. In August of 2003 an experiment on soil moisture is carried out in Beijing TongZhou district. The Tongzhou district locates in the southeast of Beijing city and its area is about 907 sq.km. In this experiment, we collected 3022 sample points' soil moisture data (Figure

1). The paper continues to analyze the experiment data, and then by these analysis, we can know how many draught fixed monitor sites should be built and where these monitor sites should be located in the district. These analysis and methods in the paper can guide the future work and research. The soil moisture sample points' spatial distribution map was showed by GIS software in figure 1. The soil moisture sampling points are expressed as small black points in the figure.

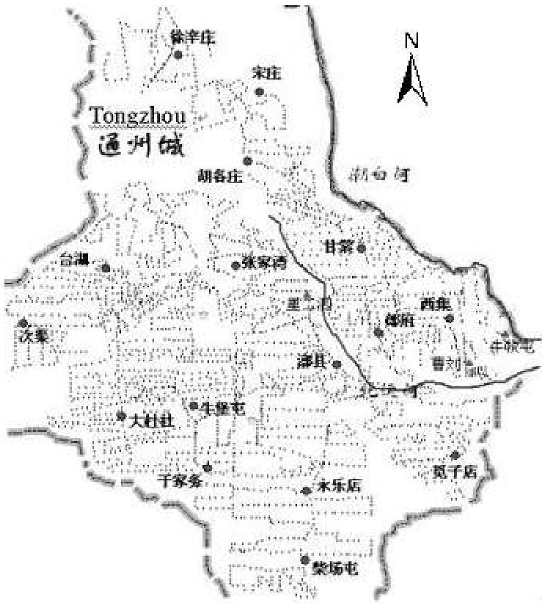

Figure 1 The spatial distribution map of sample points

METHODS

The principles of building a draught monitor site

According to the past research, we could receive the following principle of building a draught monitor site.

(1) The fixed draught monitor site can't just represent some one point's soil moisture. The site should represent draught trend of near region. So the site's soil moisture must be representative in a certain region.

(2) The distribution of draught monitor sites should be large and reasonable enough to analyze the draught situation in a certain region.

(3) Convenient to install, easy to maintain and safe

(4) Inexpensive. Building too many fixed sites will result in a considerable expense.

According to above-mentioned principles, we must select the most suitable place to built fixed draught sites by cautious and scientific attitude. Every draught monitor site's soil moisture should represent the most spacious region's draught situation and can be more convenient to forecast the future soil moisture content or draught. A rational and effective draught monitor system is the important basis of forecasting soil moisture content and fighting a draught.

How to locate a draught monitor site reasonably in a certain region

According to the principles of building a draught fixed site, we must classify some sampling points whose geographical coordinate and soil moisture value are similar to a subset. The subset should reflect near region's soil moisture content.

At first, we define 3022 sampling points' data format as follows:

$z_i \quad (X_i \quad Y_i \quad S20_i) \qquad 1 \le i \le 3022$
(1)

In the formula, the X_i is the sampling point i 's longitude, the Y_i is the sampling point i 's latitude and $S20_i$ is the sampling point i 's soil moisture value in 20CM depth of burial. And then we define $d(z_i \quad z_j)$ as the distance between the sampling point i and the sampling point j , the formula for the distance is :

$$d(z_i - z_j) = [(x_i - x_j)^2 + (y_i - y_j)^2 + (s_{20,i} - s_{20,j})^2]^{\frac{1}{2}} \qquad (2)$$

The distance we defined match three conditions as follows:

$d(z_i \quad z_j) \ge 0,$

$d(z_i \quad z_j) \quad d(z_j \quad z_i),$

$d(z_i \quad z_j) \le d(z_i \quad z_k) \quad d(z_k \quad z_j)$

Many savants and scientists call the distance as Euclidean-distance. According to the Euclidean-distance, the sampling points whose distance is shorter are classified the same subset. At the same time, the sampling points whose distance is longer are classified to another subsets. At last all the sampling points will belong to different subsets

Generally the purpose of spatial clustering analysis is that analyzes spatial objects' group and classifies the objects into different subgroup and at last find out some spatial rules.

Now there are many clustering algorithms. Owing to the measured sampling points number 3022 is much bigger than 100, we select K-means Clustering to analyze these data. The process is showed in Figure 2.

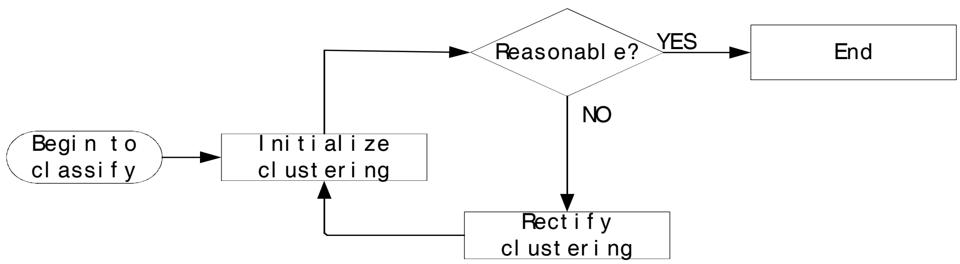

Figure2 The process of clustering

The steps are as follows:

1. Select k initial modes, one for each cluster. The Figure 3 displays the seven initial modes' cluster center

Initial Cluster Centers

	Cluster						
	1	2	3	4	5	6	7
X	116.5751	116.7713	116.7954	116.6709	116.7112	116.7822	116.8922
Y	39.77252	39.64642	39.77158	40.00212	39.96533	39.70857	39.73867
S20	.060	.068	.338	.061	.284	.205	.045

Figure 3 The seven initial cluster centers

2. Allocate an object to the cluster whose mode is the nearest to it according to the first step. Update the mode of the cluster after each allocation.
3. After all objects have been allocated to clusters, retest the dissimilarity of objects against the current modes. If an object is found such that its nearest mode belongs to another cluster rather than its current one, reallocate the object to that cluster and update the modes of both clusters.
4. Repeat the third step until no object has changed clusters after a full cycle test of the whole data set. And then we can get final seven cluster centers (Figure 4)

Final Cluster Centers

	Cluster						
	1	2	3	4	5	6	7
X	116.6455	116.7460	116.7043	116.6874	116.7702	116.7483	116.8441
Y	39.79078	39.69331	39.78450	39.95435	39.88550	39.82315	39.77447
S20	.093	.088	.211	.121	.162	.084	.117

Figure 4 The seven final Cluster centers

ANOVA

	Cluster		Error			
	Mean Square	df	Mean Square	df	F	Sig.
X	2.408	6	.001	3015	2134.095	.000
Y	2.315	6	.001	3015	1590.419	.000
S20	.552	6	.001	3015	533.884	.000

The F tests should be used only for descriptive purposes because the clusters have been chosen to maximize the differences among cases in different clusters. The observed significance levels are not corrected for this and thus cannot be interpreted as tests of the hypothesis that the cluster means are equal.

Figure5 Single factor variance analysis

At the same time, we can execute single factor variance analysis to check the three variables' effect on clustering process. From Figure 5, we can find every variable is very important to cluster. Every sampling points' longitude, latitude and soil moisture value are useful for final cluster centers.

How to get the reasonable amounts of draught monitor sites in a certain region

In the above analysis, we suppose the reasonable amounts of draught monitors sites as seven in TongZhou district at first. And then we calculated the reasonable place where the sites should be installed by clustering analysis. The amounts are assumptive, so now we must find out the academic basis. There are many index and parameters in clustering analysis. In the paper, we will use Davies-Bouldin index to evaluate the effect of the clustering analysis because Davies-Bouldin index is fit for K-means Clustering analysis and fit for the principle to build draught monitor sites.

Generally Davies-Bouldin index DB index will reduce with the increase of the distance between different subset and the decrease of the distance between different samples in the same subset.

$$DB = \frac{1}{k}\sum_{i=1}^{k} \max\left\{\frac{D_k(Z_i) + D_k(Z_j)}{D_k(Z_i, Z_j)}\right\} \tag{3}$$

The formula 3 shows the method to calculate the DB index. Through calculating the DB index, we can reduce man-made errors. After Calculated by MATLAB software, the result was displayed in Figure 6. We suppose the maximum of clustering subsets to be twenty.

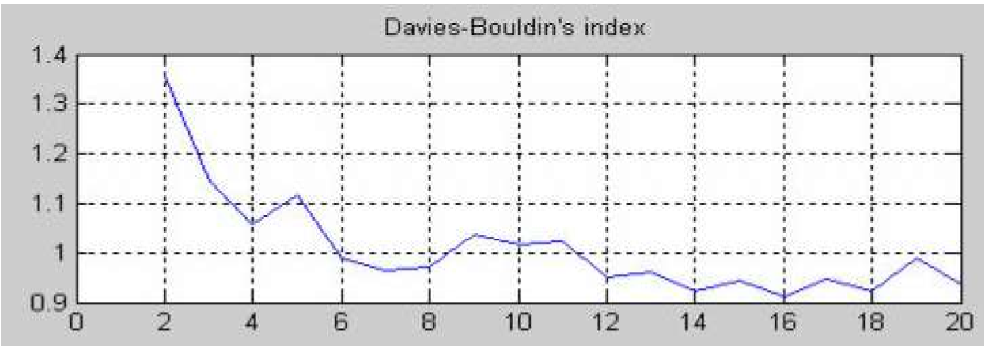

Figure 6 Davies-Bouldin index trendline of K-means Clustering analysis

From Fig 6, we can see DB index does not reduce monotonically. When the amounts of clustering subset equal 4, we can get the first rock bottom. When the amounts are 7, we can get the second rock bottom. We can find when the amounts are bigger and bigger, the DB index will smaller and smaller. But at the same time if we accept bigger amount, more draught monitor sites will be built, it will cost more in despite of the value of DB index is smaller. So according to the principles of building draught monitor sites, we accept the final cluster amounts as 7.

RESULTS

The final result was showed in the Fig. 7 drawed by ArcGIS software. The seven flags represent the final cluster centers. From the above analysis, the draught monitor sites should be located in the seven cluster centers. We can monitor effectually the regional draught status of Beijing Tongzhou district just through these seven sites building in the proper place.

Figure 7 The final clustering result

CONCLUSIONS

In the paper, we researched and discussed how to get the reasonable amounts of draught monitor sites and how to locate reasonably a draught monitor site in a certain region. We can find out that clustering analysis and DB index are fit for researching drought monitor sites' distribution and building. In a certain region, we can build quantificational drought monitor sites to reflect the real draught situation of the whole region. The research may provide reliable academic basis for the future draught monitor.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Prethodno priopćenje
Preliminary communication

DIFFERENT FERTILIZATION TECHNIQUES AND THEIR INFLUENCE ON POTATO YIELD

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SUMMARY

Field trials established in 2004 and 2005 studied effects of growing technology, time of fertilizer application, deposition method, form and rate of fertilizers on potato yields. Industrial fertilizers containing nitrogen were incorporated during first cultural practices in early spring and immediately prior to planting. Ammonium sulfate – ammonium form (granules) and DAM 390 – nitrate, amide and ammonium form (solution) were used for the application. The fertilizers were broadcasted and local incorporated. Special fertilizer applicators were used (for solid and liquid fertilizers). The applicator of solid fertilizer was mounted in the three-point tractor hitch with front hydraulic hitch, integrated with planter. The drive was performed with transfer of torque from the axle using chain drives. The volume of fertilizer rate was regulated by the moving of chain wheels and chain in the system. The applicator of liquid fertilizers was directly mounted on the potato planter. A 300 l container was fixed in front three-point hitch. Pump drive was performed through back power take-off. Switching on and off of the applicator was hydraulically controlled together with planter operation. A nozzle was placed at the back of the front plough of the planter in order to apply fertilizer into soil prior to potato seed placement.

Local application of 110 kg N/ha at planting brought higher yields only when liquid fertilizer DAM was applied, namely by 12,5 % on the average of the years 2004 and 2005 compared to pre-plant broadcasting. Local application of 80 kg N/ha as DAM achieved a 2,5 % higher yield compared to broadcast application of 110 kg N/ha. It is resulted that the efficiency of 80 kg N (local) was comparable to 110 kg N (broadcast). In the case of solid SA fertilizer tuber yields are more favorable due to the year 2005 for broadcast application. Enormous yields were derived due to weather progress (especially in June and July) in 2005. Nitrogen rates between 80 kg N and 110 kg N caused a 10 % increased tuber yields on the average of the years 2004 and 2005.

***Key words**: potato, fertilization, nitrogen, yield*

INTRODUCTION

Fertilization and nutrition are the important intensification factors in the potato growing system. Nutrient rates have a direct impact on potato yields and quality.

In the Czech Republic, the system of organic and mineral fertilization recommends an incorporation of approximately 35 t/ha farmyard manure (or other manure) and mineral fertilizers containing phosphorus, potassium and magnesium in the autumn following the pre-crop harvest. The requirement for P, K and Mg fertilization could be determined from soil nutrient content, as provided by the national Central Institute for Supervising and Testing in Agriculture in regular six-year cycles. Based on existing criteria for nutrient content and comparison of the factual nutrient values in soil samples determined in Mehlich III extract, the level of rates could be recommended for various regions and kinds of agricultural lands (Cepl 2004). The fertilizers are broadcasted as solid crystallic form. P, K and Mg fertilization supplements the nutrient supply and modifies relations of nutrients on the site for the whole crop rotation. If supply and nutrient relations are optimal, it is possible not to apply commercial fertilizers in the autumn.

Commercial fertilizers containing nitrogen are applied before planting in the spring. In light soils, commercial fertilizers containing all nutrients could be also applied in the spring. Nitrogen rates are differentiated dependent on duration of growing period of the variety, utility type of growing and also on rate of manure in the autumn. Soil inorganic nitrogen content could be also taken into account after soil de-freezing in the spring. Commercial fertilizers are broadcasted again, usually as powder or crystallic form before planting.

In last decade the way of potato growing has been substantially changed in the Czech Republic. Besides the conventional spring soil preparation, planting, earthing and hoeing till plant emergence, so-called de-stoning technology has been applied. Soils for potato growing contain high amount of skelet-stones that significantly contributed to mechanical tuber damage. The aim of introduction of de-stoning technology was an elimination of mechanical damage due to stone removal and the technology also provided higher tuber yields, since careful cultivation and soil separation reduced soil compaction. The technology consists in the application of three basic practices: furrowing (two-row furrower forms furrows to the depth of top soil in the width of two rows), stone and clod separation (separator cultivates every furrow, smaller stones and clods are placed in the bottom of the furrow, larger stones and clods are placed in a container and a flat bed in the width of two-rows is formed, working bodies are stars, strips or combination of both) and finally planting with two-row planter is performed into de-stoned soil (Fér, 2004). It is presupposed that commercial fertilizers (mostly only nitrogen fertilizers) applied in this system prior to the first practice – furrowing will be distributed by following mechanical practices in the whole top soil profile and only part of them will be utilized for the nutrition of planted potato crops. The realization of the idea of local, band fertilization has begun more than 40 years ago, the first research studies were finished in the Czech Republic in the 70's of last century (Vokál, Radil, 1977), The authors found that results of local N fertilizer application as solid form were not unambiguous and the applicability was limited with low level of fertilizers. Pickny and Grocholl (2003) presented results of 10-year trials and recorded positive effects of row fertilization and a strong influence of the year weather conditions on the yield increase compared to broadcast application. Wulf (1996) noted that an effect of row fertilization in potatoes is highly dependent on the terms of the site and variety. A positive yield effect of row application of nitrogen and phosphorus fertilizers could be obtained especially by low nitrogen level, low soil supply and low fertilization level. He recommended to growers to use their own experiences; then it is not possible unambiguously to determine the effects of row fertilization, since many factors could influence yield formation. It also proven by Neubauer (1993), who founds a positive effect of the combination of row nitrogen fertilization and ridge pre-formation on potato yield in light sandy soils. Increasing soil fertility, advantages of this way of fertilization were reduced. Row fertilization stabilized yield and acted against yield decrease, when interrow distance was more than 90 cm. Better nitrogen utilization should be highly regarded from the ecological viewpoint. Considering the way of nitrogen fertilizer incorporation many authors emphasize the Cultan technology (Controlled Uptake Long Term Ammonium Nutrition). Sommer and Schumacher (1999) report that CULTAN system is based on nitrogen supply as ammonium instead of nitrate. In addition to more target N plant supply, an about 30 % higher degree of nitrogen fertilization efficiency is achieved. If balanced nutrient supply was provided, better tuber quality could be ensured. Using CULTAN system microelement plant supply, weed control based on latent shortage of nitrogen and plant control based on systemic insecticides and fungicides could be combined. However, Back (2004) indicates that worse tolerance of ammonium fertilizer for plants, higher machinery need and purchase cost could be a disadvantage of the system. He also recommends paying an attention to this technology, particularly in arid localities or for non-irrigated potato growing.

METHODS

The objective of the study is to determine an effect of application timing of nitrogen fertilizers, the deposition method of nitrogen fertilizers, forms and rates on potato yields. Two forms of commercial nitrogen fertilizers were applied: solid (granulated) and liquid. Solid fertilizer: ammonium sulfate SA ($(NH_4)_2SO_4$) – ammonium form containing 20,3 % N. Liquid fertilizer: DAM 390 – a solution of ammonium nitrate (NH_4NO_3) and urea ($CO(NH_2)_2$) with an average content of 30 % mass nitrogen, out of this 25 % as ammonium, 25 % as nitrate and 50 % as urea. Liquid nitrogen fertilizer DAM 390 in optimal composition of 42,2 % ammonium nitrate, 32,7 % urea and 25,1 % water contains 39 kg nitrogen per 100 l solution.

A field trial was carried out between 2004 and 2005 in an agricultural enterprise specialized in potato production. Conventional large-scale technology using de-stoning line of Reekie Company (two-row furrower, separator and two-row planter) was applied for trial establishment.

The fertilizers were applied with broadcaster of commercial fertilizers (solid form) or as area spraying (liquid form) prior to bed formation. Local application of solid fertilizers was done at planting.

The applicator of solid fertilizer (BPH-400) was mounted in the three-point tractor hitch with front hydraulic hitch, integrated with planter. The drive was performed with transfer of torque from the axle using chain drives. The volume of fertilizer rate was regulated by the moving of chain wheels and chain in the system.

The applicator of liquid fertilizers was directly mounted on the potato planter. A 300 l container was fixed in front three-point hitch. Pump drive was performed through back power take-off. Switching on and off of the applicator was hydraulically controlled together with planter operation. A nozzle was placed at the back of the front plough of the planter in order to apply fertilizer into soil prior to potato seed placement.

Trial treatments:

Totally, seven treatments were established differing in nitrogen rate, fertilizer type, timing and deposition way. In treatment 1 – 80 kg N/ha was applied as SA locally at planting, in treatment 2 – 110 kg N/ha was pre-planting broadcasted as SA, in treatment 3 – 110 kg N/ha was locally applied as SA at planting, in treatment 4 – 80 kg N/ha was locally applied as DAM at planting, in treatment 5 – 110 kg N/ha was pre-planting broadcasted as DAM and in treatment 6 – 110 kg N/ha was locally applied as DAM at planting. Treatment 7 served as a control without N fertilizer application.

Early potato variety Dali was used for the trials. The size of each trial plot was 350 m^2. The harvest was done in the period of physiological maturity with two-row harvester Grimme GZ 170. During growing period measurements with N-tester were done. N-tester is a device optically measuring intensity of green coloration. This technique is indirectly based on chlorophyll content measurements and according to the results the nitrogen nutritive state could be estimated. In 2004 two measurements were done, measurement I on June 18 and measurement II on July 20. In 2005 only one measurement was done, on July 18.

RESULTS AND DISCUSSION

Figures 1 and 2 present the results of potato yield.

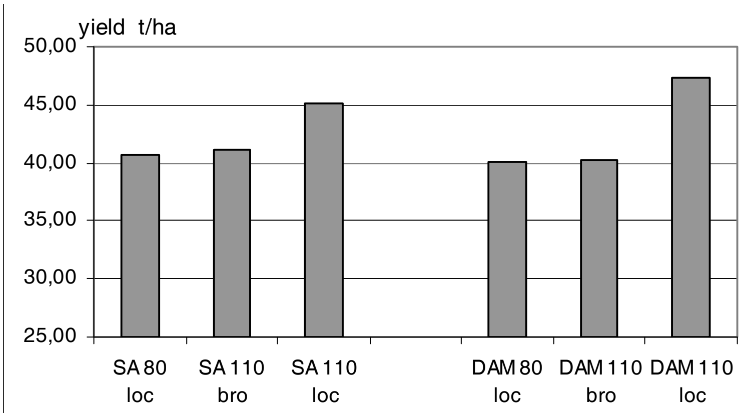

Fig. 1 Effect of treatments on potato yield in t/ha in 2004

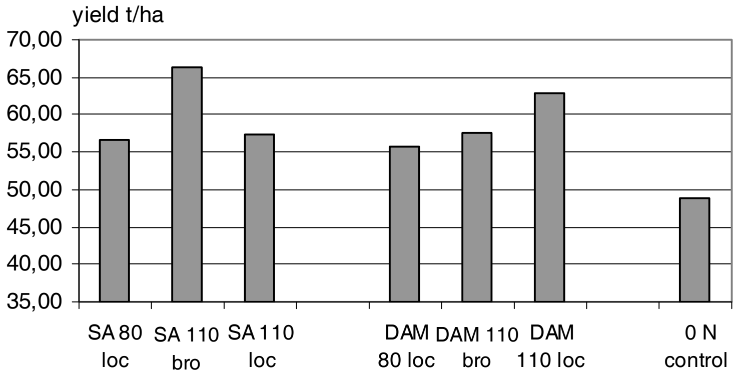

Fig. 2 Effect of treatments on potato yield in t/ha in 2005

Year effect

A very strong effect of year was recorded on potato yield. The relative yield increase was 40 % in favor of 2005 between years. This year, a record potato yield was derived in the Czech Republic – 29,65 t/ha on approximately 36 045 ha of potatoes. The reasons could be found in weather conditions, especially in the effect of rainfall amount and rainfall distribution during June and July, as shown in Tab. 2. It was noted that the highest potato yields are achieved in the years with dry weather conditions during tuberization and tuber initiation and high rainfalls during intensive potato growth. The reason of high yield in 2005 could also be the progress of soil organic N mineralization. During intensive potato growth high amount of rainfalls was recorded that increased so far low intensity of mineralization, i.e. supply of N was high for plants.

Tab. 2 Weather conditions (meteorological station PRI Valecov)

studied parameter	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
long-term mean	33,68	31,70	39,03	42,45	76,33	91,35	80,89	86,60	48,15	46,41	38,99	36,46
rainfalls in mm 2005	87,00	44,80	13,30	26,80	86,30	34,90	215,20	86,30	36,90			
rainfalls - % long-term mean	258,31	141,32	34,08	63,13	113,06	38,20	266,04	99,65	76,64			
rainfalls in mm 2004	82,50	41,90	36,50	57,20	62,90	96,50	69,60	46,10	55,50	35,00	76,10	19,40
rainfalls - % long-term mean	244,95	132,18	93,52	134,75	82,41	105,64	86,04	53,23	115,26	75,41	195,18	53,21
long-term mean	-3,42	-2,05	1,30	7,26	11,58	15,22	16,47	16,36	12,29	7,96	3,11	-2,20
temperature in °C 2005	-1,30	-4,20	0,84	8,00	12,00	13,60	16,40	14,50	14,00			
Temperature in °C 2004	-4,57	0,74	1,66	8,00	10,20	14,30	16,40	17,80	12,10	9,10	3,08	1,27

Relation between trial treatments, crop nutrient state according to N-tester and potato yield

N-tester (Minolta) is a device measuring intensity of green color of leaves, which is in a direct relation to chlorophyll content. However, determined value is no-named number.

The results of N-tester measurements related to tuber yield are the objective of Fig. 3 (year 2004) and Fig. 4 (year 2005). Figures indicate that N-tester measurements partially reflected the effect of treatments, what was later expressed in potato yield, although a stronger correlation relation was only determined in the second measurement. In 2005 no relation was found between values of N-tester and potato yield.

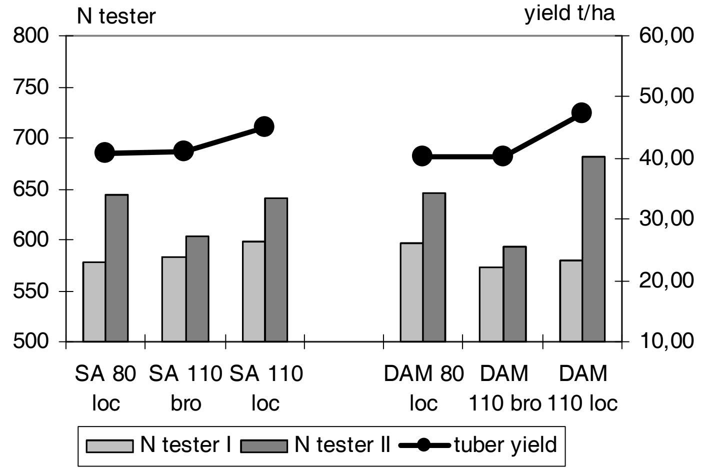

Fig. 3 Results of N tester measurement related to tuber yields in 2004

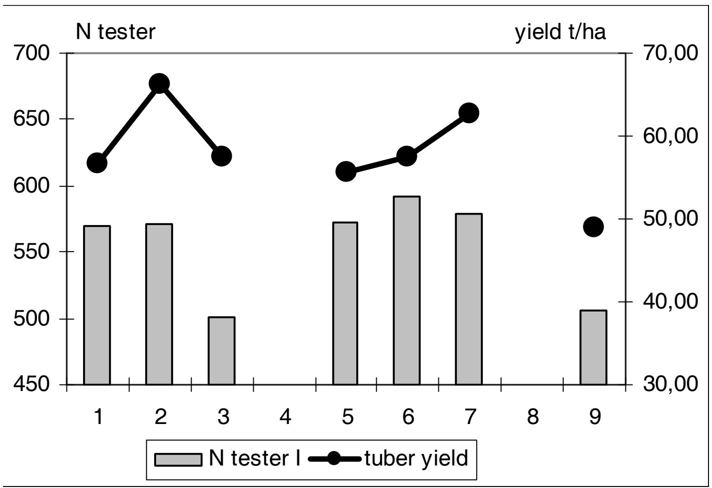

Fig. 4 Results of N-tester measurement related to tuber yields in 2005

The effect of deposition method (local and broadcast) and timing on tuber yield

Results indicate that compared the same N rates (110 kg/ha) and the same fertilizer type potato yield was 9,7 % (SA) and 17,3 % (DAM) higher in local application at planting in 2004 than in pre-plant broadcasting. On contrary, a 13,4 % lower tuber yield was recorded, when SA was locally applied in 2005. Considering DAM trend of previous year was maintained and a 9,1 % higher yield was found with local application. Averaged over two years, stronger effect of the year 2005 was expressed and reflected in the whole tendency of reduced yield for local application. Compared the deposition method and timing we found 3,6 % higher tuber yields for local applications on the average of both fertilizer types and the same N rate (110 kg/ha).

The effect of nitrogen rate on potato yield

In 2004 a higher nitrogen rate of 110 kg/ha ensured 14,3 % higher potato yield compared to 80 kg/ha, in 2005 7,0 % higher potato yield was achieved; yield increase between non-fertilized control compared to the rate of 80 kg N/ha was 15,0 % and compared to 110 kg N/ha it was 22,9 % in 2005.

The effect of fertilizer form on potato yield

Solid, granulated form of commercial nitrogen fertilizer as SA and liquid form as DAM was used for the trials. On the average of N rates and deposition method no differences were found between both forms in 2004, in 2005 a 2,5 % higher tuber yield was found, when SA was applied. The results do not indicate that fertilizer form has a significant effect on potato yields.

CONCLUSIONS

Local application of 110 kg N/ha at planting brought higher yields only when liquid fertilizer DAM was applied, namely by 12,5 % on the average of the years 2004 and 2005 compared to pre-plant broadcasting.

Local application of 80 kg N/ha as DAM achieved a 2,5 % higher yield compared to broadcast application of 110 kg N/ha. The results indicate that the efficiency of 80 kg N (local) was comparable to 110 kg N (broadcast).

In the case of solid SA fertilizer potato yields are more favorable due to the year 2005 for broadcast application.

Enormous yields were derived due to weather progress (especially in June and July) in 2005.

Nitrogen rates between 80 kg N and 110 kg N caused a 10 % increased tuber yields on the average of the years 2004 and 2005.

ACKNOWLEDGEMENTS

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 621.317.7:631.331
Stručni rad
Expert paper

MOŽNOST DOGRADITVE ELEKTRONSKE NAPRAVE INOTRONIC PS100 ZA NADZOR DELOVANJA SEJALNICE

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SAŽETAK

Za olajšanje voznikovega dela pri sejanju je proizvajalec sejalnic INO Brežice d.o.o. leta 2003 izdelal napravo za nadzor delovanja sejalnice INOtronic PS100. Naprava je sposobna nadzirati vrtenje sejalnih kolutov, ob zaustavitvi pa javiti napako na sejalnem aparatu z akustičnim in vizualnim signalom. Pomanjkljivost naprave je nezaznavanje prazne nasipnice. Z dograditvijo tipala majhne količine semena na dno nasipnice, dosežemo večjo uporabnost in zanesljivost naprave. V trenutku, ko nivo semena pade pod tipalo se prekine oddajanje impulzov induktivnega senzorja v razdelilno enoto, kar sproži signal za napako na sejalnem aparatu. Tipalo mora biti vgrajeno na primernem mestu, dovolj robustno, občutljivo, odporno na vlago in prah ter poceni. Preskušanje različnih tipal na modelu sejalnice in pri setvi je pokazalo, da zelo dobro delujeta kapacitivni senzor ter stikalo z žičnim vzvodom in vrtljivo osjo. Visoka cena in občutljivost na umazanijo prvega, kažeta v prid drugega, ki je enostaven, ne potrebuje napajanja in je bistveno cenejši. V primeru dograditve v elektronsko napravo INOtronic PS100 je zaradi elektronskih komponent, primernejši kapacitivni senzor.

Ključne reči: *sejalnice, naprave za nadzor sejalnic, kapacitivni senzor, stikalo*

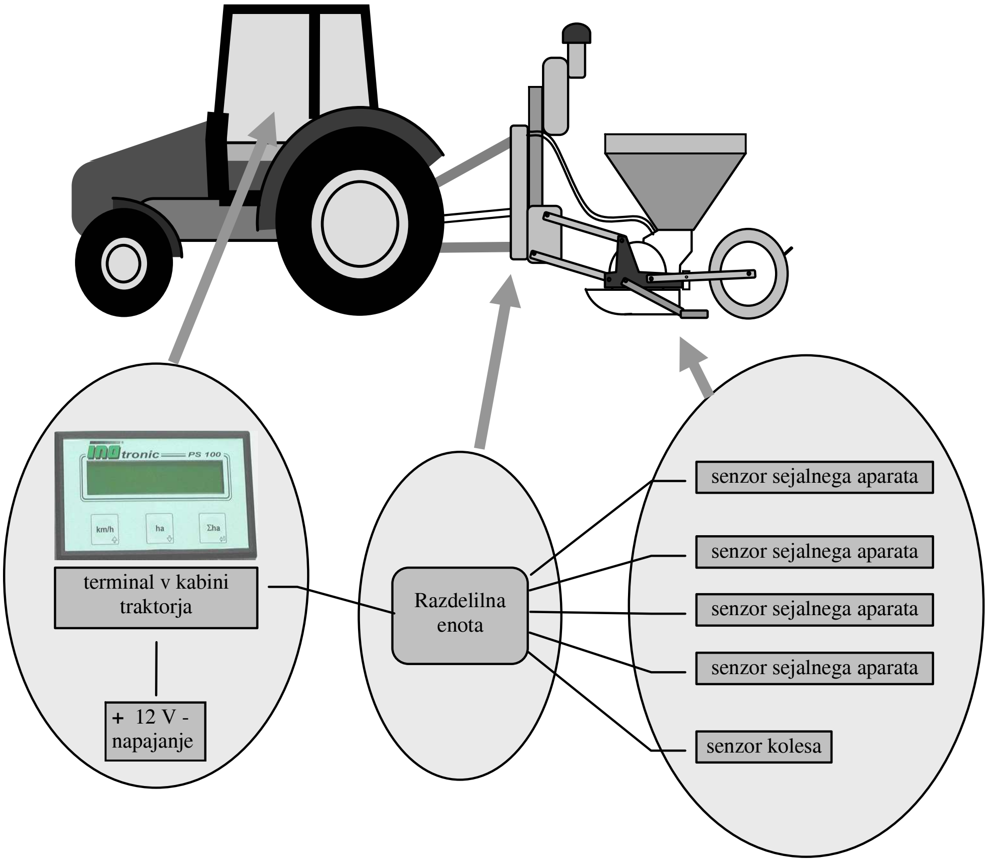
UVOD

Elektronsko nadzorovane naprave srečujemo na vsakem koraku. Postale so nuja in potreba, saj omogočajo nadzor zapletenih, monotonih in ponavljajočih opravil.

Delo s sejalnico je za voznika zelo monotono, ker mora biti zbran in natančen, da spremlja sled črtalnika ter vodi traktor čimbolj naravnost. Ob tem mora spremljati še delovanje sejalnice, morebitne zamašitve sejalnih lemežev in količino semena v nasipnici.

Setev brez pomočnika, ki bi sproti neprekinjeno in iz neposredne bližine nadzoroval delo vseh izmetal ter tok semena iz sejalnih cevi v brazdice, je stvar zaupanja v stroj, v čistočo semena in brezhibno pripravljeno zemljo [1].

Setev poljščin na končni sklop rastlin zahteva natančno setev, zato je kakovost dela sejalnice ključnega pomena. Za dober nadzor nad delovanjem sejalnice potrebujemo kakovostno in zanesljivo napravo, ki bo pravočasno in natančno opozarjala voznika na nepravilnosti v delovanju.



Slika 1 Shema postavitve in priključitve naprave za nadzor sejalnice INOtronic PS100

Prve naprave za nadzor, ki so se po letu 1980 pojavile na sejalnicah, so bili merilniki posejane površine. To so bili mehanski števci z "reset" tipko, ki se pritisne na začetku njive, na koncu pa pokaže izmerjeno posejano površino [2]. Razvoj elektronskih komponent je omogočil razvoj v sejalni lemež vgrajenih senzorjev izpadanja semena in senzorjev hitrosti vožnje. S senzorji povezan terminal v kabini traktorja deluje kot kontrolno informacijski sistem in daje uporabniku sprotne informacije o delovanju izmetalnih naprav, hitrosti vožnje in posejani površini. Sodobnejše naprave se že vključujejo v sistem "precision farming"-a in omogočajo nadzor setve ter sprotno spreminjanje hektarske doze glede na prej ugotovljeno stanje rodovitnost tal sejane površine.

Za olajšanje voznikovega dela je proizvajalec sejalnic INO Brežice d.o.o. leta 2003 izdelal in predstavil napravo za nadzor delovanja sejalnice INOtronic PS100, ki spremlja vrtenje sejalnih kolutov, hitrost vožnje in velikost posejane površine. Na majhnem monitorju prikazuje hitrost setve in velikost posejane površine.

Elektronska naprava INOtronic PS100 za nadzor sejalnice ima vgrajena tipala za nadzor vrtenja sejalnih kolutov in pogonskega kolesa. V primeru zaustavitve sejalnega koluta sporoča napako vizualno na monitorju in akustično z zvočnim signalom. Pri tej napravi bi bilo smiselno vgraditi še tipala nizke količine semena, ki bi voznika ob monotoni setvi opozorila, da bo v kratkem zmanjkalo semena v nasipnici.

Možnost dograditve tipala majhne količine semena na omenjeno napravo je zelo preprosta. Poiskati je potrebno le primerno tipalo in ga na primeren način vgraditi ter povezati z napravo, ki bo majhno količino semena sporočila enako kot napako za zaustavitev sejalnega koluta [3].

METODE ISTRAŽIVANJA

S ciljem, da bi našli najustreznejše tipalo, je bilo opravljeno preskušanje v prvi fazi na simulacijskem modelu sejalnice Pan - Agra Becker. Model je sestavljen iz pogonskega kolesa, menjalnika, sejalnega aparata in puhala. Za pogon modela služi elektromotor, ki poganja pogonsko kolo. Le-to preko verižnikov, verig in menjalnika poganja sejalni kolut v sejalnem aparatu. Menjalnik ima šest prestav za nastavitev vrtilne hitrosti sejalnega koluta in s tem razdalje med semeni. Elektromotor poganja tudi puhalo za izpihovanje semen in tekoči trak, na katerega padajo semena.

Slika 2 Simulacijski model sejalnice

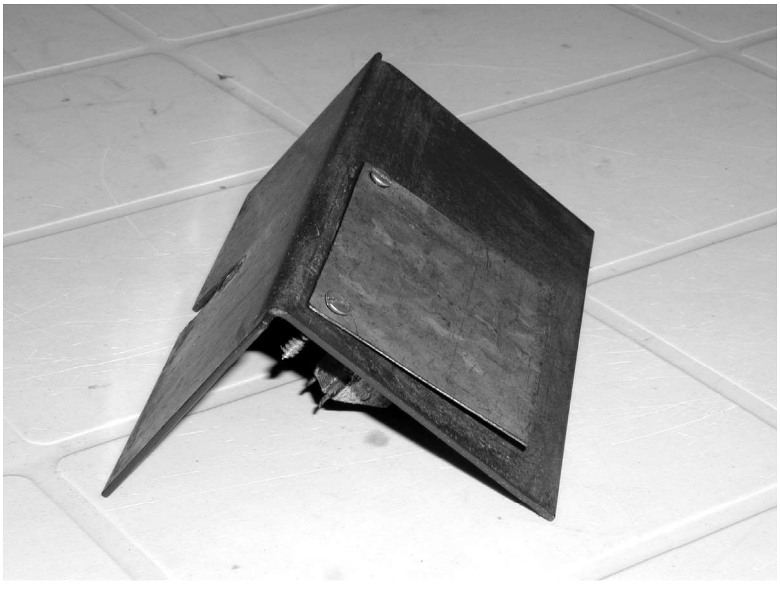
Na simulacijskem modelu izbrani in preskušeni tipali sta bili v drugi fazi vgrajeni in preskušeni še na štirivrstni pnevmatski sejalnici Pan - Agra Becker, ki je identična sejalnici INO Becker in je bila priključena k standardnemu traktorju Landini Globus 60 s štirikolesnim pogonom. Sejalnica je namenjena za setev koruze, zato ima v sejalnih aparatih vgrajene sejalne plošče s 24 - timi luknjami. Medvrstna razdalja je nastavljena na 70 cm. Pritisno globinska kolesa na sejalnih aparatih so bila kovinska.

Za ugotavljanje nizke količine semena v nasipnici je bilo potrebno najti ustrezno tipalo, ki bi ga lahko povezali na že obstoječo napravo INOtronic PS100 nadzor sejalnic. Ker so delovne razmere pri delu s sejalnico pogosto zelo neugodne, mora biti tipalo robustno ter neobčutljivo na tresljaje, udarce, vlago in prah. Hkrati pa mora biti dovolj občutljivo, zanesljivo in poceni. Pri preskušanju je bilo uporabljeno:

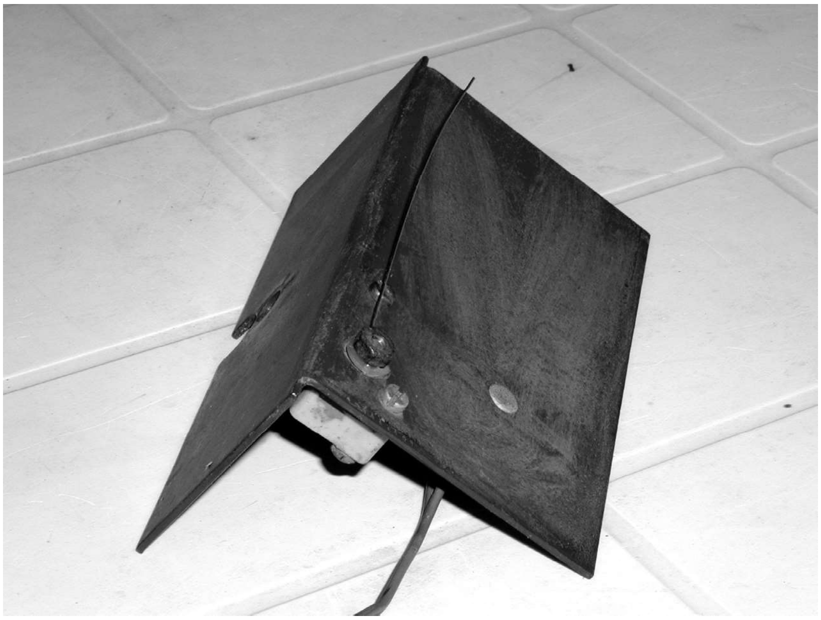
- mikro stikalo,
- stikalo z žičnim vzvodom in vrtljivo osjo ter
- kapacitivni senzor (DCC 18 4629).

Vsa tri tipala so serijske proizvodnje.

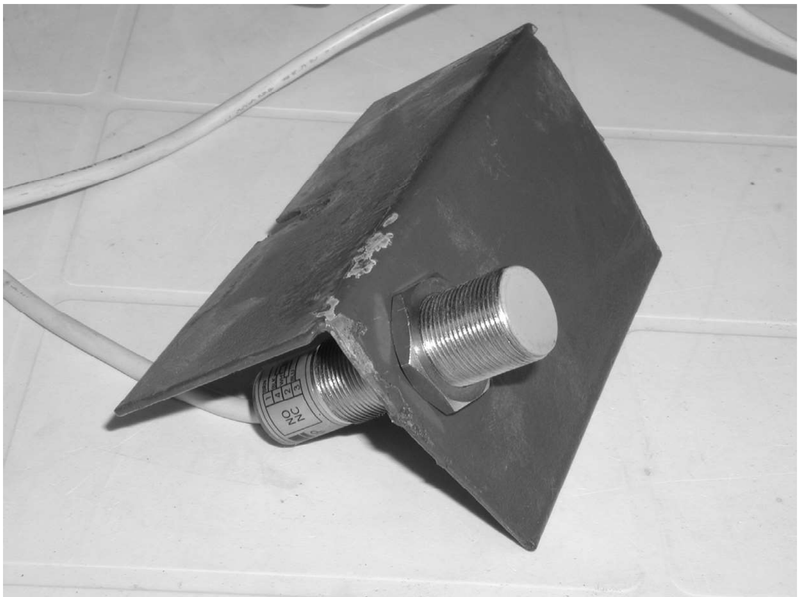
Tipala so bila vgrajena na pločevini z dna nasipnice, kapacitivni senzor pa je bil vgrajen tudi s sprednje strani nasipnice. Na mikro stikalo je bilo potrebno prigraditi pločevino, saj je bila potisna sila zrnja na pritisni čep stikala premajhna za preklop kontaktov.



Slika 3 Vgradnja mikro stikala s pločevino



Slika 4 Vgradnja stikala z žičnim vzvodom in vrtljivo osjo



Slika 5 Vgradnja kapacitivnega senzorja na pločevini z dna nasipnice

Slika 6 Kapacitivni senzor vgrajen s strani nasipniceStikala so bila med preskušanjem povezana z baterijsko svetilko, ki je služila kot indikator delovanja, za kapacitivni senzor pa je bila uporabljena 18 V baterija in merilnik električnih veličin MI 7043.

REZULTATI I DISKUSIJA

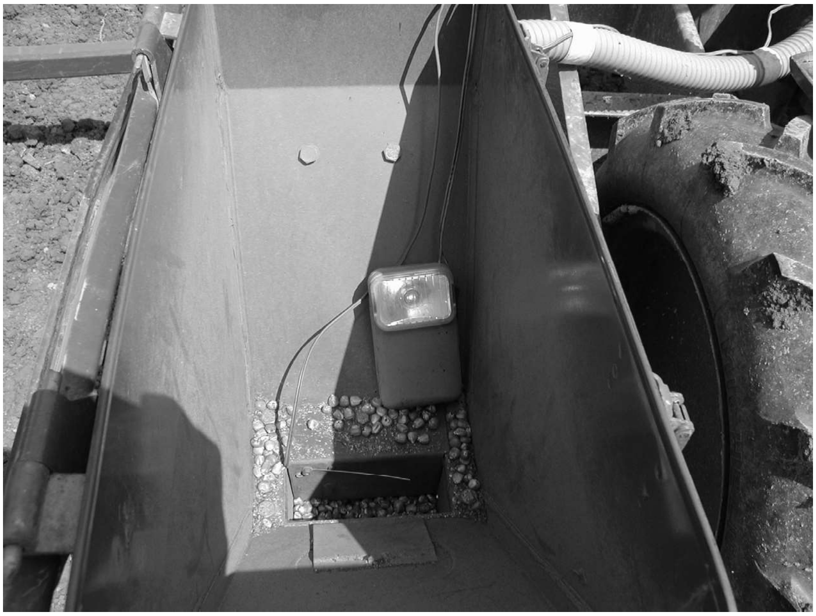
Že na simulacijskem modelu se je mikro stikalo pokazalo kot neprimerno, saj se je zaradi zračnega toka sejalnice in posledičnega "šviganja" semen v prazni nasipnici pogosto zataknilo. Zato sta bila pri setvi na njivi preskušeni le stikalo z žičnim vzvodom in vrtljivo osjo, ter kapacitivni senzor.

Stikalo z žičnim vzvodom in vrtljivo osjo

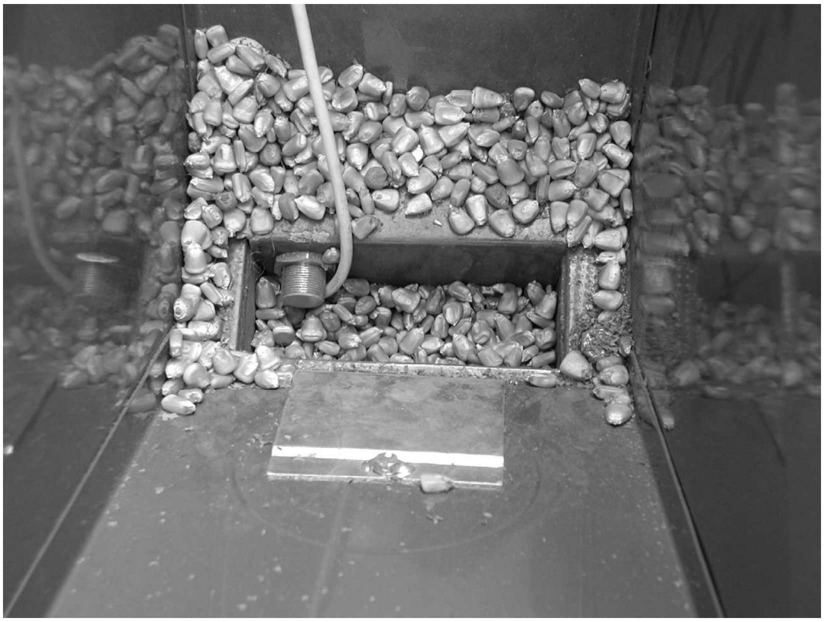
Ugotovljeno je bilo, da se pri počasnem polnjenju nasipnice žični vzvod stikala ob padanju semen včasih ne pomakne navzdol in ne sporoči signala polne nasipnice. Takoj po zagonu sejalnice in premiku semen v nasipnici pa se stikalo preklopi. Med delovanjem sejalnice ni bilo opaženih nobenih motenj. Signal za prazno nasipnico se sproži šele, ko je v nasipnici približno 1000 semen (slika 7).

Kapacitivni senzor

Velika prednost kapacitivnega senzorja je brezkontaktno zaznavanje snovi in predmetov, kar zelo poenostavi prepoznavanje semena v nasipnici. Zanesljivost delovanja je popolna, če je čelna aktivna ploskev senzorja čista in suha. Takoj po nasutju semena senzor sporoči signal polne nasipnice, in ga sporoča vse do trenutka, ko se seme odmakne s čelne aktivne ploskve (slika 8).



Slika 7 Količina semena ob vklopu žarnice

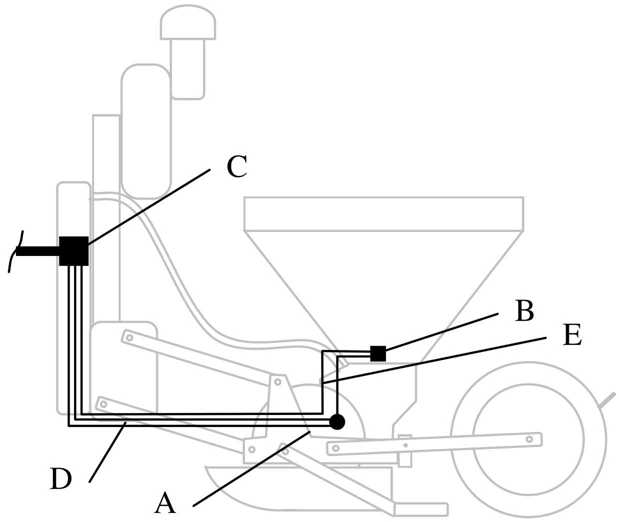


Slika 8 Količina semena ob vklopu signala pri postavitvi senzorja na dno nasipnice

ZAKLJUČAK

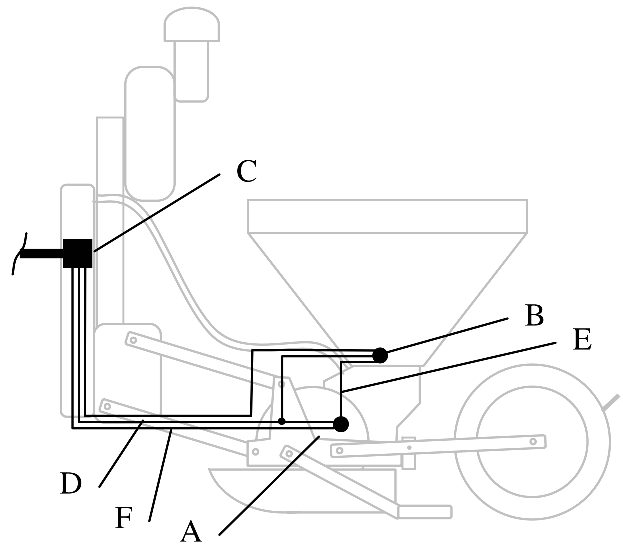
Preskus različnih stikal in senzorja je pokazal, da sta za ugotavljanje majhne količine semena v nasipnici primerna kapacitivni senzor ter stikalo z žičnim vzvodom in vrtljivo osjo. Pomembna prednost stikala je nizka cena in enostavnost vgradnje, kapacitivni senzor pa je pri zaznavanju semena natančnejši. Za dograditev v elektronsko napravo INOtronic PS100 sta uporabna oba.

Pri odločitvi za stikalo z žičnim vzvodom, se ta priključi na delovni kontakt zaporedno na signalni vod, med senzor in razdelilno enoto, kot je prikazano na sliki 9. Stikalo v primeru, kadar je nasipnica prazna prekine signale (impulze), ki jih pošilja senzor v razdelilno enoto. Naprava za nadzor sejalnice bo sporočila enak signal, kot v primeru, če se ustavi sejalni kolut.



Slika 9 Shema priključitve stikala (A – induktivni senzor na sejalnem kolutu, B – stikalo v nasipnici, C – razdelilna enota, D – napajanje, E – signalni vod)

Nekoliko drugače je potrebno povezati kapacitivni senzor, ki za delovanje potrebuje napajanje (slika 10). Dokler je seme v nasipnici, delovni kontakt tega senzorja služi za napajanje induktivnega senzorja. Kadar zmanjka semena v nasipnici, se napajanje prekine, to pa povzroči prekinitev oddajanja signalov induktivnega senzorja in proženje signala za napako na sejalnem kolutu posameznega agregata.



Slika 10 Shema priključitve kapacitivnega senzorja (A – induktivni senzor na sejalnem kolutu, B – kapacitivni senzor v nasipnici, C – razdelilna enota, D – napajanje (zgornji +, spodnji -), E – delovni kontakt za napajanje induktivnega senzorja (+ pol), F – signalni vod)

Za vgradnjo v napravo za nadzor INOtronic PS100 bi vsekakor predlagal kapacitivni senzor, saj je naprava sestavljena iz povsem elektronskih komponent. V navodila za uporabo sejalnice bi bilo potrebno le dopisati opozorilo, da lahko v nasipnico stresamo samo suho seme in da je potrebno pred vsako uporabo sejalnice očistiti senzor s čisto suho krpo.

Stikalo z žičnim vzvodom in vrtljivo osjo je zaradi nizke cene zelo primerno za preproste naprave za nadzor ali za umne samograditelje, ki želijo sami izdelati enostavno in uporabno napravo za nadzor semena v nasipnici.

Poudariti je treba, da je zanesljivost delovanja obeh tipal preverjeno le na semenu koruze. Za uporabo tipal pri setvi drugih semen je potrebno ponovno preverjanje zanesljivosti delovanja.

Naprava INOtronic PS100 je bila izdelana po željah proizvajalca sejalnic po enostavni in čimbolj učinkoviti napravi za rusko tržišče. Dodatek za ugotavljanje nizke količine semena v nasipnici je le zasilna rešitev. Popoln nadzor setve lahko dosežemo le z nadzorom izpadanja in štetjem semen.

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UPGRADING OF THE INOTRONIC PS100 ELECTRONIC DEVICE FOR THE SEED DRILL OPERATIONS CONTROL

ABSTRACT

In order to improve the seed drill operator's conditions during sowing, in 2003 the manufacturer of seed drills Ino Brežice d.o.o. developed an INOtronic PS100 device for the electronic seed control. The device is designed to control the rotation of seed wheels and in case of stoppage to signal the error with acoustic and visual signals. The deficiency of the electronic device is the fact that it does not signal when the seed container runs out of seed. By building in a sensor for small quantities of seed on the bottom of the seed container, the utilisation and reliability of the device could be improved. This sensor at the moment when the level of seed falls below the the sensor interrupts releasing of impulses via the inductive sensor to the distribution unit, which triggers the signal for the error on the seed drill. Such a sensor must be built in at an appropriate place, it must be of a robust enough structure, sensible enough, resistant to moisture and dust, and not too expensive. Testing of various sensors on a seed drill model and seed drill during sowing operations showed that the capacity sensor and and the wire-lever micro-switch and rotary axis work very well. A high price and sensibility to dirt of the first one speaks in favour of the second one, which is simple, does not need charging and is significantly cheaper, but in case of the INOtronic PS100 upgrading due to electronic components the capacity sensor would be a more appropriate choice.

Key words*: seed drills, seed drill control devices, capacity sensor, micro-switch*

34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.331
Stručni rad
Expert paper

DISTRIBUCIJA SJEMENA PŠENICE U SJETVI STROJEM "RAU-KOMBISEM"

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SAŽETAK

U članku je prezentirana distribucija sjemena pšenice u izravnoj sjetvi strojem "Rau-Kombisem". Tijekom istraživanja postavljen je sjetveni pokus na dva pokušališta na površinama PZ "Jankovci" u Vukovarsko-srijemskoj županiji. Istraživana je uzdužna i poprečna distribucija sjemena, te distribucija sjemena po dubini. Analiza navedenih distribucija realizirana je nakon nicanja usjeva, a dobiveni podaci su obrađeni i prezentirani standardnim znanstveno-statističkim metodama uz podršku programskog paketa EXCEL 5.0. Rezultati istraživanja ukazuju na nezadovoljavajuću distribuciju sjemena po površini (uzdužna i poprečna) i po dubini, što je podudarno s dosadašnjim istraživanjima kvalitete sjetve standardnom agrotehnikom.

***Ključne riječi**: distribucija sjemena, površina, dubina, izravna sjetva*

UVOD

Temeljni cilj sjetve pšenice i ostalih poljoprivrednih kultura je ostvarenje ujednačenog ulaganja sjemena na optimalnu dubinu i ravnomjeran raspored po vegetacijskom prostoru. Ovaj cilj nije zadovoljavajuće realiziran postojećim rješenjima univerzalnih žitnih sijačica Malinović, N. (1988.) i postojećim varijantama obrade tla Šumanovac, L. i sur. (2000.).

Naime, svi sjetveni aparati ostvaruju volumno, a ne pojedinačno izuzimanje sjemena radi čega nastaje problem neujednačene raspodjele, odnosno neujednačene distribucije sjemena po površini i po dubini. Na suvremenim sijačicama ugrađuju se sjetveni aparati za pojedinačno doziranje sjemena ka sjetvenim ulagačima i centralno za opskrbu više sjetvenih ulagača. Problem koji time nastaje je neujednačena distribucija sjemena po sjetvenim ulagačima. Znatan problem nastaje i kod uzdužne raspodjele sjemena, glede vremenskog redoslijeda sjemenki na izlazu iz provodnika sjemena koji odgovara frekvenciji eksponencijalne distribucije, što je prisutno kod svih sjetvenih aparata sa volumnim doziranjem sjemena Heege, H. J. (1981.). Ova pojava je izraženija kod manjih razmaka zrna u redu. Dosadašnja istraživanja Šumanovac, L. i sur. (2000.) ukazuju na veliku distribuciju sjemena pšenice po dubini u različitim varijantama obrade tla. Istodobno, konvencionalnom obradom tla nije moguće postići zadovoljavajuću strukturu tla, te je i radi toga kvaliteta sjetve neodgovarajuća. Sagledavajući ove nedostatke među inim konstruirani su strojevi za izravnu sjetvu koji bi trebali ublažiti ove nedostatke i značajno poboljšati distribuciju sjemena po površini i po dubini, koja je preduvjet visokog i stabilnog uroda svih poljoprivrednih kultura.

Zahtjevi glede racionalnije obrade tla i sjetve, minimalnog gaženja tla i ino značajno su narasli, a taj napredak je ostvaren između ostalog i konstrukcijom stroja "Rau-Kombisem" koji te radne operacije obavlja istodobno. Radni dijelovi navedenog stroja obavljaju rahljenje, sitnjenje i stabilizaciju tla, te za razliku od radnih dijelova drugih strojeva isti nemaju negativan učinak na fizikalno-mehaničku strukturu tla.

MATERIJAL I METODE

Tijekom proizvodne godine (2003./2004.) postavljen je sjetveni pokus u PZ “Jankovci”na dvije različite lokacije. Istraživanja su obavljena na površinama K.O. Petrovci na proizvodnim površinama "PZ-Metz", sjetvene površine 4,5 ha. Površina na kojoj je obavljeno drugo identično istraživanje iznosi 3,5 ha, a izvedeno je na proizvodnim površinama K.O. Petrovci pod nazivom "PZ-Senek". U sjetvenim pokusima na oba pokušališta korištena je sorta pšenice "Ludwig", sjetvene norme od 180 kg/ha, a predkultura je bila merkantilni kukuruz. Sjetva je obavljena izravno u tlo, bez prethodne obrade strojem "Rau-Kombisem", radnog zahvata od 3,6 m, agregatiranim s traktorom “Fendt 824”, snage 170 kW. Sjetva je obavljena 17. 10. 2003. godine po oblačnom vremenu.

Podešenosti stroja bile su za obje lokacije identične, i to:

- Broj okretaja klinastog rotora rototillera u II stupnju prijenosa iznosio je 297 min^{-1},
- Odbojni lim podešen u maksimalni gornji položaj,
- Sjetveni ulagači nisko su postavljeni kako bi se postigla željena dubina sjetve od 3-5 cm, te međuredni razmak od 130 mm,
- Sjetvena norma (skala "N"), te
- Brzina sjetve od 7 km/h.

Tijekom istraživanja obavljene su sljedeće identične analize na obje lokacije, i to:

a) Uzdužna distribucija sjemena i dubina analizirana je nakon nicanja biljaka u fazi razvoja 2-3 lista, brojanjem biljaka svakog drugog reda u dužini od tri metra u deset ponavljanja. Dubina je utvrđena mjerenjem razmaka od sjemenke do prijelaza u svjetlozelenu boju biljke.

b) Poprečna distribucija sjemena analizirana je mjerenjem razmaka između redova na radnom zahvatu stroja u deset ponavljanja.

Rezultati su obrađeni i prezentirani standardnim znanstveno-statističkim metodama uz podršku programskog paketa EXCEL 5.0.

REZULTATI ISTRAŽIVANJA I RASPRAVA

Analiza uzdužne distribucije sjemena pšenice

Prigodom ocjene kvalitete rada stroja u sjetvi, iznimno je važno utvrditi uzdužnu raspodjelu, odnosno uzdužnu distribuciju sjemena. Uzdužni razmak sjemena u redu ovisi poglavito od konstrukcijskog rješenja sjetvenog aparata, načina transporta sjemena od trenutka izuzimanja sjemena do sjetvenog ulagača, od oblika i dužine provodne cijevi, njihovog rasporeda i kuta nagiba istih, te od geometrije, odnosno konstrukcije sjetvenog ulagača. Vremenski redoslijed sjemena na izlazu iz provodnika sjemena ili ulasku u sjetveni ulagač odgovara frekvenciji eksponencijalne distribucije $y=1,5036\ e^{0,3856x}$, u I. pokušalištu. Uzdužna distribucija sjemena u II. pokušalištu izražena je kvadratnom jednadžbom $y=-1,2619x^2 + 9,8333x + 0,4286$. Temeljem rezultata istraživanja, razvidno je da postoji signifikantna razlika relativnih frekvencija sjemena po grupnim razmacima i sukladno tome nezadovoljavajuća uzdužna distribucija sjemena u oba pokušališta. Razlog tomu su neodgovarajuća obrada tla radi povećane količine biljnih ostataka, odnosno kukuruzovine, zakorovljenosti posebice u I. pokušalištu, povećane vlažnosti tla i konstrukcijskog rješenja korištene sijačice s volumnim izuzimanjem sjemena. Naime, volumno izuzimanje (doziranje) sjemena i relativno dugi provodnici razlog su među inim čimbenicima ovakvoj uzdužnoj distribuciji sjemena. Izražena je pojava hrpica, odnosno većeg broja zrna u grupnom razmaku iznad 70 mm, posebice u postavljenom pokusu u I. pokušalištu. Do sličnih ili identičnih distribucija došli su tijekom svojih istraživanja Malinović, N. (1988.) i Šumanovac, L. i sur. (2000.). Rezultati analize uzdužne distribucije sjemena pšenice u I. i II. pokušalištu prezentirani su tablično (Tab.1.). Temeljem dobivenih rezultata istraživanja, razvidno je da postoji signifikantna razlika relativnih frekvencija sjemena po grupnim razmacima i sukladno tome nezadovoljavajuća uzdužna distribucija u oba pokušališta. Razlog tomu je slabije nicanje radi nešto veće vlažnosti tla, te neodgovarajuće (loše) obrade, dok je u drugoj varijanti obrade tla slabije izražen razmak od 70 mm zbog bolje predsjetvene pripreme tla. Razlog tako malom broju posijanog sjemena unutar granica od 0 – 20 mm s tek 20 % je u tome što brzina sjetve iznosi 7 km/h, a norma sjetve 180 kg/ha. Do sličnih ili identičnih distribucija došli su tijekom svojih istraživanja Malinović, N. (1988.) i Šumanovac, L. i sur. (2000.).

Tablica 1 Relativna frekvencija po grupnim razmacima uzdužne raspodjele sjemena
Table 1 Relative frequency according to group distances of the lengthwise seed distribution

I. Pokušalište 1st experimental site												
Ponavljanja Repetition	1	2	3	4	5	6	7	8	9	10	Prosjek Average	%
Grupni razmaci Group distances, mm	Broj biljaka unutar grupe Number of plants withing a group											
0 – 10	0	1	3	0	0	2	0	0	4	2	1,2	2
10,1 – 20	3	7	0	1	4	3	2	3	0	1	2,4	4
20,1 – 30	5	4	3	2	1	0	2	7	2	4	3,0	5
30,1 – 40	2	7	5	7	6	3	5	2	3	2	4,2	7
40,1 – 50	1	0	4	11	33	5	0	5	10	9	4,8	8
50,1 – 60	9	11	12	4	8	13	6	7	3	11	8,4	14
60,1 – 70	20	11	25	19	25	13	18	10	14	7	16,2	27
> 70	22	17	17	16	14	28	23	11	20	30	19,8	33
II. Pokušalište 2nd experimental site												
Ponavljanja Repetition	1	2	3	4	5	6	7	8	9	10	Prosjek	%
Grupni razmaci Group distances, mm	Broj biljaka unutar grupe Number of plants withing a group										Average	
0 – 10	11	21	14	17	7	9	16	12	15	13	13,5	9
10,1 – 20	17	13	8	11	21	13	19	20	35	8	16,5	11
20,1 – 30	28	33	40	28	19	33	19	21	31	48	30,0	20
30,1 – 40	40	55	31	45	47	59	33	28	60	52	45,0	30
40,1 – 50	19	27	18	14	23	13	26	25	33	27	22,5	15
50,1 – 60	9	7	13	17	4	7	11	17	14	6	10,5	7
60,1 – 70	7	11	10	4	8	7	12	9	8	14	9,0	6
> 70	3	5	0	7	4	1	0	2	7	1	3,0	2

Analiza poprečne raspodjele sjemena pšenice

Rezultati istraživanja ukazuju na nezadovoljavajuću poprečnu distribuciju sjemena ostvarenu tijekom sjetve. Naime, međuredni razmak između sjetvenih ulagača konstrukcijski je zadan i iznosi 130 mm.

U I. pokušalištu na tom razmaku 120-140 mm posijano je samo 19 % sjemena, dok je u II. pokušalištu na razmaku 120-140 mm posijano čak 64 % sjemena. Razlog tomu je što su u I. pokušalištu znatnije bili izraženi biljni ostaci i korov, što je otežavalo izvođenje sjetve, a time i navedene distribucije, dok je u II. pokušalištu prisutnost korova i biljnih ostataka bila značajno manja. Poprečna distribucija sjemena u I. pokušalištu izražena je kvadratnom jednadžbom $y=1,7738x^2 - 7,0833x + 7,1429$, dok je u II. pokušalištu izražena istovjetno kvadratnom jednadžbom $y=-2,7024x^2 + 23,226x - 24,571$.

Tablica 2 Relativna frekvencija po grupnim razmacima poprečne raspodjele sjemena
Table 2 Relative frequency according to group distributions of the crosswise seed distribution

I. Pokušalište 1st experimental site												
Ponavljanja Repetition	1	2	3	4	5	6	7	8	9	10	Prosjek	
Grupni razmaci Group distances, mm	Broj izmjerenih razmaka Number of measured distances										Average	%
0 – 100	0	0	0	0	0	0	0	0	0	0	0	0
100,1 – 110	2	9	11	10	13	9	7	12	4	3	8	2
110,1 – 120	14	16	21	20	25	11	10	14	20	19	17	4
120,1 – 130	28	34	36	31	27	29	23	31	28	33	30	7
130,1 – 140	54	48	47	53	56	50	51	56	51	54	52	12
140,1 – 150	124	132	125	127	131	137	136	121	127	130	129	30
> 150	197	190	191	199	198	200	192	197	191	185	194	45
II. Pokušalište 2nd experimental site												
Ponavljanja Repetition	1	2	3	4	5	6	7	8	9	10	Prosjek	
Grupni razmaci Group distances, mm	Broj izmjerenih razmaka Number of measured distances										Average	%
0 – 100	13	16	7	5	12	10	7	15	4	11	10	2
100,1 – 110	17	21	25	18	22	23	15	16	21	22	20	4
110,1 – 120	57	49	51	57	50	61	64	49	59	53	55	11
120,1 – 130	187	189	180	171	188	182	198	179	190	186	185	37
130,1 – 140	137	132	130	137	133	140	142	141	127	131	135	27
140,1 – 150	74	61	69	75	71	72	66	68	70	74	70	14
> 150	27	19	21	31	26	21	28	26	24	27	25	5

Analiza raspodjele sjemena pšenice po dubini

Na distribuciju sjemena po dubini utječe niz čimbenika, od kojih su najznačajniji sljedeći: predsjetvena priprema tla, konstrukcijsko rješenje nosača i samog sjetvenog ulagača, i izbor sjetvenog agregata, te njegova podešenost u danim proizvodnim uvjetima. Optimalna dubina sjetve pšenice iznosi 40 mm, sa dozvoljenim odstupanjem ± 10 mm. Dosadašnja istraživanja Šumanovac, L. i sur. (2000.) na daju podatke kojim intenzitetom navedeni čimbenici utječu na ravnomjernost distribucije sjemena pšenice po dubini. Postojeća tehnička rješenja strojeva bilo za konvencionalnu ili izravnu sjetvu i u optimalnim uvjetima ne mogu rezultirati ujednačenom distribucijom Malinović, N. (1988.), što znači da nema optimalnih konstrukcijskih rješenja, već distribucija ovisi prvenstveno o predsjetvenoj pripremi tla, količini biljnih ostataka u tlu, zakorovljenosti, vlažnosti tla i ostalo. Ukoliko su isti nepovoljni niti jedan stroj neće dati zadovoljavajući rezultat. Temeljem prikupljenih podataka, koji su prezentirani tablično (Tab. 3.) može se zaključiti da nema velikih razlika u istraživanim distribucijama. U I. pokušalištu 67 % sjemena je posijano na optimalnu dubinu, dok je u II. pokušalištu čak 73 % sjemena posijanu unutar te dubine. Razlog ovoj iznimno dobroj distribuciji nastao je kao posljedica same konstrukcije ispitivanog stroja.

Tablica 3 Relativna frekvencija sjemena u grupnim razmacima po dubini
Table 3 Relative seed frequency in group distributions across the depth

I. Pokušalište 1st experimental site												
Ponavljanja Repetition	1	2	3	4	5	6	7	8	9	10	Prosjek	
Grupni razmaci Group distances, mm	Broj mjerenja po dubini Number of measurments over the depth										Average	%
10,1 – 20	29	38	47	28	33	50	44	37	40	44	39	13
20,1 – 30	49	47	39	41	43	58	51	49	31	42	45	15
30,1 – 40	70	61	64	68	74	53	69	69	68	65	66	22
40,1 – 50	130	128	139	143	128	125	137	140	141	139	135	45
> 50	10	12	17	9	7	21	19	25	16	14	15	5
II. Pokušalište 2nd experimental site												
Ponavljanja Repetition	1	2	3	4	5	6	7	8	9	10	Prosjek	
Grupni razmaci Group distances, mm	Broj mjerenja po dubini Number of measurments over the depth										Average	%
10,1 – 20	41	50	49	38	37	40	47	49	46	43	44	11
20,1 – 30	50	61	55	59	49	63	62	51	57	53	56	14
30,1 – 40	107	99	105	101	98	87	111	98	91	103	100	25
40,1 – 50	185	201	197	179	190	195	196	200	187	190	192	48
> 50	5	12	7	8	4	15	7	6	12	4	8	2

Na prednjem dijelu istog nalazi se rototiller (sitnilica), čiji se se odbojni lim može podešavati, a time i usmjeravati masa tla prema sjetvenim ulagačima, odnosno dubina sjetve. Odbojni lim rototillera bio je podešen u maksimalni gornji položaj što je imalo za posljedicu nabacivanje dovoljne količine tla da prekrije sjeme, odnosno bio je podešen za sjetvu ispod struje rotora. Nakon sjetve nije bilo neposijanog sjemena na površini. Distribucija sjemena po dubini u I. pokušalištu je asimetrična, kvadratnog oblika $y=-4,8571x^2 + 30,543x - 18,2$. U II. pokušalištu distribucija je također asimetrična i kvadratnog oblika $y=-6,1429x^2 + 38,457x - 27,8$.

ZAKLJUČAK

Temeljem rezultata dobivenih ovim istraživanjem može se zaključiti kako ostvarena raspodjela sjemena pšenice u izravnoj sjetvi strojem “Rau-Kombisem” po površini nije zadovoljavajuća, dok su rezultati raspodjele po dubini u granicama zadovoljavajućih. Iznimno je važno da u oba pokušališta nema većeg broja zrna u grupnom razmaku 0-10 mm s udjelom od 2 % i 9 %, te 10,1-20 mm s udjelom od 4 % i 11 %. Rezultati poprečne analize ukazuju da u I. pokušalištu nije ostvaren zadani međuredni razmak radi velike količine biljnih ostataka i prisutnog korova. U II. pokušalištu djelomično je ostvaren zadani međuredni razmak 120– 140 mm s udjelom od 64 % posijanog sjemena unutar razmaka. Rezultati analize raspodjele sjemena po dubini, na obje lokacije ukazuju da je zadana dubina 3-5 cm ostvarena s udjelom iznad 65 %. Rezultati analize rasporeda sjemena po dubini su djelomično zadovoljavajući, budući da je odbojni lim rototillera bio maksimalno podignut, te je struja tla bila usmjerena na sjeme.

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THE DISTRIBUTION OF WHEAT SEED IN SOWING WITH MACHINE "RAU KOMBISEM"

SUMMARY

The paper presents the wheat seed distribution in the in the direct sowing process performed by the machine "Rau-Kombisem". In the research the sowing experiment was established at two experimental sites beloging to PZ "Jankovci" in Vukovarsko-srijemska county. Both the lengthwise and the crosswise seed distributions were examined as well as the depth distribution. The seed germination was followed by an analysis of the above mentioned distributions and the were processed and presented using the standard scientific and statistical methods supported by EXCEL 5.0 programme package. The results of the research show an unsatisfactory seed distribution over the surface (both lengthwise and crosswise) as well as over the depth, which is in a close relationship with the previous researches of the sowing quality when standard agrotechnics was used.

***Key words**: seed distribution, surface, depth, direct sowing*

34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 632.954:632.982
Izvorni znanstveni rad
Original scientific paper

RESPONSE TIME OF DIRECT INJECTION SYSTEM FOR SITE-SPECIFIC HERBICIDE APPLICATION

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SUMMARY

A laboratory model of a direct injection system was designed for the metering of appropriate herbicide into a carrier close to the nozzles. Two experiments were performed to investigate the dynamic behaviour of this system. In the first experiment the position of the injection point was the centre of a boom section and in the second experiment the chemical ingredient was injected close the nozzle. For these experiments a laboratory model of an injection sprayer system was employed. The concentration of metered chemical ingredient was measured down-stream of the injection point using a conductivity sensor based on the sensing of the electrical conductivity of a salt solution. This sensor was developed for the evaluation of the response times of the sprayer.

The direct nozzle injection assembly had a minimal response time of less than 2.8 s from injection point to nozzle tip. Injection in a boom section resulted in response times with a maximum of 7.5 s. This implies a maximum position error of 6.8 to 16.7 m at 8 km h^{-1} forward speed of a sprayer with a camera system for weed detection.

Key words: *direct injection sprayer, weed detection, online herbicide application, response time.*

INTRODUCTION

In order to use the full advantages of site-specific weed control herbicide application based on information about the distribution of weed species, it is necessary to use an application technology which is able to change the application rate and the type of herbicide rapidly. One option is to employ sprayers with an integrated direct injection system. In injection sprayers, herbicides and carrier are kept separate. According to the indications of the weed treatment map (offline application) or of the weed analysis camera system (online or real time application) (Gerhards et al., 2001), the herbicides are metered into the carrier and mixed immediately before entering the nozzles. One crucial factor in current direct injection systems is the response time, i.e., the time it takes for the mixed solution to flow from the injection point to the spray nozzles. For online application, the distance between the point of injection and the nozzle has to be minimized. Nozzle injection promises very short response times of less than 3 seconds. However, it has the disadvantage of inappropriate mixing of the carrier with the chemical in the nozzle. This problem is not significant in boom injection systems due to the long time for mixing. Frost (1990) described a method for response time minimization in boom injection systems by reducing boom diameter. An advantage of this system is that it does not require additional plumbing to deliver the chemical to each nozzle.

In the proposed direct injection system, the proportional valve was used for the metering of appropriate herbicide into the carrier close to the nozzles. Two points of injection were investigated for response time characteristics. One of the points of injection was placed in the middle of the boom and the second one before the individual nozzle.

For measuring the response time, a method for the dynamic measuring of mixture concentration in the nozzle was developed. A conductivity sensor was used for the dynamic measurement of the mixture concentration of injected salt solution as described by Paice (1997). This method was used in a laboratory model of an injection sprayer system for the immediate determination of response time parameters.

DIRECT INJECTION SPRAYER DESIGN

The direct injection sprayer system combined with a weed detection camera system was designed to fulfill the requirements of real time herbicide application. The main limiting factor of online application is the total response time of the sprayer system T_S consisting of the individual periods of time elapsing during each step of the online application process.

$$T_S = T_d + T_R$$

The first part in the sum is the time required for the detection and recognition of the weeds T_d. Because of the high processing requirements, the time of detection for a system with CCD cameras is about 1 second (Gerhards et al. 2001). The second part is the response time T_R, which depends on the location of injection, the number, length and diameter of the nozzle supply lines and on the mixture flow rate.

In the proposed system (Fig. 1), a CCD camera with a spatial resolution of 3 m is mounted to each boom section. The distance between the camera and the boom is about 1 m. The camera system provides information about the amount and type of herbicide of weed to the spray computer, which controls the flow rate in the system (Gerhards et al., 2001).

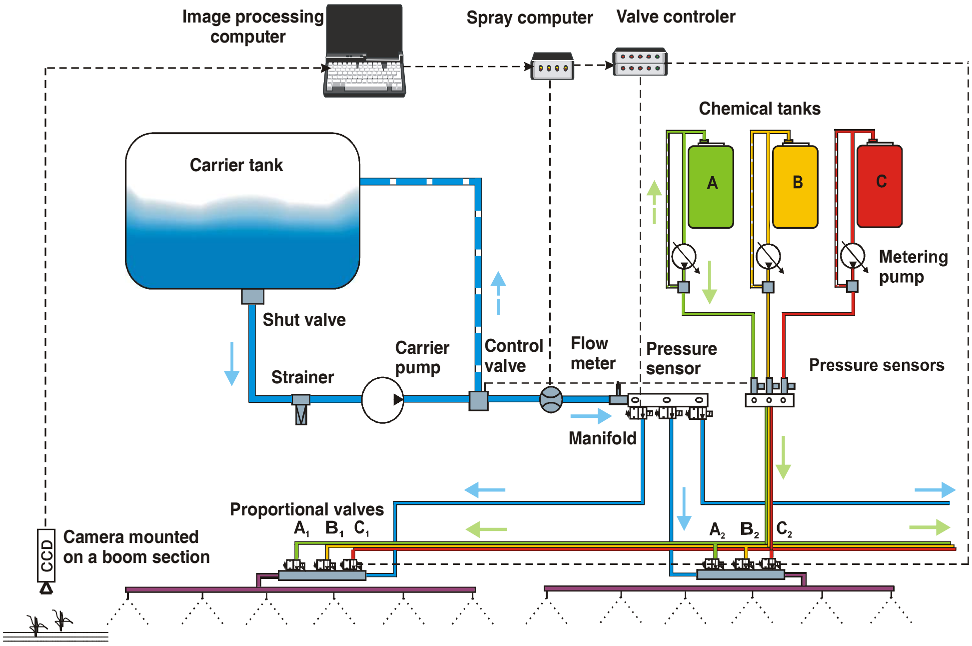

Fig. 1 Scheme of the proposed direct injection system

MATERIALS AND METHODS

Experimental Arrangement

An experimental arrangement was assembled to evaluate the accuracy and time response of the direct injection system (Fig. 2). The hydraulic system delivers the active ingredient to the point of injection, which was placed at the boom (T-configuration, Fig. 2 I.) and at the nozzle (straight configuration, Fig. 2 II.).

The system includes an active ingredient (tracer) tank. A gear injection pump and a proportional valve (pulse width modulated) were used for the metering of an appropriate amount of tracer into the carrier. The same type of valve was used for both configurations mentioned above. The tracer flow was measured with a capillary flow sensor. The relative pressure in the tracer tubes was measured by a pressure transmitter.

A sprayer diaphragm pump supplied the carrier flow through the manifold to one boom section. The carrier pressure was measured using a pressure transmitter, while a magnetic-induction flow meter measured the carrier flow. In the boom injection configuration, a T-connector was used to connect the carrier line with the tracer line. The boom section was 3 m long with 6 nozzles spaced 50 cm apart. In the nozzle injection configuration, the T-connector was located immediately before the conductivity sensor at the nozzle nearest to the connecting line. The distance between the centre of the T- connector and both electrodes was 40 mm.

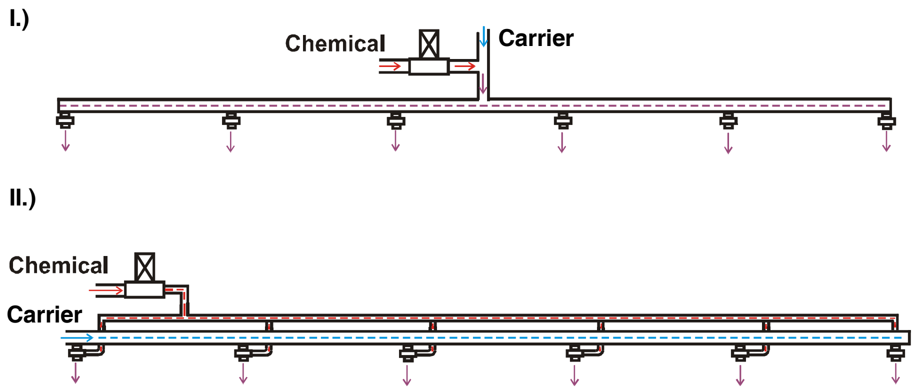

Fig. 2 Boom configurations, section of 3 m width

Dynamic Measurement of Spray Mixture Concentration

For the determination of response time, a method for the dynamic measurement of spray mixture concentration was developed (Hlobeň et al., 2003). This method is based on sensing the electrical conductivity of a sodium chloride (NaCl) solution which flowing between electrodes in a measuring cell. The sensor causes the voltage to break down according to the conductivity of the spray mixture. NaCl diluted in water at a basic concentration of 20 g l^{-1} replaced the active ingredient for this method.

The conductivity inline measuring cell was installed at one nozzle location immediately before the nozzle in the spray boom of a laboratory model of a direct injection sprayer system. The system pressure was set by degrees to 1, 3, and 5 bar. The carrier flow through the measuring cell was maintained at a constant level using XR 80015, 8003, 8005 flat fan nozzles. The tracer flow ranged from 0.0 to 520 ml min^{-1} depending on the differential pressure and the proportional valve control signal.

The mean of tracer flow rate, the carrier flow rate and the concentration of the basic solution were used to calculate the mixture concentration. Mean and standard deviations (SD) of the output voltages from 6 replications were determined for each system pressure and mixture concentration.

Measurement of Response Time

The objective of these experiments was to measure the dynamic response parameters which can be used to evaluate the applicability of the tested systems for variable-rate herbicide application. Response times were measured for both configurations, nozzle and boom injection, and for the whole range of applied nozzles and system pressures. Two transient characteristics for the mixture concentration were measured to evaluate the response time of the injection system.

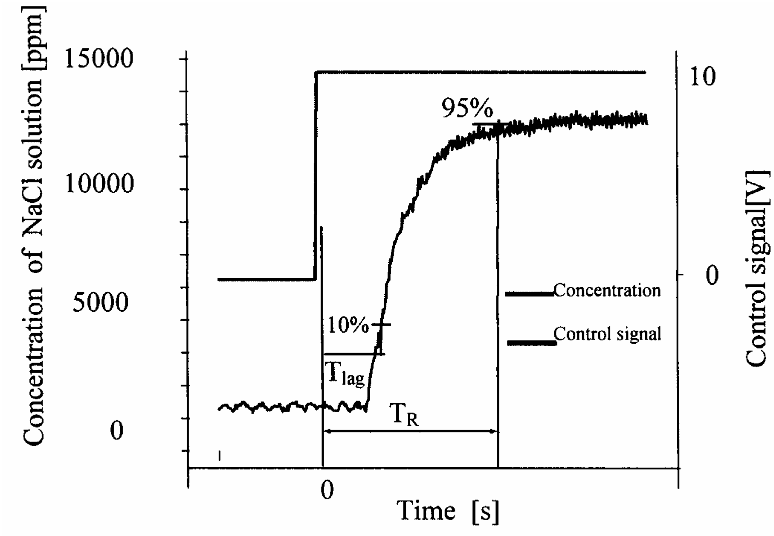

Fig. 3 Diagram of the course of tracer concentration with indicated time parameters, response time T_R and lag time T_{lag}

The response time was defined as the time required until the output response to a step input reaches a concentration of 95% (Fig. 3). The value of a concentration of 95% was chosen as efficacy threshold (a concentration of chemical for satisfactory weed control) (Bennett et al., 1997). The lag time is the time passing from the start of ingredient injection until a concentration of 10 % is exceeded (Fig. 3).

RESULTS AND DISCUSSION

Dynamic Response Results

Nozzle Injection Results

The nominal nozzle flow rates between 0.34 and 3.2 l min^{-1} are equivalent to the application rates required in a real-time application approach using cameras for the recognition of weeds. A proportional valve was operated to inject a constant volume of the tracer. Different constant carrier flow rates were maintained during each measurement. In a second experiment the carrier flow rate was kept constant, while the tracer flow rate was varied from 10 to 100 ml min^{-1}. In a third part of the experiment the influence of viscosities on the response time was studied. The range of viscosities was chosen from among the current active ingredients, varying from 1 to 200 mPa.

Measurements of response parameters were well repeatable with the largest SD being 0.6 for the 6 replications of data collected.

Fig. 4 compares average lag and response times for a constant nozzle flow rate. The active tracer flow rates rise from 10 to 100 ml min^{-1}. The graph indicates that increasing the tracer flow rate greatly reduced the lag time (time elapsing until the concentration of the plant protection agent in the carrier reaches 10 %). The greatest lag time of 0.25 s was obtained at a flow rate of 10 ml min^{-1}, while the shortest lag time measured was 0.1 s at a tracer flow rate of 100 ml min^{-1}. Response time varied between 2.05 and 2.8 s in this configuration.

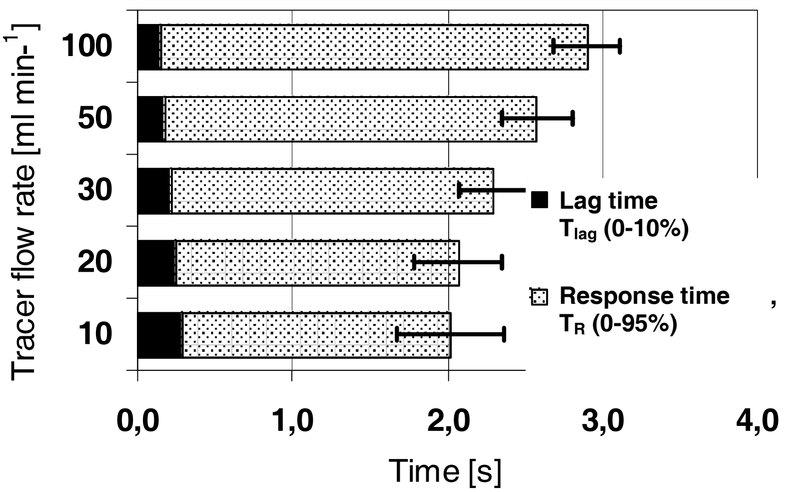

Fig. 4 Comparison of lag (T_{lag}) and response time (T_R) at constant nozzle flow rate of 1.14 l min^{-1} for different tracer flow rates (location of injection: nozzle)

The lag time of 0.1 s to 0.25 s, which can also be interpreted as the time required for the material transfer from the proportional regulating valve to the nozzle or to the conductivity sensor, makes up only a minor share of the response time, and it is mainly dependent on the tracer flow rate. These low lag time values can be attributed to the short distance of 40 mm between the centre of the T-connector, where the tracer is injected into the water flow, and the two electrodes of the conductivity sensor. The greater share of response time is accounted for by the process of mixing the water with the active ingredient, the duration of which is increased considerably by a raised flow rate and, consequently, by a changed material transfer.

Moreover, the reaction of the hydraulic system to changes in the carrier flow rate at a constant tracer injection rate were investigated.

Fig. 5 depicts the lag time and response time at constant tracer flow rate. If the carrier flow rate is raised from 0.34 to 3.2 l min$^{-1,}$ the response time changes from 2.3 s to 0.6 s. Within the changed variation range of the flow rates, this time span is an indication that the carrier has a greater influence on response time than do changes in the tracer rate. In this case, too, the changes in lag time are small, between 0.2 s and 0.4 s.

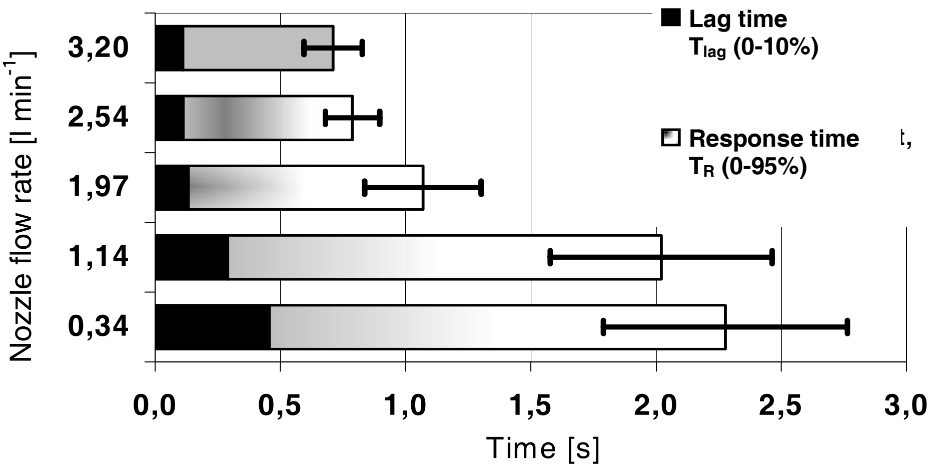

Fig. 5 Comparison of lag (T_{lag}) and response time (T_R) for different carrier nozzle flow rates at constant active ingredient flow rate (10.0 ml min^{-1}, location of injection: nozzle)

Boom Section Injection

Fig. 6 outlines the proportion of lag time, or of the time required for the transfer of the tracer to the conductivity sensor, to response time. The tracer was injected at the centre of the boom section at different nozzle flow rates. Depending on the nozzle flow rates, response times varied between 3.8 s and 6.9 s. The lag times were 2.7 s and 4.8 s, thus accounting for a greater share in response time than the mixing process itself. This result differs considerably from the values that were determined for direct injection at a nozzle; it is attributable to the long distance of approximately 1.5 m between the point of injection and the conductivity sensor at the outer nozzle. Due to the long transfer distance and the larger boom diameter, in this constellation the lower flow rate is noticeable in an increase in lag time.

Fig. 7 depicts the average response times TR for direct boom-section injection for different boom diameters. The measurements were made at the outer nozzle of the boom. The boom tubes had interior diameters of 6, 8 and 12.7 mm. Depending on the valve characteristics, the tracer flow rates ranged from 270 to 515 ml min^{-1}. At 1.77 s, the shortest response time was measured at a boom diameter of 6 mm and a nozzle flow rate of 2.5 l min^{-1}.

The maximum response time of 7.5 s was measured at a boom diameter of 12.7 mm and a nozzle flow rate of 1.1 l min^{-1}. Thus, as expected, boom diameter has a major influence on response time. Still, the response time for direct boom injection makes it necessary to disconnect the camera of the weed detection system from the spray booms. With these response times, distances between 3.9 m and 16.7 m would be covered at a forward speed of 8 km/h. With such distances covered during the adjustment of the required application rate, site-specific weed control is only possible with recourse to the mapping concept.

However, the additional work step required for this, makes weed control more expensive in comparison with the online method.

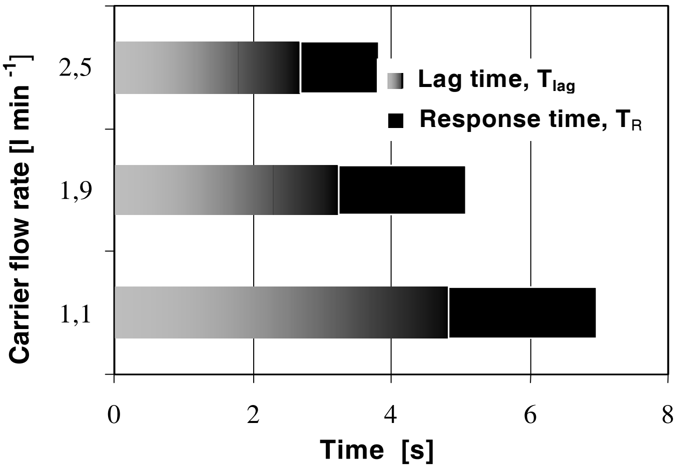

Fig. 6 Lag time (T_{lag}) and response time (T_R) for different carrier flow rates with constant tracer flow rate of 10 ml min^{-1} (location of injection: boom section)

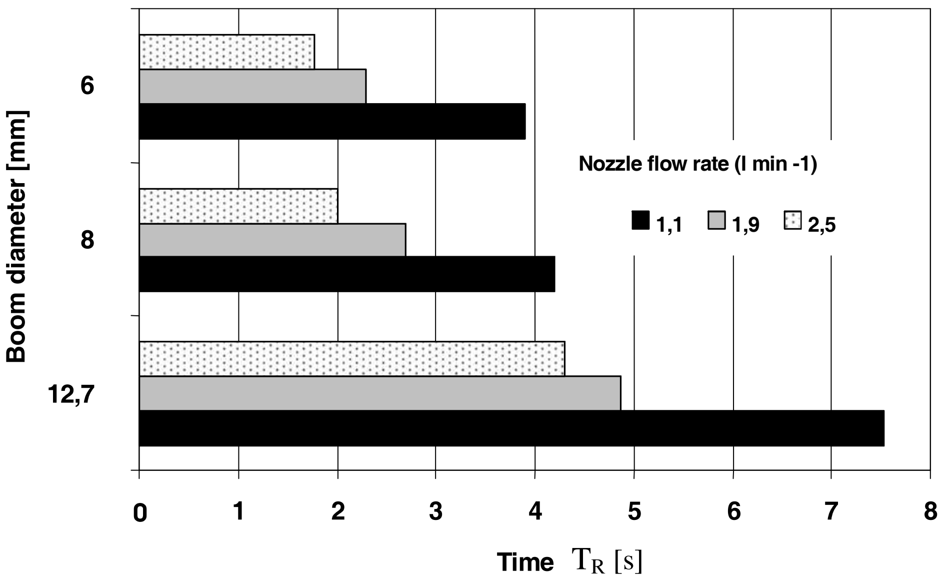

Fig. 7 Comparison of response time (T_R) for different boom diameters and 3 carrier flow rates (location of injection: boom section)

CONCLUSIONS

The proposed laboratory model of a direct injection system was proved suitable for the measurements of response and lag time characteristics. The results of the dynamic measurements of mixture concentration showed good levels of accuracy for the conductivity sensor and proved the practicability of this method. There are significant functional relations between mixture concentration and output signal. The inline measuring cell can be installed in any place throughout the length of the spray boom. Thus, it can be used to determine lag and response time.

The results obtained from the series of tests indicate that it is feasible to design a sprayer with a direct nozzle injection system in which the flow of the chemicals is controlled by means of a proportional valve. With injection close to the nozzle response time is less than 2.8 s. If the boom section is used as an injection point, the boom diameter greatly influences the response time. The shortest response time for this case is 1.7 s at the highest nozzle flow rate of 2.5 l min^{-1}. However, compared to nozzle injection there is no improvement possible. Even if the boom diameter is reduced, an acceptable response time will not be obtained. For nozzle injection, improvements by optimising the mixing process are still possible, and hence it is possible to reduce the response time.

With evolving computer technology, it will be possible to reduce the time necessary for image processing, thus gaining greater time reserves for a successful variable application.

ACKNOWLEDGEMENTS

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 632.51:632.982.7
Izvorni znanstveni rad
Original scientific paper

EFFECT OF HOT FOAM APPLICATION ON LAWN

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SUMMARY

Hot foam application is a thermal weed control method, which is based on the effect of hot water and which is already used on municipal areas. In order to examine the effect of hot foam application, a field trial on lawn –perennial ryegrass (lolium perenne) – was conducted in 2005. In the first weeks after application all hot foam volume rates (between 1.0 and 4.5 l/m²) reached a great reduction in lawn coverage. The variation of the distance between foam nozzle and soil as well as the variation of the foaming agent concentration seemed to have a very low effect. After four weeks lawn coverage was about 5% at an application rate of 4.5 l/m² and about 35% at an application rate of 2.1 l/m².

Key words: *hot foam, thermal weed control*

INTRODUCTION

In today’s agriculture weed control is normally done with herbicides. Reasons are their high efficiency, easy application and low costs for machinery as well as for active substances. But the use of herbicides is restricted more and more and consumers are increasingly demanding organic food, so physical methods of weed control gain in importance. This examination focuses is on weed control methods for orchards and vineyards.

At first there are mechanical devices such as root pruners or rotary cultivators. Depending on the weather, there are about five applications per year necessary [1]. Problems can occur in case of high and dense weed or in humid weather. Mechanical tools may hurt tree trunks or roots. The area around trunks is out of reach, so about twice a year additional weeding by hand is necessary.

Thermal machines on the base of flaming or infrared radiation, which are mainly used on municipal areas or in vegetable gardening, are not very common in orchards and vineyards. In a field trial in an apple orchard, an infrared machine needed up to ten applications per year [1]. Dry weed material may be ignited and lead to formation of smoke or burns at trees. Open flames may damage barks and crowns. In dry summers or in southern countries this technique does not seem to be applicable. To ensure an efficient application a heat retention device is necessary [2]. But this complicates application around the trunk area und makes machines bulky.

In order to avoid the disadvantages of flaming, hot water technique is used, which provides lower energy consumption [3]. These machines also need a heat retention device. Furthermore a water tank has to be carried along.

In hot foam machines the isolating effect of foam replaces heat retention devices and provides an application over a distance up to 50 cm. Using this technique the area around tree trunks can be reached. At present hot foam is mainly used on municipal areas [4, 5]. Depending on surface and coverage with weed, between three and four applications of hot foam at a volume rate between one and two litres per square metre are necessary per year. The only manufacturer of hot foam weed control machines is Waipuna™ (New Zealand).

METHODS

For the field trials the Hohenheim hot foam experimental system was used (Figure 1). From a 1000 litre tank trailer water is pumped at a volume rate of about 34 l/min through two fuel oil driven boilers having a heat capacity of 280 kW both together. To heat up 100 l water from 15 °C to 110 °C about 1.5 l fuel oil are required. At the boiler outlet 0.4% foaming agent is added to the water being under a pressure of about 0.5 MPa. The foaming agent is an environmentally friendly, readily biodegradable tenside named Alkylpolyglucoside (APG). Then hot foam is produced from the mixture in two special foam nozzles and applied on the weed at temperatures up to 98 °C. The working width is 40 cm.

Figure 1 Hohenheim hot foam experimental machine mounted on a Deutz Agrocompact 75 during test application on lawn. Behind, the machine is linked with a 1000 litre water trailer.

At the experimental machine several measuring data are recorded: The operating speed, temperatures of cold and hot water as well as the air temperature with thermocouples type T, the temperature of the hot foam in the foam nozzles with resistance thermometers PT-100 and the flow rate of the cold water. The data is collected and stored in an Agilent 34970 data acquisition/switch unit at a frequency of one or two Hertz. After a trial the data is forwarded to a PC for analysis.

With field trials on lawn the influence of hot foam application rate (water application rate of hot foam), of the foaming agent concentration and of the distance between foam nozzles and soil is to be examined. Therefore on 12th April 2005 four lawn varieties of perennial ryegrass (lolium perenne) were drilled on a field with an area of one hectare. The varieties were Verdi, Rival, Caddy and Vienna (each 25%). The field is plane and has a loamy soil with a soil unit of 66. Before and after drilling (30 g/m²) the field was rolled with a Cambridge roller. The long-time annual rainfall is 700 l/m², the mean annual temperature 8.8 °C. On 15th June and on 8th August 2005 the field was fertilised with 100 l Ammonium nitrate/urea solution, which is 36 kg pure nitrogen per hectare. The solutions were diluted with 400 l water. The lawn was mown regularly; big weed plants were eliminated by hand. Therefore at the beginning of the field trial the lawn was uniform. Tab. 1 shows an overview of the test settings. All settings were tested twice at randomised areas (stripes with a length of 25 m). Magic Wet Hot Foam, an APG was used as foaming agent.

Tab. 1 Scheme of the treatments of the field trial.

Distance Nozzle - Soil	**Concentration Foaming Agent**	**Operating speed / Hot Foam Quantity**	**Operating speed / Hot Foam Quantity**
cm	**%**	**km/h / l/m²**	**km/h / l/m²**
10	0,34	1,2 / 4,5	1,7 / 3,1
		2,6 / 2,1	3,7 / 1,5
		4,6 / 1,2	5,6 / 1,0
15	0,34	2,6 / 2,1	3,7 / 1,5
20	0,34	2,6 / 2,1	3,7 / 1,5
25	0,34	1,2 / 4,5	1,7 / 3,1
		2,6 / 2,1	3,7 / 1,5
		4,6 / 1,2	5,6 / 1,0
20	0,17	2,6 / 2,1	3,7 / 1,5
	0,34	2,6 / 2,1	3,7 / 1,5
	0,52	2,6 / 2,1	3,7 / 1,5
	0,70	2,6 / 2,1	3,7 / 1,5

The trial was conducted on 1st September 2005 at sunny warm weather (27 °C); the length of the lawn was about 5 cm. It was mown one day before and then carried away.

In order to evaluate the effect of hot foam application on lawn, a rating frame (100 x 25 cm) was used, Figure 2. At every setting five areas for the frame were randomised, marked with sticks and rated with the frame. At the marked areas ratings were conducted at intervals of one week from person A and B beginning one week after application. Rated was the coverage of the frame area with green plants in percent.

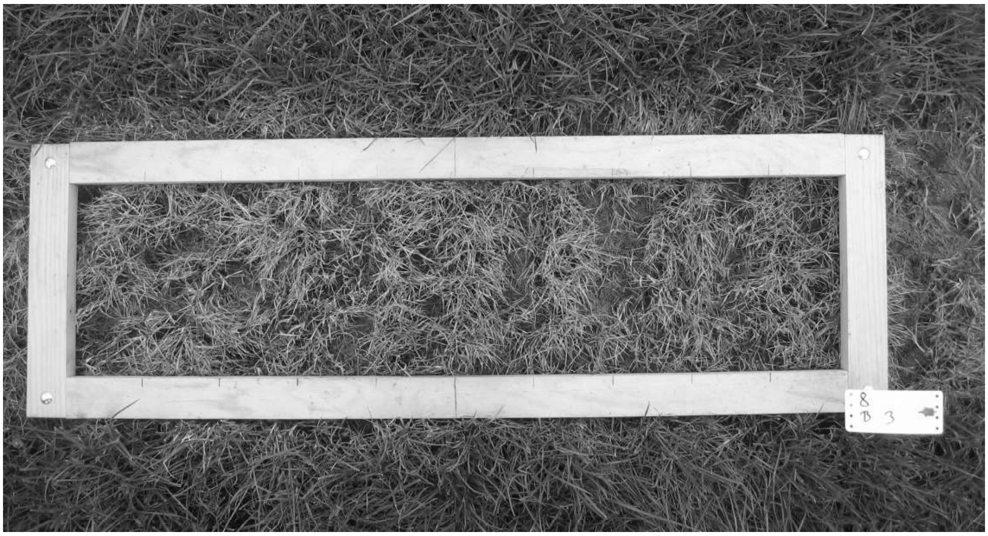

Figure 2 Rating frame 100 x 25 cm.

RESULTS

Immediately after hot foam application, the lawn starts to fade and after a few hours it starts to get brown. In the first ratings after application differences within one setting were small. But a high coverage is more difficult to rate than a small coverage, so differences within one setting became major the following weeks, Figure 3. Not all the vegetative points of the lawn plants were controlled by hot foam, so some lawn plants were able to recover from the application slowly but differently. This is another reason, that differences became major. There were also differences between person A and B and they also became major from week to week, but they were negligible.

Every setting was tested at least twice, some were tested four times, Figure 4. Here the differences between the single areas also became major from week to week.

The influence of the distance between foam nozzle and soil, which was meant to be of importance, was not very big as it is shown in Figure 5 and Figure 6. These differences also became major from week to week and a smaller distance seems to have a better effect.

In Figure 7 and Figure 8 areas were compared, which were treated with different foaming agent concentrations. After a few weeks higher concentrations show slightly better results in both cases.

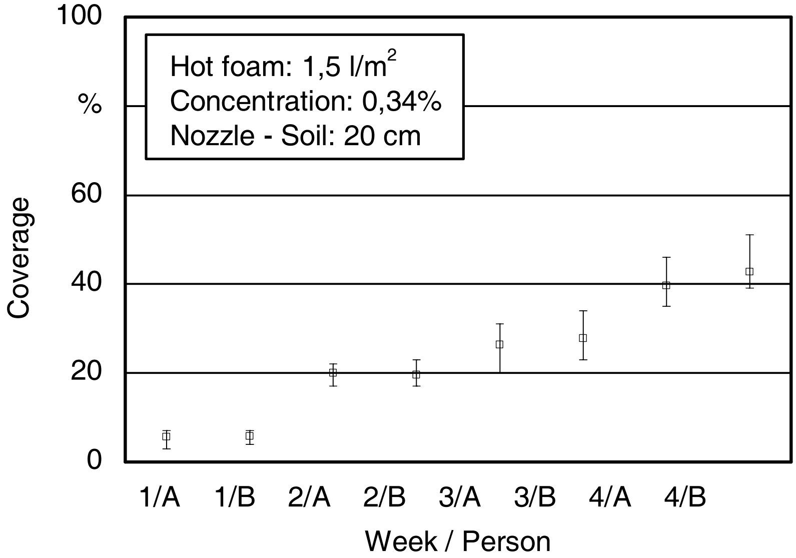

Figure 3 Ratings of person A and B at intervals of one week.

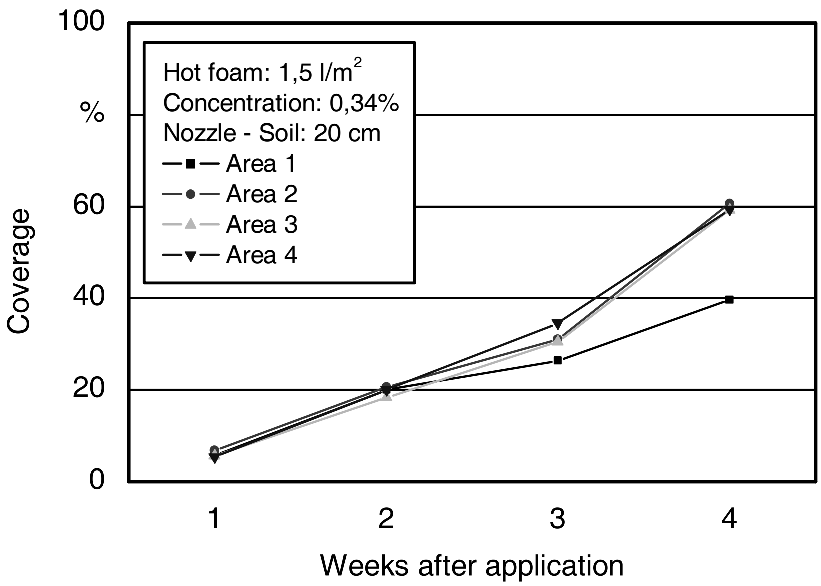

Figure 4 Ratings at four areas, which were treated with the same setting.

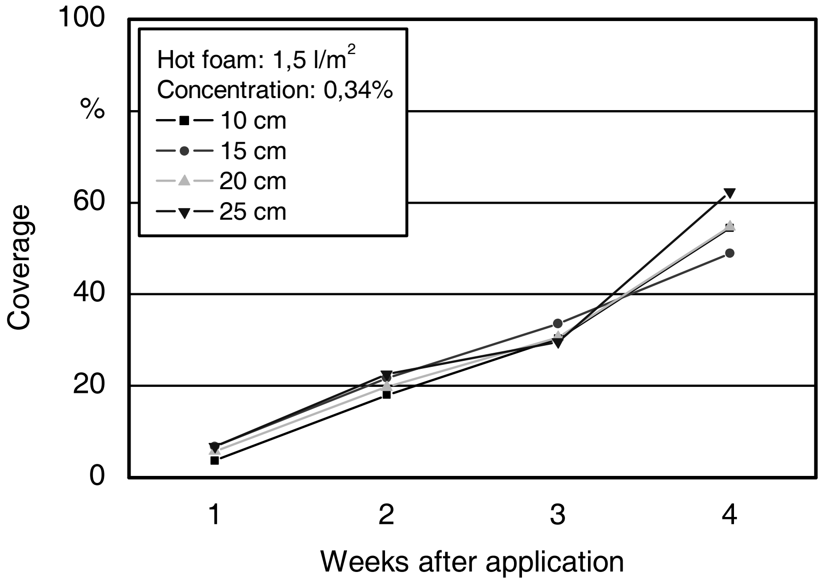

Figure 5 Influence of several foam nozzle distances on the lawn coverage

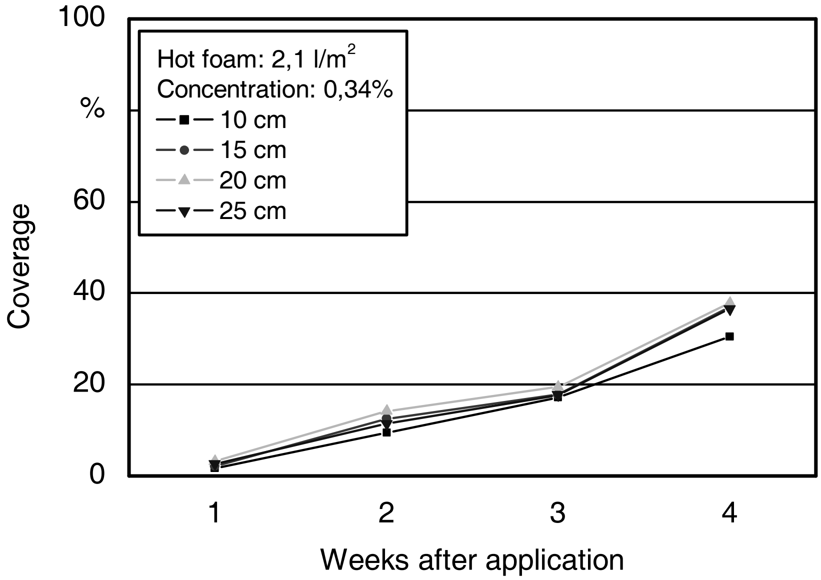

Figure 6 Influence of several foam nozzle distances on the lawn coverage

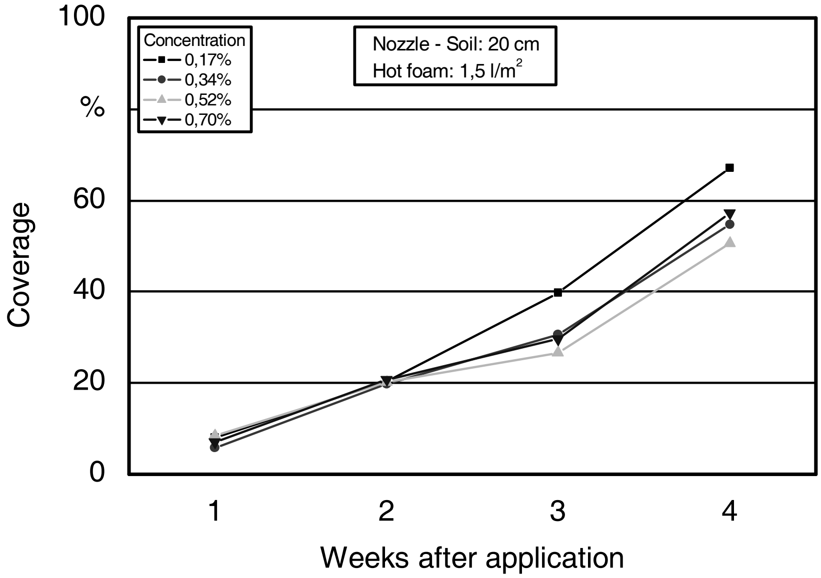

Figure 7 Influence of several foaming agent concentrations on the lawn coverage

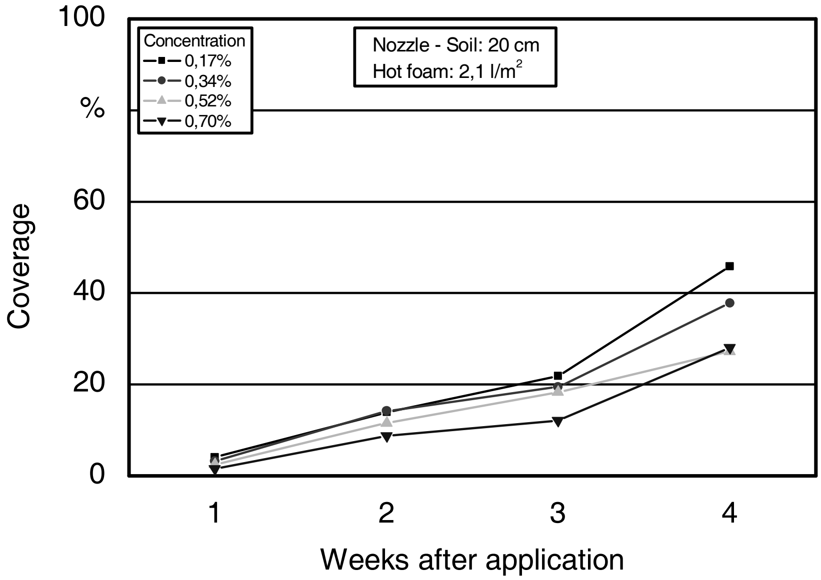

Figure 8 Influence of several foaming agent concentrations on the lawn coverage

The highest effect on coverage was reached by variation of the hot foam application rate, as shown in Figure 9. Even with a hot foam volume of 4.5 l/m² the perennial ryegrass was not completely controlled. In the first weeks after application all hot foam volumes were effective and reached a considerable reduction in coverage. After four weeks, coverage was about 30% or lower only at hot foam application rates of 2.1 l/m² or more.

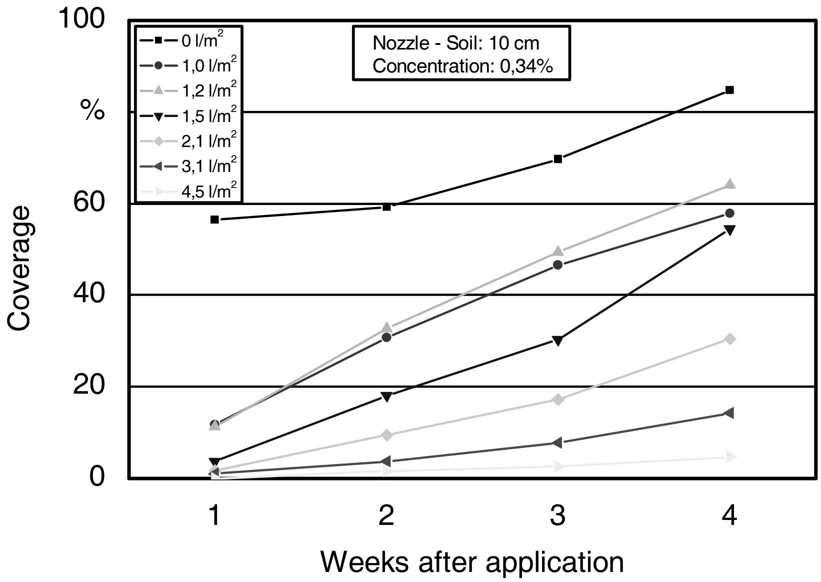

Figure 9 Influence of several hot foam volumes on the lawn coverage

CONCLUSIONS

This field test was conducted in order to find out, how the effect of hot foam application is influenced by several parameters. To be able to compare different treatments, a uniform lawn area was chosen. Only with different application rates of hot foam, it was possible to reach significant differences in effect. Even with an application rate of 4.5 l/m² the lawn growth was not completely controlled, because it was not possible to reach the lower vegetative points of all plants. Probable reasons are that some were too deep and others were covered by other plants. A further increase of application rate might be not economical, more likely the repetition of treatment with moderate volume rates.

The results show that a considerable inactivation of lawn over a period of several weeks is possible with hot foam at water application rates up to 2.1 l/m² In this way a temporary reduction of competition for water and nutrients in permanent grass mulch growing systems like vineyards or orchards is possible, as well as a slow down of plant mass increase in special municipal areas like roadsides or fences.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.7:631.17
Tehnička bilješka
Technical note

RESEARCH AND DEVELOPMENT ON FIELD COMPUTER BASED ON PC104 SYSTEM

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SUMMARY

A field computer based on embedded PC104 motherboard is developed. PCM-3350, a kind of industrial PC/104 motherboard is chosen as the core of the hardware. The TFT LCD is integrated as output device, the touch panel as input device and the hard disk as storage device and an intelligent adapter between CAN Bus network and PC/104 system as bridge to communicate with CAN node. The Field Computer supports RS-232 and USB serial ports, and it also supports Compact Flash Card as mobile storage medium. A GPS-OEM board is embedded, which makes the Field Computer has more options on GPS. For software system, MapObjects 2.0, a kind of GIS Active X Control from ERSI was chosen to develop the software, which makes it possible to realize the integration of GPS and GIS in agriculture application. The software could complete the functions such as GPS data receiving and processing, field mapping, grid sampling, features logging, parallel swathing, data collecting via the adapter between CAN Bus network and PC/104 system and so on.

Key words: *field computer PC/104 CAN bus smart technology, precision agriculture.*

INTRODUCTION

Field computer is a kind of embedded mobile computer system fixed on farm machinery. It can be used as a real-time information management tool for precision agriculture, such as field data acquisition, variable rate control and so on. It can work well in harsh terms with functions of data input, data output and storage. Field computer can combine with GPS receiver, navigation instrument, sensing equipment, variable control system and GIS used in farming. So it can achieve automation and intelligentize of farm information management.

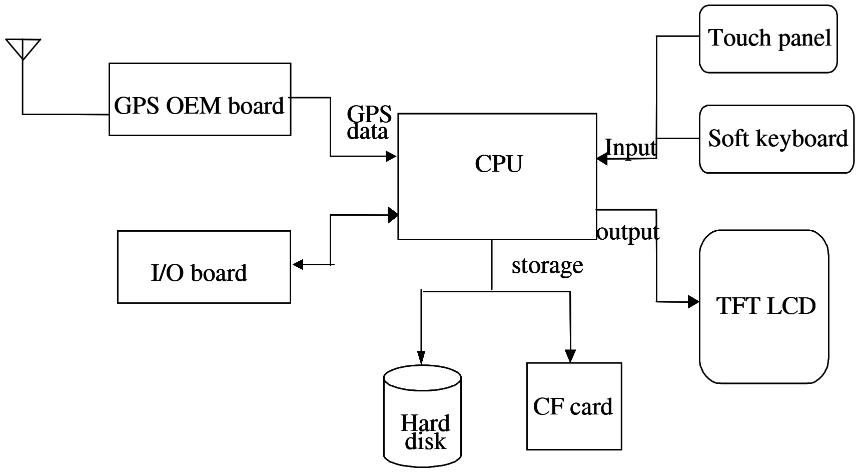

Fig. 1 Technical line of the field computer

DEVELOPMENT

Development of Hardware

As a computer, the function parts of the field computer had master control board, input equipment, output equipment and storage equipment. In a word, it consisted of a CPU, a GPS OEM board, an I/O board, a touch panel, a soft keyboard, a TFT LCD, a hard disk, and a driver of Compact Flash Card. PCM-3350, a kind of industrial PC/104 motherboard, was chosen as the core of the field computer. A TFT LCD integrated with a tough panel was selected as the input/output interface, and a hard disk was taken as the storage device (Fig 2). Table 1 shows the main groupware of the system.

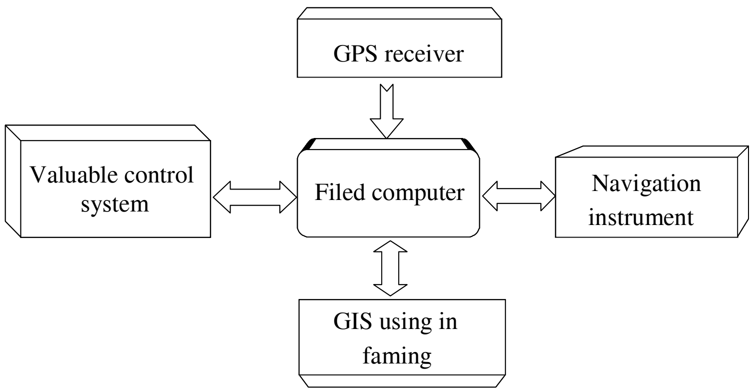

Fig. 2 The structure of the field computer

Table 1 List of the main groupware of the system

Groupware	Type	Product description
CPU module	PCM 3350	Embedded PC/104 CPU module
Output equipment	V16C6448AC	6.4" Liquid crystal display differentiate 640*R, G, B*480
GPS	GPS 25LP	GPS-OEM board product by Gamin
Input equipment	Magic Touch	6.8"Resistance touch screen
Storage equipment	IBM	20G memory space
Power module	DC-DC module	12 V to 5 V DC-DC power module

The development of the adapter between PC104 system and CANBUS

The main function of the adapter was to build a bridge between CAN Bus and PC104 system. Thus the adapter was needed to incept data from CAN and then transferred to PC104 system, and transferred data from PC104system to CAN. In order to meet the demand of the real-time control with a very high level of security in farm data collection, the adapter must have high receiving and transmitting data speed. In order to make the data receiving and data transmitting accurate, the hindrance between PC104 and CAN should be avoided. In the hardware development, a microprocessor was used as the control unit of the adapter, which made the adapter intelligent. Fig.3 shows the operational principle of the intelligent adapter. The adapter included: A CAN bus interface used to connect CAN, a CAN BUS transceiver 82C250 used to transmit and receive data from CAN, a CAN controller used to process data and then transmit it to CAN BUS transceiver, or to transmit and receive data from CAN BUS transceiver, a PC/104 bus-slot used to connect with main board, a MCS-51 microprocessor (MCU) used to maintain CAN serial, a Parallel interface circuit (8255A) used to transmit data in parallel mode, and a opt coupler used to enhance the anti-jamming of the system.

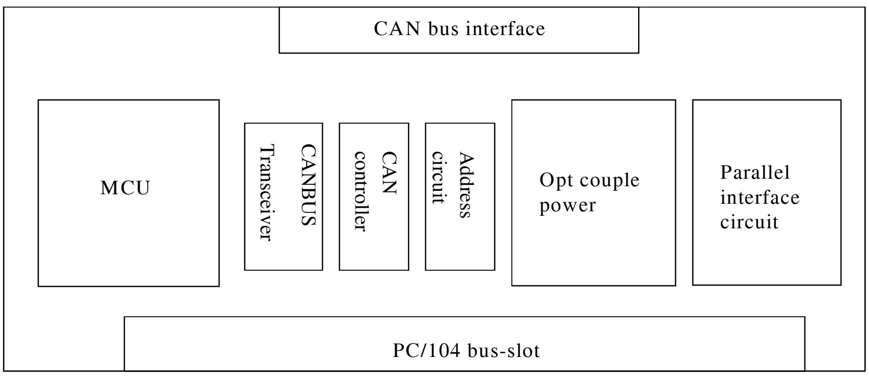

Fig. 3 System diagram of the adapter between PC104 and CAN

Design of Software

The adapter mainly took charge of data translating between PC104 and CAN node. The designed software included two parts. One was the adapter driver VxD and the initialization of CAN interface. The other was MCU control program.

1) Adapter driver VxD

The driver mainly included interface function to take charge of the communication between the field computer and 8255A. The programming of the driver was based on Visual Basic 6.0. The adapter must compile VxD (virtual device driver) to call the low-level hardware of the computer. We used DLL to encapsulate VxD so that users could use VxD more conveniently. The DLL provided several functions such as port setting, port closing, port writing, and port reading.

2) Initialization of CAN interface and MCU control program

The MCU control program was used to take charge of the communication between 8255A and CAN controller. It was finished by ASM51 assemble language. The main tasks of the software were: translating the commands of the computer to the CAN controller, and then transmitting them to CAN Bus; and transmitting all kinds of state from CAN to 8255A.One of the key points of the software was the initialization of the CAN controller SJA1000.

In a word, the adapter has follow characteristics:

a) Strong compatibility

The adapter did not impropriate main board MAB. It only needed four free port-settings so that it would not appear the problem of the resource disturbance.

b) High data transmission speed

Since the adapter used parallel communication mode the data transmission speed was very high.

c) Intelligentization

The MCU of the adapter made it intelligent to transmit and receive CAN-data packets. It not only could minimize the adapter's size and power consumption, but also could reduce the tasks of the PC104, which was only needed to take charge of transmitting and receiving CAN-data packet without conducting maintenance works.

Software system of field computer

MapObject2.0, a kind of GIS Active X Control from ERSI, was chosen to develop the software, which makes it realize the integration of GPS and GIS in agriculture application. The software was developed under the environment of Visual C++6.0,which has friendly interface and abundant functions. The software was divided into six functional modules: GPS data receiving and processing module, field-mapping module, grid-sampling module, features logging module, parallel swathing module, and CANBUS data collection module. The introduction of the software focused on parallel swathing module. The GPS data receiving and processing module and field-mapping module were the base of the parallel swathing module.

GPS data receiving and processing module

The GPS data receiving and processing module mainly took charge of processing GPS data. The computer obtained GPS positional information through serial port, and then parsed the standard format of the GPS positional data. And then displaying information in forms of status map, the Signal-to-Noise ratio of satellite, and the satellite distribution map and so on. The module also had the function of changing longitude coordinate and latitude coordinate to plane coordinate; the function of real time coordinate conversion and single dot coordinate conversion. It could also make the dispersed dots collected from GPS receiver be showed as punctation vector data, filamentary vector data or planner vector data.

Field mapping module

Before we began field operation, we defined the bounds of the field firstly. It is the base of many other functions such as parallel swathing, and is performed by driving along the border of the field a cycle.

Parallel swathing module

The design of the parallel swathing module was based on the GPS data receiving and processing module and field mapping module. In field operation, the light bar navigation system was often used to monitor field operation, to improve the efficiency and accuracy of the field operation. The software imitated the design idea of the light bar navigation system, and then realized the function of parallel swathing to agriculture machinery. The parallel swathing module would make a parallel swathing map according to the bounds of the field, defined operation breadths and straight line of reference. And then the software displayed the simulation interface of the parallel swathing module. Just as showed in Figure 4, the before line/after line button were used to choose the target line. The indicator lights in the middle of the interface were used to indicate deflection. When the blue indicator light on, it shows that the agriculture machinery is working on the target line. The green indicator lights in sides were used to indicate the machine departures from the target line. The number of the lighting green lights showed the distance of the machine departures. The blank at the bottom of the interface showed the distance between the GPS dot and the target line. So parallel swathing navigation could be made according to the indicator lights. Figure 5 shows the operational procedure of the parallel swathing module.

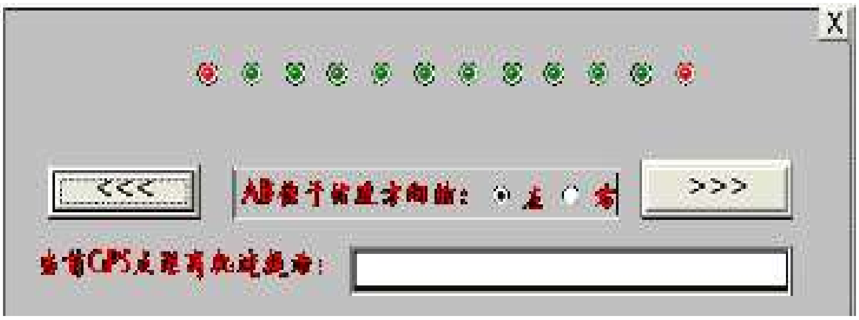

Fig. 4 The interface of the parallel swathing module

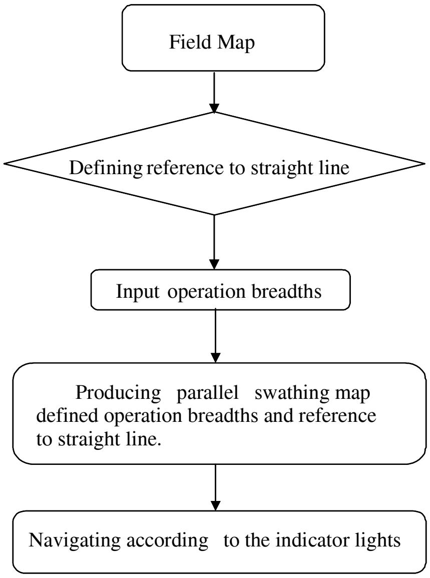

Fig. 5 Operational procedure of the parallel swathing module

CONCLUSIONS

A field computer based on embedded PC104 motherboard is developed. The innovation points of the system are:

(1) Using mature technology of industrial control domain to tap the field computer to make the system have credible capability.

(2) In order to use the field computer as an independent application unit or an independent CAN node for precision agriculture, an intelligent adapter between CAN Bus and PC104 system was also developed.

MapObjects2.0, a kind of GIS Active X Control from ERSI, was chosen to develop the software, which makes it possible to integrate GPS and GIS in agriculture application. The innovation points of the software is:

(1) Using Map Objects to tap software, so the software has user - friendly graphical interface, less bottom coding and lower difficulty of exploitation.

(2) We used DLL to encapsulate VxD so that users could use VxD more conveniently. The DLL provided several functions such as port setting, port closing, port writing, and port reading.

(3) The software has the function of the parallel navigation.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.
Tehnička bilješka
Technical note

THE MEASURE OF HUMIDITY AND TEMPERATURE USING SMART SENSORS

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SUMMARY

Relative humidity is an important parameter for many agricultural environments. In the last years, due to the integration of electronics components and computing, the manufacturing technology of sensors and actuators had evolved very much leading to the appearance of so called 'smart transducers'. This paper presents some aspects about the usage of two smart sensors: humidity and temperature sensor SHT11 and temperature sensor DS1820.

***Key words**: Humidity, temperature, smart sensor, microcontroller, programming*

INTRODUCTION

Relative humidity is very important in diverse areas of measurement and control technology. Also, this parameter is very important for many agricultural environments, such as fruit and vegetable storage facilities, greenhouses, and tobacco curing and handling facilities. Manufacturers are not only improving the accuracy and long-term drift of their sensors, they are improving their durability for use in different environments, and simultaneously reducing the component size and the price.

Conventional sensors determine relative air humidity using capacitive measurement technology. For this principle, the sensor element is built out of a film capacitor on different substrates (glass, ceramic, etc.). The dielectric is a polymer which absorbs or releases water proportional to the relative environmental humidity, and thus changes the capacitance of the capacitor, which is measured by an onboard electronic circuit. The relative humidity and temperature are interrelated, and relative humidity is the dependent variable. Therefore, it is meaningless to specify a certain relative humidity without also specifying a corresponding temperature.

In the last years, due to the integration of electronics components and computing, technology of producing the sensors and actuators had evolved very much leading to the appearance of so called ‘smart transducers’.

The aim of this paper is to present some intelligent sensors for measuring the humidity and the temperature.

SMART TRANSDUCERS AND EMBEDDED SYSTEMS

A sensor is a component which perceives a physical property (for example: temperature, humidity, pressure, magnetism or motion) and transmits the result into a measurement that can be interpreted by the computer system. Thus, a sensor maps the value of some environmental attribute to a quantitative measurement [1].

An actuator is a component which is used to move or to control some environmental attribute. Because sensors and actuators are both positioned at the interface of systems they are often subsumed by the term transducer. In 1982, Ko and Fung introduced the term “intelligent transducer” [2]. An intelligent or smart transducer is the integration of an analog or digital sensor or actuator element, a processing unit, and a communication interface. In case of a sensor, the smart transducer transforms the raw sensor signal to a standardized digital representation, checks and calibrates the signal, and transmits this digital signal to its users via a standardized communication protocol [3]. In case of an actuator, the smart transducer accepts standardized commands and transforms these into control signals. In many cases, the smart transducer is able to locally verify the control action and provide a feedback at the transducer interface. Smart transducer technology supports the development of transducer networks that allow monitoring, plug-and-play configuration, and the communication of digitized transducer data over the same bus line. Such a smart transducer network provides a framework that helps to reduce the complexity and cost of large distributed real-time systems [2].

An embedded system is a computer system that is designed to perform a dedicated or narrow range of functions as part of a larger system, usually with minimal end-user or operator intervention [5]. In many cases, an embedded system is based on a microcontroller with the programs stored in the flashable ROM (read only memory). Embedded programmable microcontrollers are used for consumer-electronics devices, kitchen appliances, automobiles, networking equipment, and control systems [5]. Generally, embedded microcontrollers provide very little resources. Especially low-cost microcontrollers featuring small amounts of program and working memory have been programmed in low level language (Assembler) but there exist relationship of using high level languages like Basic, C or Pascal since it is easier to be used even for not professional.

With the advent of cheap and small embedded microcontrollers, it became possible to build a distributed system out of a set of sensors, actuators, and control nodes, each equipped with a microcontroller unit and a network interface.

EXAMPLES OF SMART SENSORS: SHT11, DS1820

Here are some problems one encounters when applying humidity sensors:

- Analog to digital interface and external circuitry: Many sensors convert the humidity signal to a voltage or to a basic parameter such as capacitance or resistance. Additional circuitry is needed in order to read that signal with a microcontroller such as the BASIC Stamp. At the very least, there is an analog to digital or analog to time converter. This may take a couple of op-amps or an oscillator circuit, perhaps with provision for calibration of slope and offset.
- Temperature compensation and dew point calculation: It is very useful to have an accurate temperature sensor in the same package as the humidity sensor, in order to calculate the dew point accurately, and also to temperature compensate the humidity signal if necessary. A separate interface and analog to digital channel may be required for the temperature sensor.
- Calibration: The humidity transduction circuit requires initial calibration. Calibration constants for each individual sensor may come on a paper certificate, and those constants have to be dialed in, or entered into the microcontroller program, or provision has to be made for the end user to enter them. Provision has to be made for changing the sensor element at intervals of time (depending mostly on the challenge from the environment), or provision has to be made for recalibration or calibration checks using saturated salt solutions or other means.
- Mounting, protection and response time: This is where the humidity sensor meets the real world. The sensor element itself has to be exposed to the hydro- and thermo-environment, but the electronics and the sensor element itself have to be well protected from condensation, dust and fumes that could degrade the calibration and eventually destroy the sensor. Some available humidity sensors are designed strictly for indoor use in mild environments. Other sensors incorporate several levels of protection that go a long way to protecting them at the core from the hostile environment but it is possible to obtain quite slow response.

The SHT11 is a digital device that, when queried, returns two bytes of measurement data and one byte of CRC checksum [6]. Using a microcontroller, the data must be converted into the actual value for temperature or humidity by using simple formulas given in the SHT11 data sheet. It requires no calibration and is reasonably accurate (for temperature, better than ±0.4 °C between –40 and 100 °C, and ±3% for relative humidity). This smart sensor comes from the factory in a tiny package that incorporates the analog to digital interface. Calibration values are stored internally in EEPROM and figure into the chip digital output. The microcontroller must read out the humidity and temperature values through the two-wire digital serial interface. The only math required is a simple scale and offset.

The DS18B20 is a digital thermometer featuring ±0.5°C accuracy over a -10°C to +85°C range [7]. Data is read out over a 1-Wire serial bus in 2's complement format with 9- to 12-bit user-configurable resolution. Resolutions greater than 9 bits can be calculated using the data from the temperature, COUNT REMAIN and COUNT PER °C registers in the scratchpad memory. The DS18B20 offers thermostatic functionality with over-temperature

(TH) and under-temperature (TL) user-programmable set points stored in on-chip EEPROM. An internal flag is set when the measured temperature is greater than TH or less than TL. If thermostatic operation is not required, the two bytes of EEPROM reserved for TH and TL may be used for general-purpose nonvolatile storage. Each DS18B20 features a unique and unchangeable 64-bit silicon serial number, which serves as the bus address for the sensor. This allows multiple DS18B20 devices to coexist on the same 1-Wire bus. The DS18B20 is powered via a 3.0V to 5.5V power supply.

USAGE OF INTELLIGENT SENSORS

The explosive development of the informatics technology has lead to increasing of the number of applications in all the fields. An important aspect is the fact that these technologies have become very friendly. As it follows, more specialists from other fields have become not only users but also developers of new applications. Let's take an example: the microcontroller. Today are available on the market a lot systems for development that are very easy to be used. Hardware and software development lead to a more evident usage of the high level programming languages like (Basic, C, Pascal), the assembly language, (low level language, not so used by non-specialists) being only strictly necessary only in the critical sections from the view point of time (but there exist a lot of applications in which such problems of calculus time may not appear). On the other hand the hard and soft producers offer more applications that facilitate the usage of microcontrollers. Also many examples of usage can be used by obtaining through usage of the Internet.

In figure 1 it is presented a scheme that permits the interfacing of intelligent sensors SHT11 (humidity and temperature) and DS1820 (temperature), scheme realized based on the microcontroller ATmega 8 of Atmel family [8].

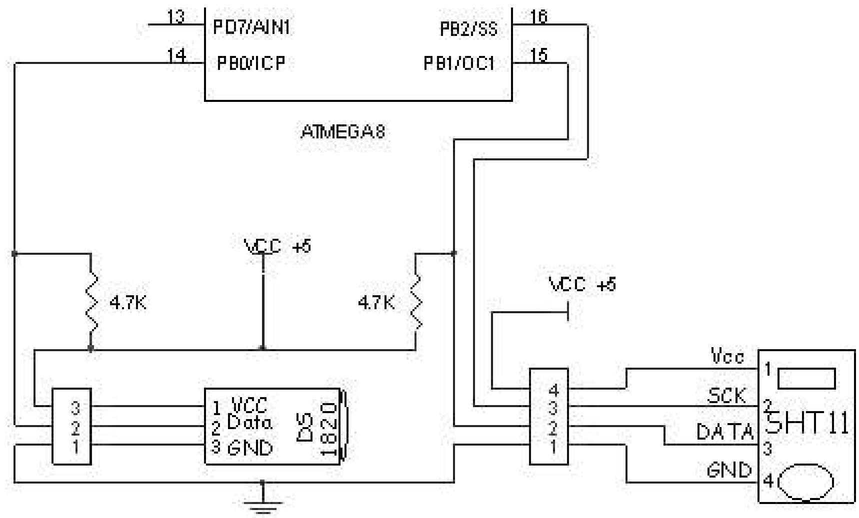

Fig. 1 Electric scheme of the application

The Atmel ATmega8 microcontroller is a low-power CMOS 8-bit microcontroller based on the AVR RISC architecture. The ATmega8 provides the following features: 8K bytes of In-System Programmable Flash with Read-While-Write capabilities, 512 bytes of EEPROM, 1K byte of SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible Timer/Counters with compare modes, internal and external interrupts, a serial programmable USART, a byte oriented Two-wire Serial Interface, a 6-channel ADC (eight channels in TQFP and MLF packages) where four (six) channels have 10-bit accuracy and two channels have 8-bit accuracy, a programmable Watchdog Timer with Internal Oscillator, an SPI serial port, and five software selectable power saving modes.

For visualizing and memorizing the data obtained through the intelligent sensors there is a possibility to use a PC. For this is needed to connect the microcontroller to PC by a serial or parallel interface as well as the realization of a PC application will permit data processing. A possibility is using Delphi environment, an environment based on the Pascal language environment. In what it follows we'll present the *Delphi* application that will permit the reading of the two sensors. It was started from the idea to realise as much as simple the software application. Thus, it was chosen to use virtual instruments [9] using the package *Vcwd7.dpk*. Also it was chosen the component package *AsyncFreeD7.dpk* [10] that permits realization of the serial interface communication.

It is used the components *AFComPort* and *AFPortRadioGroup* (for serial interface) and components *VrAngularMeter*, *VrDigitGroup*, *VrLabel*, *VrMatrix*, *VrClock* and *VrGradient* as virtual instruments.

The procedures of the program are:

```
var
  Form1: TForm1;
   TSht, Dp, Rh:single;  //Temperature, Dew Point, Humidity Sht11
   TDs:single;              // Temperasture Ds1820
   conectare:boolean;    // verify connecting RS232
   contor:integer;          //counter for verify RS232

procedure TForm1.FormCreate(Sender: TObject);
begin   //init serial port RS232
conectare:=false; contor:=0; port.open;
end;

pocedure TForm1.PortDataRecived(Sender: TObject; Count: Integer);
var s,ss:string; p:integer;
begin
s:=port.ReadString;   //serial message
p:=pos(chr(13),s);     //end of message
ss:=copy(s,2,p-2);     //read sensor value
contor:=4;                //init counter
if length(s) >1 then case s[1] of
            'a': TDs:=StrToFloat(ss);  // temperature DS1820
            'b': TSht:=strtofloat(ss);    // temperature SHT11
```

```
            'c':  Dp:=StrToFloat(ss);    //Dew Point
            'd':   Rh:=StrToFloat(ss);  //Humidity
  end;
end;

procedure TForm1.Timer1Timer(Sender: TObject);
begin   { Verify connecting }
if contor<=0 then  conectare:=false else begin  conectare:=true; dec(contor); end;
if conectare then begin    { Virtual instruments}
VrAngularMeter1.Position := TSht; VrDigitGroup1.Value:=TSht;
VrAngularMeter2.Position := Rh; VrDigitGroup2.Value:= Rh;
VrAngularMeter3.Position := Dp; VrDigitGroup3.Value:= Dp;
VrAngularMeter4.Position :=TDs; VrDigitGroup4.Value:= TDs;
end;
end;

procedure TForm1.FormClose(Sender: TObject);
begin
port.Close; //close serial port
close;          // close application
end;
end.
```

In figure 2 it is presented a view of a part of the user interface.

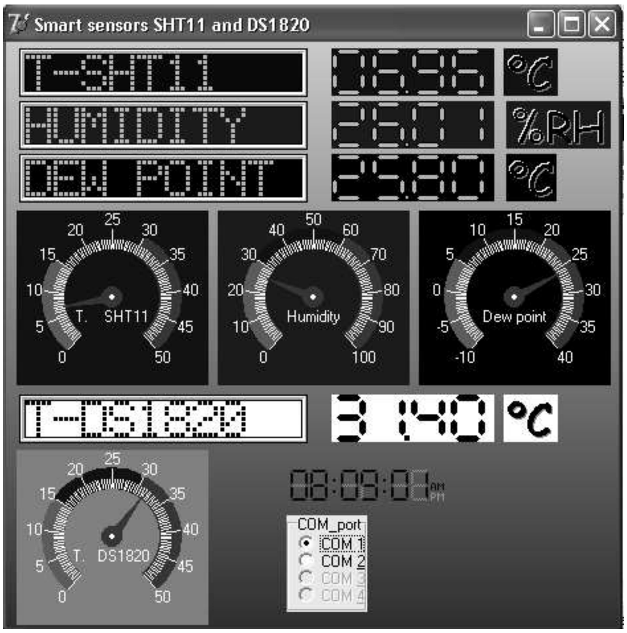

Fig. 2 User interface

The application on microcontroller (Fig. 3) was build using the *Bascom* environment [11] which is based on the usage of the high level programming language *Basic*. The program realise the following operations:

- reading data from the two intelligent sensors;
- computes the values of temperature, humidity and dew point;
- transmits the data processed from PC using a serial interface.

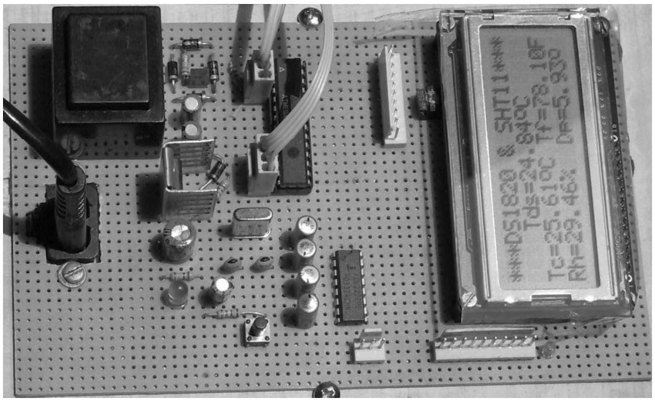

Fig. 3 Hardware implementation

CONCLUSIONS

In this paper were presented some aspects regarding to the usage of the intelligent sensors for measuring the humidity and temperature. These parameters are very important for many agricultural environments, such as fruit and vegetable storage facilities, greenhouses, and tobacco curing and handling facilities. There is a trend in simplification of the approach in which the intelligent sensors, microcontrollers as well as the associated software components can be used, this leading to the new opportunities in different fields of activities, including in agriculture.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.437:631.471
Prethodno priopćenje
Preliminary communication

A SOIL SENSING AND MAPPING SYSTEM ON SOIL ELECTRICAL CONDUCTIVITY

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SUMMARY

In order to satisfy the demand of fast measuring soil properties in the farm, and support decision-making in precision management of crop, an on-the-go measuring system of soil electrical conductivity is developed. The measuring system adopts the four-electrode method and consists of four parts: the sensor unit included six electrodes, the power source, the control and display unit, and the data processing software. Two electrodes of sensor unit are used to inject constant alternating current into soil, and other electrodes are used to detect the voltage drop between electrodes. The voltage drop then is used to estimate the soil EC. The electrodes is designed to be shovel shape, so that the system can not only measure soil EC in various kinds of soils, but also can perform weeding and plowing of farm works in the period of crop growth season. The measuring system employs two arrays to investigate soil at two depths, 0-30cm and 0-80cm. The control and display unit consists of three sections: the power source section which can produce 10μA~5mA constant alternating current for input electrodes and 5V DC for the control and display unit, the adjusting signal section and the data-logger section. The data processing software can realize both the data acquisition and soil mapping. The soil EC map created by this measuring system is useful in precision farming.

Key words: *soil electrical conductivity, four-electrode method, precision agriculture.*

INTRODUCTION

It is sported that soil electrical conductivity (EC) can serve as a proxy for soil physical properties such as organic matter (Jaynes, et al., 1994), clay content (Williams and Hoey, 1987), cation exchange capacity (McBride, et al., 1990), and depth of topsoil (Kitchen and

Sudduth, 1996). These above soil physical properties all have strong correlation with crop productivity. To investigate the spatial variability of soil EC and refer other kinds of data information in a field would help us to know the status of plant growth, and then to perform precision management for the crops. As the introduction of precision farming, which is a modern agricultural management concept based on information technology, it has become more and more important to understand the condition of soil electrical conductivity (EC) in a field.

As we know, there are two methods to measure soil electrical conductivity. One is called “laboratory measure”, and the other is called “Real-time measure”. For “laboratory measure”, it is necessary to collect soil samples first, and then to prepare soil solution in laboratory. The whole process is complex and time-consuming, therefore, it is unfit for the instant and large-scale survey needed in precision agriculture. The real time soil EC sensor is mounted behind field vehicle, and can measure soil parameters directly in a large field. So the method is thought to be a simple, inexpensive approach available to precision farming today. Some real-time soil EC sensors mounted on the tractors have been developed in the recent years. However, most of the instruments based on this approach only work under non-crop condition, so the frequency of using these instruments is very low. Moreover, the price of foreign devices is also too expensive for Chinese farmers.

Hence, we developed a soil sensing and mapping system on soil electrical conductivity, in order to satisfy the demand of fast measuring soil properties in the farm, and support decision-making in precision management of crop. This on-the-go measuring system mounted on the tractor not only can measure soil EC in various kinds of soils, but also can perform weeding and plowing of farm works in the period of crop growth season. Furthermore, this system was easy to be operated by farmers to make field management decision.

DEVELOPMENT

Design of Structure

The measuring system is based on four-electrode method, which was thought to cover a big area with ease and be less susceptible to outside interference (Ehsani and Sullivan, 2002). The measuring system with six electrodes employs two arrays to investigate deep soil and surface soil respectively, and soil EC data can’t only be saved in flash disk, but also be downloaded to field computer for making the soil EC map.

The device consists of three parts: the sensor unit included six electrodes, the control and display unit, and the data processing software. Figure1 shows the scheme of the whole mapping system.

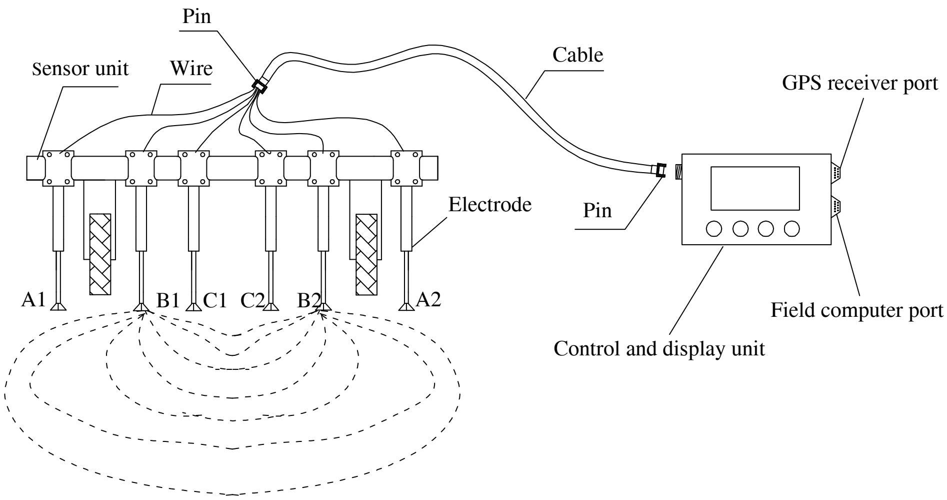

Figure 1 Scheme of the whole mapping system

Design of Sensor Unit

The frame of the sensor unit is made of steel, 185cm long, and 61cm wide. Two rubber-tired wheels are mounted on the two sides of the frame respectively, so that they will help the sensor unit to travel in field and control the penetration depth of the electrodes in soils. The height of electrodes can be adjusted according to practical demand to insure the tip of electrodes under the soil surface. As illustrated in Figure 1, the six electrodes fixed on the frame are divided into three pairs symmetrically. The inner pair of electrodes (B1 and B2) called input electrodes is connected with a constant alternating current source, while other two pairs of electrodes called output electrodes are used to detect voltage drops between the points of A1 and A2 and the points of C1 and C2 respectively. Using the voltage drop between A1 and A2, the electrical conductivity of shallow soil layer can be calculated. And using the voltage drop between C1 and C2, we can measure the bulk EC of deep soil layer.

The frame of the sensor unit adopts three-points hanging structure to connect with a tractor, thus the sensor unit will be controlled to rise or fall by the device of tractor's hydraulic pressure. Using this structure, the sensor unit has well flexibility. Through plenty of tests, we decided the best distances between any two electrodes in sensor unit. Those values of the distance fit the row width of wheat and corn in China. The tip of the electrodes is designed to be shovel shape so that the electrodes have good capability of cutting soil and weeding. Moreover, because the tip of electrodes inserts soil deeply, the tips will contact soil much morn closely. This will improve measuring stability and precision for our device too. As illuminating above, the developed sensing system has a especial advantage that the device could not only measure soil EC for various kinds of soils in no-crop condition, but also can perform weeding and plowing of farm works in the period of crop growth season.

Design of Control and Display Unit

The main functions of the control and display unit are: i) providing a constant alternating current for input electrodes; ii) measuring the voltage drop between output electrodes and executing A/D conversion; iii) changing the voltage drop into soil EC and displaying it; iv) recording the EC data together with positioning data (GPS data) in flash disk; and v) communicating with the field computer by CAN bus protocol if necessary. Figure 2 shows the scheme of the control and display unit. The unit consists of three sections: the power source section, the adjusting signal section, and the data-logger section.

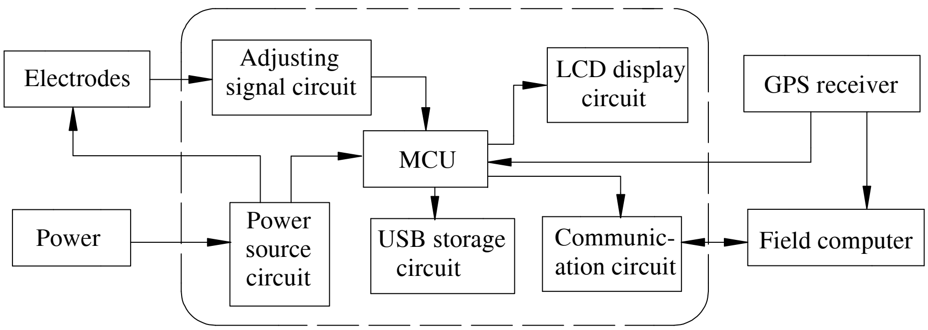

Figure 2 Scheme of the control and display unit

The power source is an important section in soil EC detector. In order to eliminate effect of ionic polarization phenomenon, constant alternating current is produced for input electrodes. The current frequency is about 300 Hz. A special circuit is designed to provide alternating constant current for the electrodes and provide +5V for the circuit board. This special circuit is mainly composed of an ICL8038, a LM324, and a few potentiometers. ICL8038 provides a sine current signal to LM324 (the distortion of the signal is 0.5%~1%). Through chip LM324 adjusting sine current signal, the signal becomes more steady, and doesn't change with soil condition changing (change < 5%). Considering the application in field, the alternating current could be adjusted within 10μA~5mA by turning a potentiometer.

The adjusting signal section has two following main function: conversing alternating current signal collected from the output electrodes to virtual value signal, and amplifying this virtual value signal for eliminating measuring error. AD536 is easy to be operated and has high conversion accuracy, thus it is selected to converse alternating current signal to virtual value signal.

The data-logger section includes a micro-processor, a USB storage circuit, a LCD display circuit, and a communication circuit. LPC 2119 using ARM7 core is used as the micro-processor. The micro- processor has 128K flash ROM, and other functions, such as includes four channels of 10-bit AD and a CAN controller. It can meet the requirements of monitoring, controlling, and data logging.

Soil EC data is stored by flash disk which conforms to the USB2.0 protocol .The GPS data received by serial port is RMC format. The control and display unit uses CAN controller integrated in LPC2119 to communicate with field computer. The controller worked with PeliCAN model can support the CAN 2.0 protocol.

Design of Data Processing Software and Operation of the Control and Display unit

The data processing software of the control and display unit was programmed in C-language, Figure 3 shows its flowchart.

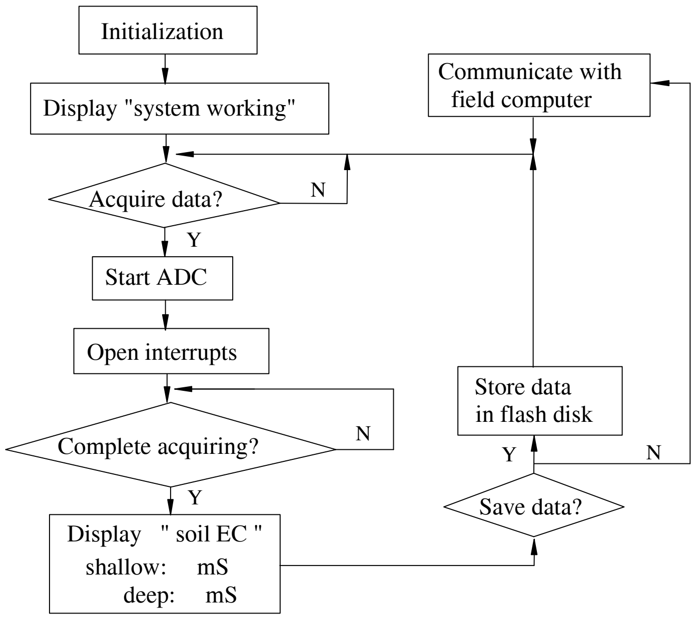

Figure 3 Flowchart of data processing software for the control and display unit

Figure 4 shows the faceplate of the control and display unit. This unit is easy to be operated. Besides POWER switch and RESET switch, the unit still have four buttons to control the device working. Button 1, Button 2, Button 3 and Button 4 are for sampling, lighting LCD, communication, and ISP respectively. The POWER switch is used to provide power to the electrocircuit of the unit and provide a constant alternating current to the input electrodes.

When turning on the Button 1, the unit would begin to acquire soil EC data. The value of EC would be displayed on the LCD and stored in flash disk simultaneity. If the sky is dark, we can push the Button 2 to light the LCD. Turning on the Button 3, we can sent the soil EC data to the field computer, and receive some commands from the field computer. We can turn on the Button 4 for downloading the new system program in ROM, if necessary.

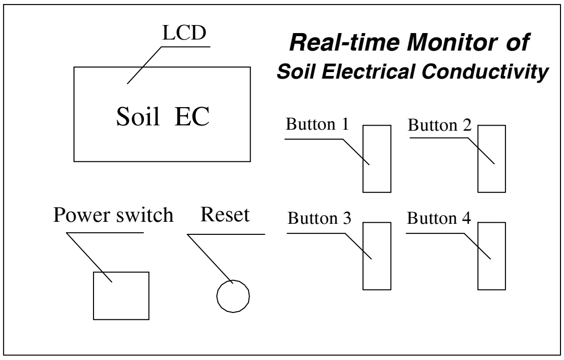

Figure 4 Faceplate of the control and display unit

PERFORMANCE TEST

Tests in Laboratory

The performance tests of the device were carried out in laboratory primarily. We placed the sensor unit in an indoor soil bin, and insured every electrode to penetrate soil. In these tests, we made the condition of the tested soil in the indoor soil bin be very closed to real soil in field, and tested the device under the different EC level. Some conclusions could be drawn from testes in laboratory as following:

- Although increasing the input between the alternating current electrodes could reduces noise and improves the measuring precision, the alternating current signal is easy to be distorted when electrodes move.
- The value of the alternating current wouldn't be affected by the depth of electrodes penetrating the soil surface. When the tips of electrodes are under the soil surface, the value will be able to keep unchanged.
- The output of detecting voltage electrodes and the input of alternating current electrodes have a linear relationship. With the value of alternating current increasing, the value of detecting voltage would increase in term of direct proportion relationship.

Tests in Trail Field

In order to further validate the performance and reliability of the soil sensing system, we carried out field tests in a trail field. The soil is firm but no-compacted and has a smooth field surface in this field, so this will improve EC measurement accuracy. The type of tested soil was grey-brown alluvial soil, which is a typical soil in northern China. Thus the result of this test was good representative for a wide area.

The whole soil EC measuring system was mounted on a tractor equipped with a DGPS receiver. The control and display unit collected the GPS and soil EC data at approximately one second intervals. The ground speed of the tractor is 5~7 kph. This speed is better for our device performing weeding and plowing. The tractor traversed field in a series of closely-spaced passes. All the input data from GPS receiver and the EC measuring device were stored in the flash disk. We chose a part of this data to show the performance of the soil sensing system. The chart of the data is shown in Figure 6. The X axis is the travel distance of the tractor. The Y axis is the soil EC measured by the developed sensing system. The one curve stands for superficial soil EC, and the other one stands for deep soil EC. As seen from this chart, the value of superficial soil EC is higher than the value of the deep soil EC, and both of two curves have an approximately same changing rule when the tractor equipped with the sensing system moves along. From these data points in these two curves, we can see spatial difference of the soil EC obviously.

Figure 5 Experiment of the soil EC sensing system in trail field

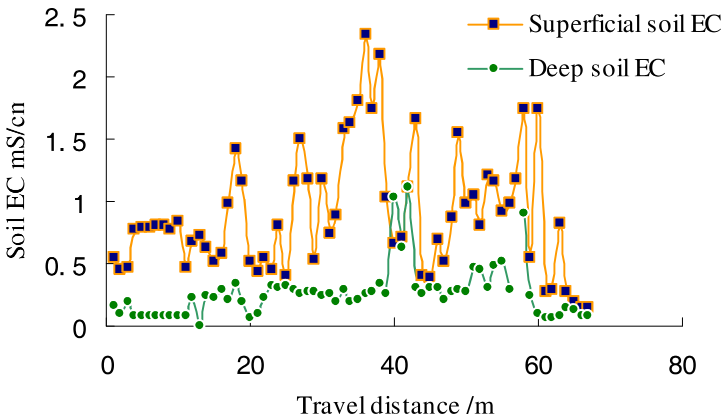

Figure 6 Result of field test for soil EC sensing and mapping system

The sensing and mapping system of soil EC was developed and its performance was tested both in laboratory and in trail field. The results showed that the developed system was satisfactory in practicality. In the future, the more field tests will be performed to improve the measuring precision of this device ulteriorly, in order to make it satisfy the demand of precision farming.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Prethodno priopćenje
Preliminary communication

USING A HALL-CURRENT-SENSOR TO MEASURE THE PENETRATION RESISTANCE

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SUMMARY

Due to the evident influence of the penetration velocity on the measurement of CI (cone index), diverse motor-operated penetrometers have been designed to keep the velocity with a constant. In this paper, an attractive method to determine the penetration force for a motor-operated penetrometer was presented. Unlike other conventional methods employing various force-sensors, this method used a Hall-current-sensor to dynamically measure the operating current of a permanent magnet DC-motor. For the proposed method, both a theoretical analysis related the operating current of the DC-motor to the penetration force and the measurement principle of the Hall-current-sensor were addressed. A soil column with three-layer water contents was used in the laboratory test. The experimental results confirm that the operating current of the DC-motor is a determinate indictor for estimating the penetration force.

Keywords: *penetration force; hall-current-sensor; penetrometer; measurement*

INTRODUCTION

Penetrometers have been widely studied and used for different applications, such as to evaluate the traffic ability and the soil resistance affecting plant's root elongation (Perumpral, 1987; Williams et al. 2005; Zhou et al. 2005). A simple penetrometer is a penetration rod having a conical tip with a force sensor, which may be a strain gauge or piezoelectric load cell (Lowery, 1986; Yong et al. 2000; Sun et al. 2004). As one of efficient methods to measure the penetration force, cone index(CI) is defined as the penetration resistance divided by cone cross-sectional area. Besides soil compaction, many factors, such as soil water content, soil texture and penetration velocity, may also have impact on CI during measurement (Ayers and Perumpral, 1982, Busscher et al. 1997, Topp et al. 2003, Hummel et al. 2004). According to the ASAE Standard (1998), the recommended velocity is 30mm s-1. Obviously, the motor-operated penetrometer facilitates to push the penetration rod into soil with the recommended velocity (Lower, 1986; Topp et al. 2003). On the other hand, compared with the hand-operated penetrometer, the motor-operated penetrometer is relatively complicated and expensive. In order to reduce the cost of a motor-operated penetrometer, we proposed a new measurement method for determining CI. This method used a Hall-current-sensor rather than a force-sensor to measure the dynamic current of the DC-motor. Therefore, the primary objectives of this study are to (i) present a theoretical analysis based on the suggested method; (ii) perform a laboratory test for validating the proposed method.

MATERIALS AND METHODS

Motor-operated penetrometer

Fig. 1 shows the diagram of the used penetrometer that consisted of a permanent magnet DC-motor (M63x60/I, Kählig Antriebstechnik GmbH, Germany), a precise force-sensor together with the associated amplifier (HBM-C9B/500N, Hottinger-Baldwin-Messtechnik, Germany), a depth transducer, a control box, an ASAE-standard penetration rod, and a rack and rigging parts. The nominal voltage and maximal output-power of the DC-motor was 12 V and 99 W, respectively. The used force-sensor was a strain-gauge load cell. The depth transducer (10-turn, 10 kΩ, a potentiometer with ± 0.25% linearity) was mounted with the same axis of the DC-motor. As the penetration rod moved down and up, the potentiometer was rotated by a rack and pinion adjustment so that the output of the depth transducer linearly varied with 0.1V cm^{-1}. The penetration velocity was 3cm s-1 and the maximum vertical movement was 50cm.

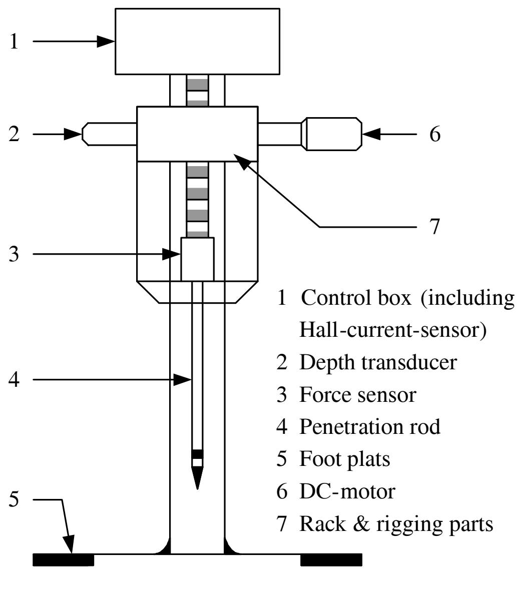

Fig. 1 Diagram of the motor-operated penetrometer

Quantity of penetration force and operating current

The relationship between the penetration force and the operating current can be quantified based on the principle of the energy translation between electric and mechanism. For a permanent magnet DC-motor,

$$M = KI_a \tag{1}$$

where M is the output torque of the DC-motor, Ia is the operating current and K is torque constant. Moreover, for the motor-operated penetrometer,

$$M\Omega = KI_a\Omega = (f_P + f_M - mg)v \tag{2}$$

where Ω is the angular speed of the DC-motor, fP is the penetration force, fM is the total mechanical-friction arisen from the rack vs. pinion and the additional bearing system, m is the mass of the total moving parts of the penetrometer and v is the penetration velocity. Taking the rotating radius r = v/Ω into Eq. 2, the relationship between the operating current and the penetration force can be expressed as

$$I_a = \frac{r}{K}(f_P + f_M - mg) \tag{3}$$

For this motor-operated penetrometer, r = 9.5 mm and K = 3.1 N cm A^{-1}. According to the above analysis, I0, a specific value of the operating current resulting from the term of (fM – mg), can be measured since fP = 0 before the tip of the penetration rod reaches the surface of soil.

$$I_o = \frac{r}{K}(f_M - mg) \tag{4}$$

Defining I=Ia – Io as a corrected measure of the operating current, then

$$I = \frac{r}{K} f_P \tag{5}$$

Measurement of operating current

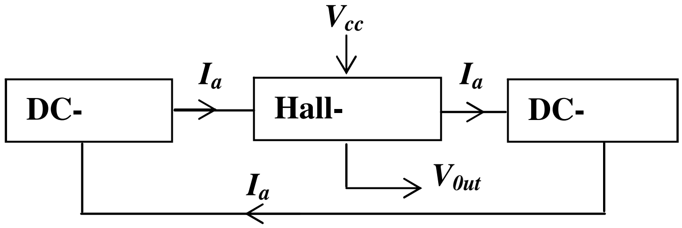

Fig. 2 Measurement principle of the operating current of the DC-motor

Fig. 2 presents a principle layout for measuring the operating current of the DC-motor. Ia, supplied by the DC-power, passes through the Hall-current-sensor and the DC-motor as a circuitry. As is known, Hall-element is made from a thin sheet of conductive material with output the connections perpendicular to the direction of current flow. When subjected to a magnetic field, it responses with an output voltage proportional to magnetic field strength. In this experiment, the type of the used Hall-current-sensor is CS010G. (Nanjing Chief-union Sensor Co. China), whose operating voltage (VCC) is 5V and the maximal measurement current is 10A within a temperature range from -10 to +70 °C. Compared to the cost of the used force-sensor, this Hall-current-sensor is much cheaper than that of the force-sensor. V_{0ut} in Fig. 2 denotes the output voltage of the used Hall-current-sensor. The relationship between Ia and V0ut is determined by

$$I_a = \frac{v_{out} - \frac{V_{cc}}{2}}{R_{in}} \tag{6}$$

Where R_{in} is the input resistance of the used Hall-sensor and its value is 0.2 ohm.

Test procedures

The test included three steps, i.e. (i) To calibrate the force sensor with a series of standard weights ranging from 0 to 500 N; (ii) To determine the value of Io defined as in Eq. 4; (iii) To validate the analysis of Eq.5. For the step (iii), a soil column shown in Fig.3 (diameter 300mm, height 450mm) was packed with three-layer of GWC (gravimetric water content). A thin plastic film was employed to separate each boundary between layers so that no moisture exchanges across each boundary. The bulk density of the soil column was 1.5 g cm-3. The textural composition of the soil samples was sand 11%, silt 55% and clay 34%.

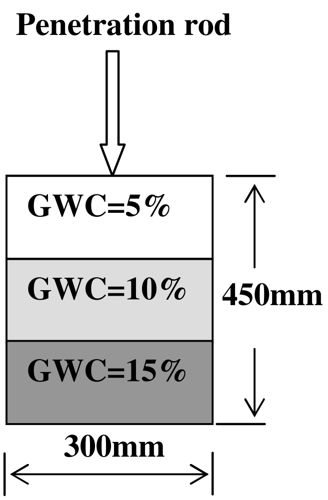

Fig . 3 Soil column packed by three-layer water contents

RESULTS AND DISCUSSIONS

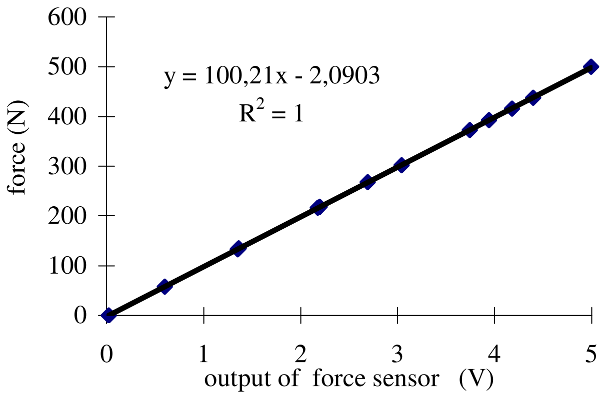

Fig. 4 Calibration results of the force-sensor

Fig. 4 shows the calibration results of the used force-sensor. It is evident that there exists an exact linearity between the output of the force senor and the exerted force ranging from 0 to 500 N. Thus, the output of the force sensor can be served as the reference signals to verify the relationship between the operating current of the DC-motor and the penetration force.

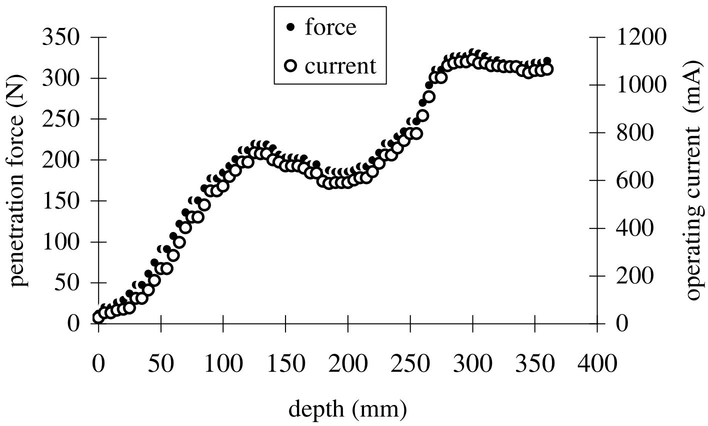

Fig. 5 Experiment results from the force- and Hall-current-sensor

Fig. 5 displays two sets of penetration data dynamically measured from penetrating the soil column prepared. One of sets (void-dot) refers to the output of the force-sensor and another set (solid-dot) to that of the Hall-current-sensor. Obviously, the tendency of each set of the measured data in Fig. 5 appears pretty resemble and especially each maximal or minimal value of the output of each sensor occurs at the same depth. As far as the behavior of the output signal of each sensor in Fig.5 is explained, Ayers and Perumpral (1982) found the relationship between CI and GWC was not monotonic so that the peak value of penetration force occurred at a moderate level of GWC.

Fig.6 reveals a statistic results between the output of the force-sensor and that of the Hall-current-sensor. The statistic results approximate to a line of 1:1, with a correlation coefficient of 0.998.

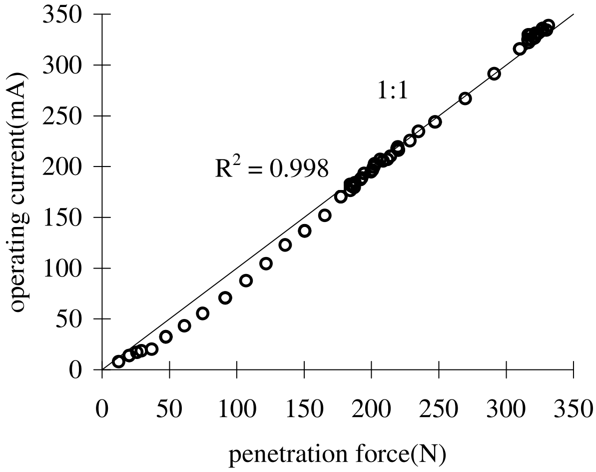

Fig. 6 Correlation between the force- and Hall-current-sensor

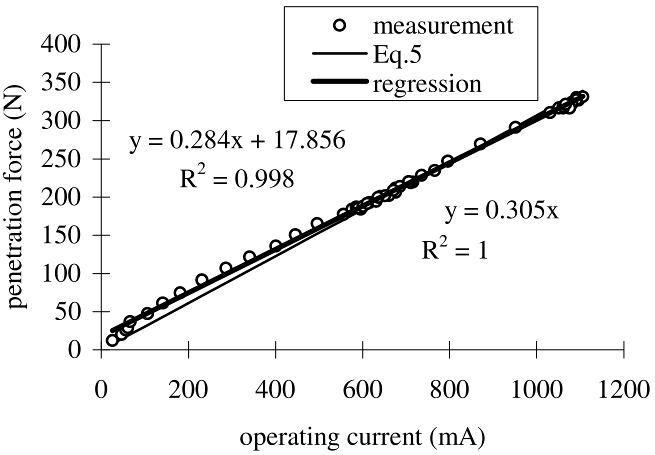

Fig. 7 Comparison among the measured data, regression approximation and the theoretical results

Moreover, Fig. 7 shows a comparison among the measured data, the regression approximation and the theoretical results calculated from Eq.5. It is noted that the tangent of Eq.5 is 0.305, whereas the tangent of the regression approximation is 0.287. This fact confirms that Eq.5 can be safely used to describe the relationship between the actual operating current of the DC-motor and the penetration force.

CONCLUSIONS

A practical method with a Hall-current-sensor for a motor-operated penetrometer to determine soil penetration force was approached. The theoretical analysis demonstrated a linear relationship between the operating current and the penetration force when a permanent magnet DC-motor was used. The experiment results agreed to that of analytical analysis with a correlation coefficient of 0.998. Therefore, the operating current of the DC-motor can act as a determinate indictor to estimate the penetration force for the motor-operated penetrometer. Additionally, three potential advantages of the proposed method may be: (i) it may significantly reduce the cost of a motor-operated penetrometer; (ii) it may simplify the mechanical structure of the penetrometer because the Hall-current-sensor, as an electronic device, needs not to consider any mechanical installation; (iii) it may be more sensitive or effective to prevent the DC-motor from overload damage.

ACKNOWLEDGEMENTS

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A GPS RECEIVER BASED ON THE VIRTUAL REFERENCE STATION SYSTEM

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SUMMARY

GPS is one of the most important aspects in Precision Agriculture. The Virtual Reference Station (VRS) system is a new technology of DGPS developed in recent years. As opposed to traditional RTK with a single reference station, the VRS is in a broad sense of multiple-reference-station networks and results in a larger service area coverage, increased robustness, and higher positioning accuracy. The VRS system is made up of a control center, more than three reference stations and the GPS rover. Integrating the data of a whole network of reference stations, precise models of the error sources are derived in the control center and used to calculate the expected RTCM corrections for the GPS rover after receiving its approximate position. Although there are some GPS receivers available for the VRS in international markets, high price becomes major obstacle of popularization in underdeveloped regions. Therefore, a low-cost GPS receiver based the VRS was developed in this study, and it belonged to the GPS rover.

The GPS Receiver had six important modules, a microprocessor, a low-cost GPS OEM, a GSM engine, a keyboard, a LCD and a USB Flash Disk. An available GPS OEM- AC12 of THALES Company with position accuracy of 5 meters without SA and 1.5 meters with DGPS was adopted. The GSM module-MC35i of SIMENCE Company was used to send the approximate position of the system to the control center and receive the RTCM corrections from the center. The keyboard was used to input different VRS service telephone numbers and control commands. And the GPS data could not only be displayed real time on the LCD, but also be stored in USB Flash Disk. The design and realization of the GPS Receiver was discussed in the study, including hardware and software etc.

The developed GPS Receiver was tested through outdoors experiments, and the results showed that the accuracy could be kept within 1.5m. It indicated good practicality for Precision Agriculture like soil sampling. And the cost of the system was significantly reduced. With substantial growth of the VRS, the GPS

Receiver based the VRS would be a good tool for Precision Agriculture in underdeveloped regions.

Key words: *VRS, GPS, GSM, RTK*

INTRODUCTION

GPS is one of most widely used surveying techniques in Precision Agriculture, which is applied for positioning and navigation. And DGPS (Differential GPS) is usually adopted to improve the positioning precision since many years. For instance, RTK (Real Time Kinematic) achieves centimeter positing accuracy. However, it requires a local base station and the distance between a rover receiver and its reference station has to be limited as low as 10 15km in order to work efficiently because GPS errors become less spatially correlated over longer baselines, causing degradation in the resulting positioning accuracy (G. R. Hu, et al. 2003; Nicholas Talbot, et al. 2003; Han SW, 1997; Herbert Landau, et al. 2002).

As a new DGPS technique since 2000, the concept of virtual reference stations (VRS) can overcome the above-mentioned limitations. It allows performing high precision RTK positioning in a multiple-reference-station network, without a user's own reference station. As opposed to a single reference station of traditional RTK, VRS can potentially reduce the operational cost and result in larger service area coverage, increased robustness, and higher positioning accuracy (Zhang, k, et al. 2003;Guorong, Hu, et al. 2002). In the recent years, VRS networks have been installed around the world, such as Japan, USA, Germany, Sweden, Spain, Singapore, Netherlands, Switzerland and so(EUREF, 2003; Zhang, K, et al., 2003). In China, about seven cities and regions have had the VRS networks, and about four provinces are ready to install VRS networks. The VRS technique had led to substantial improvements for real-time positioning.

Although there were some GPS receivers available for the VRS in international markets, the large and complex machinery system and high price become major obstacles in its dissemination in Precision Agriculture of less developed regions. Therefore, a low-cost GPS receiver based the VRS was developed and discussed in this study.

VRS CONCEPT

VRS is an integrated system of GPS hardware, software, and communications links that uses data from a network of fixed reference stations to model errors throughout a region. As shown in Figure 1, the VRS concept involves a control center, more than three reference stations and the user (GPS rover).

The user set-up in the field follows this procedure:

- The user sends its approximate position through a standard NMEA position string called GGA to the control center that is running GPSnet via a cellular modem such as a GSM mobile phone or a GPRS (General Packet Radio Service).
- The control center receives the user's approximate position and selects the nearest reference station to the user as the master reference station.

- The raw data from that reference station is then improved by applying the corrections according to the approximate position of the user, and transmitted RTCM correction data messages to the user receiver via the mobile phone.
- As soon as the RTCM correction data is received, the user receiver will compute a high quality DGPS solution, and update its update its position. The rover then sends its new position to the control center.

This technique of creating raw reference station data for a new, invisible, unoccupied station, is a so-called Virtual Reference Station (VRS) (Trimble, 2003; Herbert Landau, 2002, Landau H, et al., 2001; Vollath, U., A. Deking, et al., 2000).

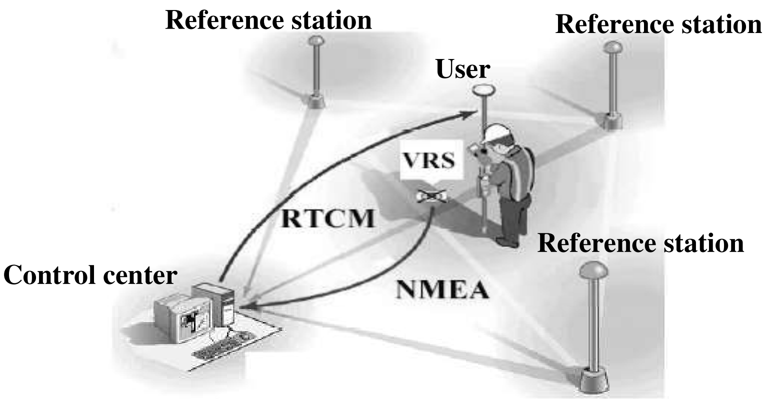


Figure 1 VRS field set-up procedure.

It is suggested that the VRS system can result in a significant improvement over the conventional RTK system. First, without set-up of base station, the user can do the job as long as the rover is within the VRS network. It reduces the equipment cost. Secondly, it results a large service area coverage. As opposed to the limitation of 10km separation of the rover to base in the conventional RTK system, the distance between the reference stations is particularly over a long distance (eg 40km-70km). Thirdly, the accuracy and reliability of positioning is highly improved due to the raw data from multiple-reference-station. Finally, the reliability and integrity of the VRS system can be monitored for critical applications, such as the quality control/assurance procedures (Zhang.K, et al. 2003; Herbert Landau, 2002).

DESIGN

A low-cost GPS receiver based the VRS was developed in this study, and it belonged to the GPS rover. The GPS Receiver had six important modules, a microprocessor, a low-cost GPS OEM, a GSM engine, a keyboard, a LCD (Liquid Crystal Display) and a USB (Universal Serial Bus) Flash Disk.

Design of Hardware

The GSM engine is used for communication with the control center of VRS system, sending its own position to the control center and receiving the RTCM correction data. Then, the GPS receiver gains DGPS data. After a series of process, the GPS data could not only be displayed real time on the LCD, but also be stored in USB Flash Disk. The GPS receiver also includes a keyboard as the control of the system.

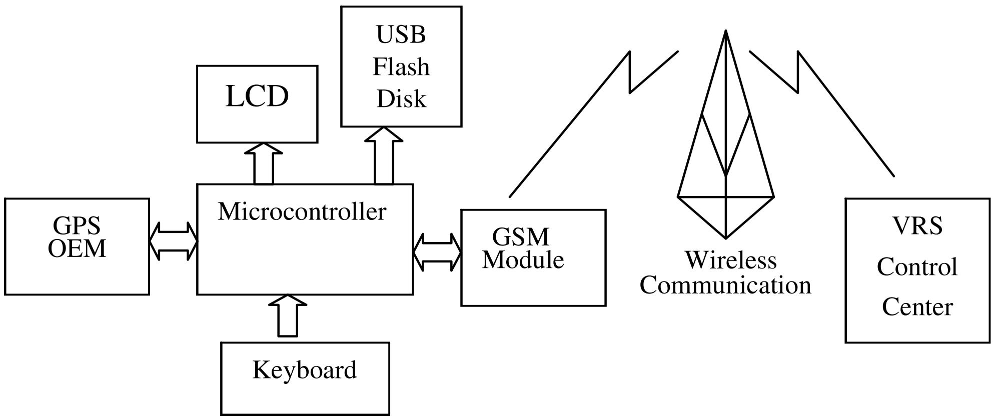


Figure 2 Diagram of the GPS receiver developed

Figure 2 shows the diagram of the the GPS receiver developed. Microcontroller communicates with GPS receiver and GSM module through RS-232 serial port.

It used AT89S52 manufactured by Atmel as the microcontroller. The controller is a low-power, high-performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory, derived from the 80C51 microprocessor family.

An available GPS OEM- AC12 of THALES Company was adopted. It is low-power (only 0.23 tile), and with position accuracy of 5 meters (95%) without SA and 1.5 meters (95%) with local DGPS. It can also gains the RTCM correction data from SBAS (WASS/EGNOS /MSAS). The position accuracy of AC12 can suit for Precision Agriculture.

GSM engine plays a very important role in the GPS receiver based on the VRS. And one of SIMENCE GSM engine--MC35i was used in the system, operating in the GSM 900 MHz and GSM 1800 MHz frequency band. It is an extremely compact and super slim communication module especially designed for telemetry, telematic and telephony, and the physical interface to the cellular application is made through a ZIF connector, which consists of 40 pins, required for controlling the unit, transferring data and audio signals and providing power supply lines.

Data storage device is a necessary part of the system. Storage media should be large enough, convenient enough and safe enough to store the GPS data for several days or even a whole harvest season. USB Flash Disk was chosen as the storage media.

The user interface consists of a keyboard and a LCD. The keyboard is used to input some parameters and settings for GSM communication. The LCD is used to display the GPS data real time.

Design of Software

The work steps of the GPS receiver developed follows the next text; Before the GPS data gathering, system configuration is needed, such as the service phone number of the control center. All the information is inputted through the keyboard. When initialization of the GPS receiver is finished, connect the control center and begin to gather GPS data. The GPS data is stored in system’s RAM, ready for LCD displaying and USB Flash Disk writing. When the system is shutting down after work, first executes the operation of safe shutdown to write the data in buffer to the USB Flash Disk, and then stops working.

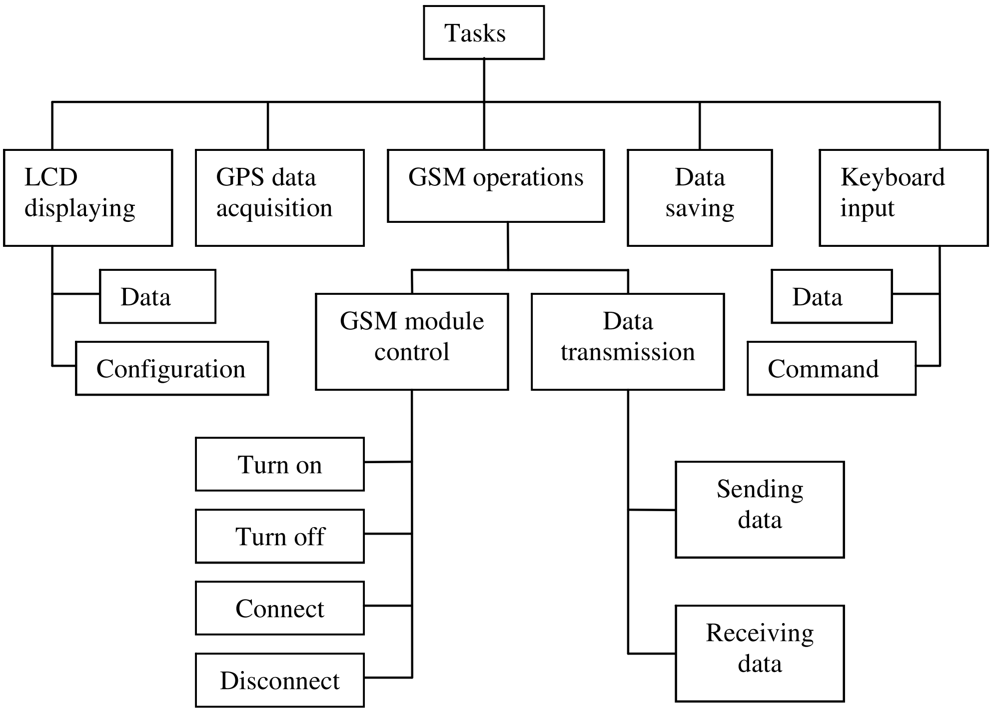


Figure 3 Tasks of the program

It is obvious that there are five main tasks to in the program, including keyboard input, GSM operations, GPS data acquisition, LCD displaying and data saving. The details of them are shown in Figure 3.GSM operations involve GSM module control and data transmission. The content displayed by the LCD can be classified into two categories: the collected data and the configuration interfaces, such as the interface for setting VRS service telephone number. The keyboard, as an input tool, has two functions, command input and data input.

I GSM operation

As mentioned above, the mobile phone data link could be GSM and GPRS. But GPRS for the VRS system in Beijing of China is still being tested, and GSM is a widely available public service. Therefore, GSM is used as the communication link between the developed GPS receiver and the VRS control center.

GSM operations were controlled by the microcontroller, including turning on or turning off the GSM module, connecting or disconnecting the VRS control center, sending own position to the control center and receiving the correction data from it. Turning on the GSM engine was controlled by an I/O of microcontroller which connected the ignition line of the GSM engine. Other operations, such as turning off the GSM module, connecting and disconnecting the VRS control center were achieved by simply sending AT Commands via serial port. There are some AT Commands needed in the program.

- ATDn mobile originated call to dial a number 'n'
- +++ switch data mode to command mode
- ATH disconnect existing connection
- AT^SMSO power down GSM engine

Once the GPS receiver developed and the control center of the VRS was connected, the data transmission was transparent through the serial port. A timer was used to control the frequency of the sending data. Every one second, the GPS receiver developed sent the position data to the control center. And the UART serial I/O port interrupt source was used for receiving the correction data from the control center and sending the correction to the GPS OEM.

II GPS Data Acquisition

The GPS OEM has two serial ports, one for receiving the correction data and another for outputting the GPS data. When the GPS OEM gained the correction data through UART serial I/O port interrupt, the GPS OEM could gain the DGPS data. An external interrupt source was used for GPS data acquisition.

III LCD Displaying

The data displaying on LCD involved longitude, latitude, the number of satellite and so on. So when a standard NMEA position string was gained from the GPS OEM, the longitude and latitude etc were picked up to the appointed arrays at first, then displayed on the LCD.

IV Storing Data on USB Flash Disk

USB Flash Disk is used as the storage media in the system. In the system initialization, program checks whether the USB Flash Disk is ready. If there is a USB Flash Disk on the GPS receiver developed, program starts file operations. An external interrupt source was used for saving GPS data to USB Flash Disk in term of sector. When there are 4K GPS data in the microcontroller Flash, an interrupt request will be generated to save the data. The data file is in ASCII format, which is popular in GIS application. To prevent the file to be destroyed by a sudden power losing, the program adds an ending sign to the file every time when it finishes a data saving. This can keep the file integrity.

V Keyboard input

The program judges the function of the pressed key, and then executes the function, such as the signal for turning on and turning off the GSM engine, character input, interface switching, data acquisition start, and so on.

TESTING AND ANALYSIS

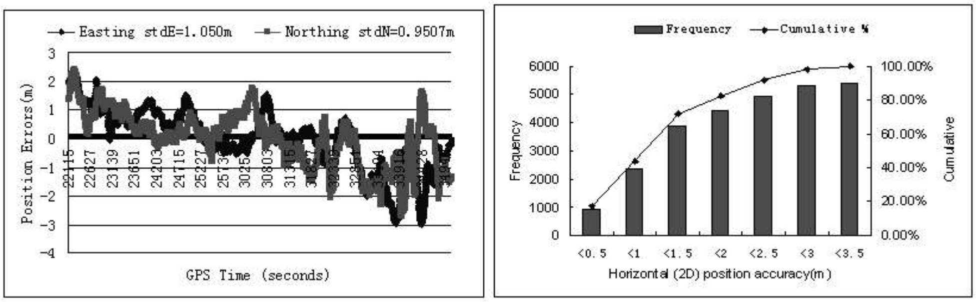
In order to evaluate the efficiency and positioning accuracy of the GPS receiver developed, a number of tests were conducted at the same location. The tests were done (10: 30-21:17 local time) on 20 October 2005 at the rooftop of the Computer Network building located at China Agricultural University. Because the GPS OEM-AC12 in the GPS receiver developed could gain both SBAS (WASS/EGNOS /MSAS) DGPS and VRS DGPS, three surveying modes were used, including raw GPS, WASS DGPS and VRS DGPS. When testing, the GPS data were continuously output every second by the GPS OEM and saved in the USB Flash Disk. The ground truth position was unknown, but it could be computed from the logged long time raw data (G.R. Hu, et al. 2003). Here, the average of all GPS data gathered was treated as the truth position in each surveying mode.

Figure 5 shows position errors in Easting, Northing and horizontal position accuracy for tests. The pictures of horizontal position accuracy present the absolute as well as the cumulative frequency. It can be seen that 98% horizontal (2D) position accuracy of raw GPS is below 3m, 99% horizontal (2D) position accuracy of WASS DGPS is below 2m, and the horizontal (2D) position accuracy of VRS DGPS is 1.5m. And the statistical results are listed in Table 1. From these results, the accuracy of the VRS DGPS is the best one of these three surveying modes, better than 1.5m in horizontal position. And WASS DGPS is also active to improve the position accuracy relative to the raw GPS. However, it is impossible to utilize WASS service in China most regions for its coverage. Hence, the test results proved that the VRS technique is an effective GPS positioning method, and it indicated that the GPS receiver based the VRS had good practicality for Precision Agriculture like soil sampling.

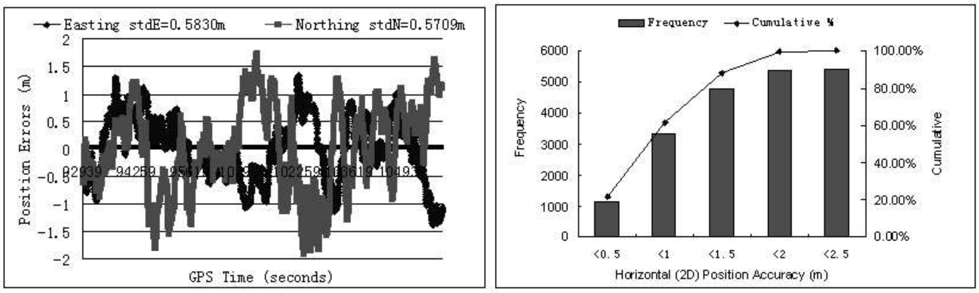
Table 1 The statistical results of accuracy in Easting and Northing

		Standard deviation (m)	Maximum (m)	Minimum (m)
a	Easting	1.0498	2.1867	-3.0033
	Northing	0.9507	-2.739	2.411
b	Easting	0.5830	1.3379	-1.3821
	Northing	0.5710	1.75	-1.93
c	Easting	0.4826	1.24374	-0.90626
	Northing	0.6113	1.385	-1.335

a)



b)



c)

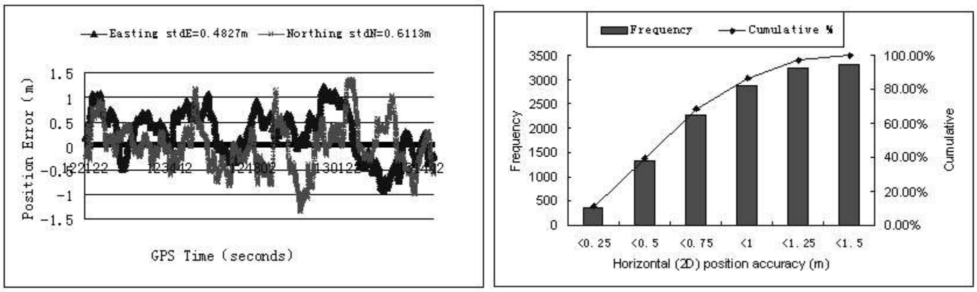


Figure 5 a) Position Errors in Easting, northing and horizontal position accuracy of the raw GPS test; b) Position Errors in Easting, northing and horizontal position accuracy of WASS DGPS test; c) Position Errors in Easting, northing and horizontal position accuracy of the VRS DGPS test

CONCLUSIONS

The Virtual Reference Station (VRS) system was a new technology of DGPS developed in recent years. As opposed to traditional RTK with a single reference station, the VRS was in a broad sense of multiple-reference-station networks and resulted in larger service area coverage, increased robustness, and higher positioning accuracy.

A GPS receiver base the VRS was developed, and the design of hardware and software for the GPS receiver were conducted. The main functions of the developed GPS receiver are obtaining the GPS correction data from the control center of VRS, gaining the DGPS data, and then displaying on LCD and saving in the USB Flash Disk.

The tests of the developed GPS Receiver showed that the accuracy could be kept within 1.5m based the VRS. It indicated good practicality for Precision Agriculture like soil sampling. And the cost of the system was significantly reduced. With substantial growth of the VRS, the GPS Receiver based the VRS would be a good tool for Precision Agriculture in underdeveloped regions.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.42:621.317.7
Izvorni znanstveni rad
Original scientific paper

STUDY OF AREA CALCULATE METHOD BASED ON GPS AND ITS APPLICATION

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SUMMARY

Aim at the lack of area calculate method based on GPS in researching of precision agriculture, a new area calculate method was put forward, which is called triangle division method. The method received area borderline orientation data by GPS, then made area polygon by coordinate conversion. The total areas which want to be measured can be calculated by analyzing these triangle areas. As an example, the area of a piece of field of 65m×58m was calculated by receiving data through GPS by using this new method. The new method was used to measure and calculate. The result showed that this method can calculate polygon area very quickly with high precision. It can be used to measure, orientation and layout based on GPS.

Keywords: *Coordinate Conversion, Area polygon, Triangle division method, Precision agriculture, Area calculate*

INTRODUCTION

In the precision agriculture application, using GPS to calculate area is a very basic and important work. At present, GPS was always used to receive data as orientation information, and afterwards GIS software (such as MapInfo, Arc View ARC info) was used to process them, but there exists several big disfigurement (Wu, 2002; Ambrosius, Beutler, Blewitt, 1998; Mason,1997; Tim, 1995; Wang, 2001; Luo, Liao, 2001; He, Fang, 2001): First is that using GIS software to get the area needs a lot of data input to GIS geography information database; The second is that using GIS software can't get the region area on real time; The third is that the existed region area method generally in low precision, and complicate in calculation (Ambrosius, Beutler, Blewitt, 1998; Mason, 1997; Tim, 1995). In order to eliminate these disfigurements in region area calculation, great many papers was referred to, and the triangle division method to calculate the region area was presented.

METHODS

Coordinate conversion of the GPS receiving data

Before the triangle division method was introduced, first coordinate conversion of the GPS receiving data was processed. Normally the data which GPS received is the longitude and latitude data, but in research and application right angle coordinate was often adopted. So, coordinate conversion was needed, and one coordinate conversion method was introduced, which is to convert WGS84 coordinate to Gos-cluge (Wang, 2001; Luo, Liao, 2001) coordinate. WGS84 coordinate (B, L), B is the latitude of GPS orientation output, L is the longitude of GPS orientation output. The corresponding Right angle was set as (X, Y).

Radius of the Earth R = 6378245.0m

The first partial ratio e = 0.081813334

$$E_0 = e^2/(1-e^2) = 0.00673852541468 \quad (1)$$

$$P_0 = \pi/180.0 \quad (E_0,\ P_0 \text{ as constant}) \quad (2)$$

The longitude of the center meridian $L_0=6\times n-3$, n as the strip sequence number of the six degree projection strip(Hang Zhou belongs to twenty first strip of the six degree projection strip)

$$A = 1+3\times e^2/4+45\times e^4/64+175\times e^6/256+43659\times e^{10}/65536+11025\times e^8/16384 \quad (3)$$

$$B = 3\times e^2/4+15\times e^4/16+525\times e^6/512+2206\times e^8/2048+72765\times e^{10}/65536 \quad (4)$$

$$C = 15\times e^4/64+105\times e^6/256+2205\times e^8/4096+10395\times e^{10}/16384 \quad (5)$$

$$D = 35\times e^6/512+315\times e^8/2048+31185\times e^{10}/13107 \quad (6)$$

$$E = 315\times e^8/16384+3465\times e^{10}/65536 \quad (7)$$

$$F = 693\times e^{10}/131072 \quad (8)$$

(A, B, C, D, E, F as constant of coordinate conversion)

X_0 is the length of the ace from ground coordinates (B, L) to meridian of the equator

$$X_0 = a\times(1-e^2)\times(A\times b-B\times\sin(2\times b)/2+C\times\sin(4\times b)/4- -D\times sin(6\times b)/6+E\times sin(8\times b)/8-F\times sin(10\times b)/10) \quad (9)$$

The input of longitude and latitude:

L: dddmm.mmmm

B: ddmm.mmmm

Conversion to degree:

$$L=[L/100]+(L-[L/100]\times 100)/60 \tag{10}$$

$$B=[B/100]+(B-[B/100]\times 100)/60 \tag{11}$$

Conversion to radian:

$$b = B \times P_0 \qquad l=(L-L_0)\times P_0 \tag{12}$$

The normal parameter of Gos projection:

$$g=\sqrt{E_0}\times \cos(b) \tag{13}$$

$$\mathrm{t}=\tan(\mathrm{b}) \tag{14}$$

$$m_0=l\times \cos(b) \tag{15}$$

$$N=a\Big/\sqrt{1-e^2\times \sin^2(b)} \tag{16}$$

(b ,*l* ,*g* ,*t* ,m_0, *N* as the middle variable)

The calculating formula of the longitude and latitude coordinate convert to right angle coordinate:

$$\begin{aligned} X &= X_0 + N\times t\times m_0^{\,2}/2 + N\times t\times(5-t^2+9\times g^2+ \\ &+4\times g^4)\times m_0^{\,4}/24 + N\times t\times(61-58\times t^2+t^4+ \\ &+270\times g^2-330\times g^2\times t^2)\times m_0^{\,6}/720 \end{aligned} \tag{17}$$

$$\begin{aligned} Y &= N\times m_0 + N\times(1-t^2+g^2)\times m_0^{\,3}\big/6 + N\times(5- \\ &-18\times t_2+t^4+14\times g^2-58\times g^2\times t^2)\times m_0^{\,5}\big/120 \end{aligned} \tag{18}$$

Triangle division method to calculate polygon area

Towards to an irregular geometry figures, there's no simple calculation formula to get the area, it can only through similar calculation. Especially to the farmland, the borderline is generally irregular, thus it's difficult to get its area. However towards to precision agriculture, it is very necessary to get the region area. Therefore, this triangle division method was presented to calculate polygon area. What is called triangle division method is to set one polygon culmination as basic point, and divide polygon to several triangles. The particular introduction about triangle division method is as follows.

Basic point selection and triangle division

One culmination (Figures1(1),1(3) culmination A)of the polygon was selected randomly as basic point , it was set point A. Culmination A was connected to the other culminations, then point selection and triangle division was finished (Figures1(2),1(4)).

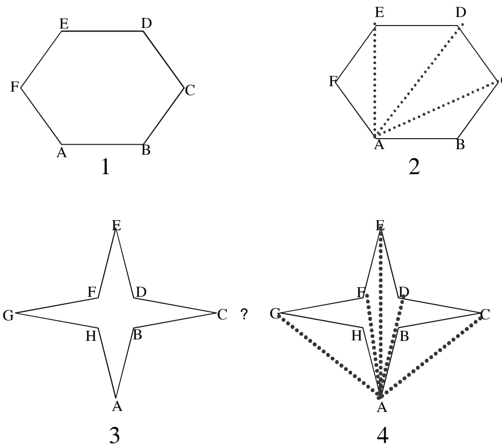

Figure 1 Polygon base point selection and triangle division

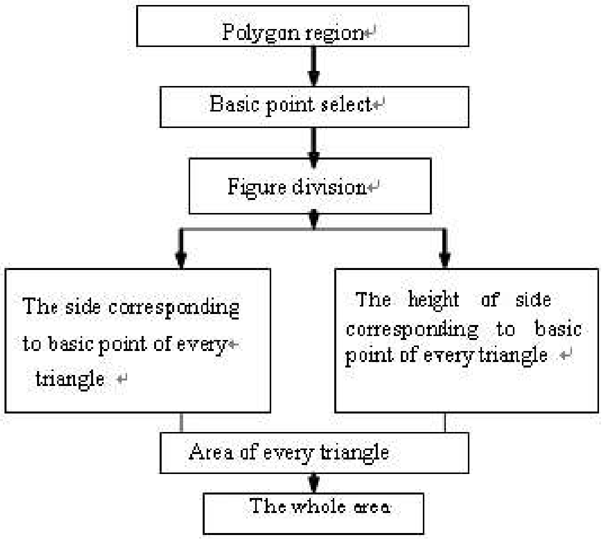

Figure 2 Polygon figures division program sketch map

Calculate the polygon area after division

Geometry figures can divide into two kinds, protruding polygon and concave polygon. It is easy to get the area towards to protruding polygon, which only needs to add all the areas of the triangle (don't need to consider the sign (positive and negative), Figures 1(2)).But to concave polygon, it needs to consider the sign (include positive and negative) of the area (Figures1 (4)).Now to prove the Figures1 (3):

$S_{ABCDEFGH}=S_{ABC}+S_{ACD}+S_{ADE}+S_{AEF}+S_{AFG}+S_{AGH}$

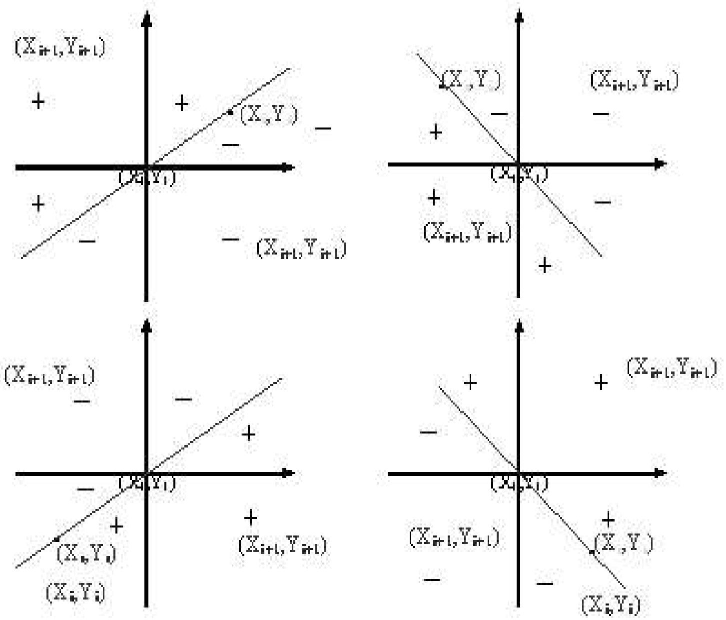

Figure 3 positive-negative judgment of Triangle area

Figure 4 Basketball field outer circle area calculate program map

From the basic point A to joint every other point of B,C,D,E,F,G,H in turn, several triangles were composed, if in these triangles ,the last culmination is at the left of the former culmination which is adjacent to it ,the area of this triangle is positive; If the last culmination is at the right side ,the area of it is negative. For example, in Figures 1(4), because the last culmination C is at the right of the former culmination B adjacent to it, the area of triangle ABC is negative. As the same reason, the area of triangle ACD is positive.

Proof: known from the Figures1 (4):

If

$S_{ABC}= -|S_{ABC}|$

$S_{ACD}=|S_{ACD}|=|S_{ABC}|+|S_{ABCD}|$

$S_{ADE}=|S_{ADE}|$

$S_{AEF}=| S_{AEF} |$

$S_{AFG}=|S_{AFG}|=|S_{AFGH}+S_{AGH}|=|S_{AFGH}|+|S_{AGH}|$

$S_{AGH}= -|S_{AGH}|$

Then

$S_{ABC}+ S_{ACD}+ S_{ADE}+ S_{AEF}+ S_{AFG}+ S_{AGH}= -|S_{ABC} |+ |S_{ABC}|+|S_{ABCD}|$

$|S_{ADE}|+|S_{AEF}|+|S_{AFGH}|+|S_{AGH}|-|S_{AGH}|=|S_{ABCD}|+|S_{ADE}|+|S_{AEF}|+|S_{AFGH}|=S_{ABCDEFGH}$

So

$S_{ABCDEFGH}=S_{ABC}+S_{ACD}+S_{ADE}+S_{AEF}+S_{AFG}+S_{AGH}$

In fact, towards to the area of random polygons, all of them can decompose to several triangles to get their areas.

According to this conclusion, it's easy to get the polygon area. It's only need to get the length of one side of triangle which is corresponding to the basic point and the height corresponding to the side. The area of polygon which was got through this method, not only adapt to concave polygon, but also to the protruding polygon, even if to all of the polygon. Thus using this method to get the area of polygon is very effective.

Flow chart of the triangle division method getting the area of polygon

Above the process of the triangle division method was analyzed. Now the sketch map of the program was given, as the gist of carrying out the program, Figure2.

Program of calculating area by triangle division method

Basic to the method introduced above and the sketch map of Polygon figures division, here the program was given. The key to realize program is to judge the sign of the area of triangle, it means that whether it is clockwise or anticlockwise from (Xi, Yi) to (Xi+1, Yi+1), the sketch map of judging about the sign of area is as follows (Figure 3).

Given the triangle area positive-negative judgment rule and it can carry out the program conveniently.

Main process to calculate the region area

Due to the GPS receiving data is one-two data per second, thus the data received is discontinuous, and therefore the chart drawing basic to this point must compose one polygon. Basic to the method introduced above, now the step about calculating region area by GPS receiving data was given (He, Fang, 2002).

Step1: orientation information of the GPS receiving region was used, the longitude and latitude coordinate was got.

Step2: longitude and latitude coordinate was converted to right angle coordinate.

Step3: polygon was drawn based on right angle coordinate.

Step4: triangle division method was used to get polygon area.

RESULTS AND DISCUSSION

GPS310 of the Magellan Company was used to measure a piece of a basketball field (66×58) for about four culminations, the data tested as Table1:

Table 1 Basketball field outer circle foursquare Longitude-Latitude coordinate

Item / Culmination	WGS right angle coordinate X(m)	WGS right angle coordinate Y(m)
1	3353608.78	229484.41
2	3353551.44	229485.21
3	3353550.34	229549.86
4	3353604.57	229553.41

Coordinate conversion, as Table2:

Table 2 Basketball field outer circle foursquare WGS coordinate

Item / Culmination	WGS right angle coordinate X(m)	WGS right angle coordinate Y(m)
1	3353608.78	229484.41
2	3353551.44	229485.21
3	3353550.34	229549.86
4	3353604.57	229553.41

Using triangle division method program to calculate polygon area, as Figure 4:

The result of calculating area: 3729.5002m^2

Error analysis:

D=(65×58-3729.5002)/65×58=1.07%

In fact, these errors are not generated by using triangle division method, but caused by information received by GPS, which belongs to the error of the GPS position. Furthermore, to the farmland information, the error of 1.07% is very small, which is according to the need of the precision agriculture. Therefore, this method has the biggish of the practical value.

CONCLUSIONS

Through the research a new method about region area based on GPS in precision agriculture was presented, the recent problem about difficult to measure irregular land area to main management of the farmland was solved. The practice application demonstrated, the area calculating method is simple and practical, also have the high precision. So it can be used in measuring, orientation, designing farmland based on GPS.

ACKNOWLEDGEMENTS

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

STUDY AND DEVELOPMENT OF A FIELD INFORMATION ACQUISITION SYSTEM BASED ON WIRELESS TECHNIQUE

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SUMMARY

Field information acquisition based on wireless communication technology is necessary for precision agriculture. Various data of a sampling point in a field from sensors like GPS were collected and real-timely transmitted via wireless communication technology. A field information acquisition system was developed in this research. An ARM9 was used as MCU. The system had some functions: data acquisition, wireless transmission and software processing. Data from sensors, such as a GPS and a USB camera, would be stored and displayed after primarily processes by a data collection unit. Also, in order to obtain more sensible and visible field information, particular interval images could be captured. A wireless transmission unit was designed with a GPRS module, which could receive and send data under TCP/IP protocol. By analyzing the data from the data logger, a farmer could be classified into different plots by different soil ingredient or growing situation of crops.

Key words: *Precision agriculture, Data acquisition, GPS, GPRS*

INTRODUCTION

Precision agriculture is a comprehensive system optimizing agricultural production by making full use of crop information, advanced technologies and management practices. For modem farms the most valuable resource is information, such as crop characteristics, soil properties, fertility requirements, weed population, insect population, plant growth response, harvest data, and post harvest processing data and so on. Filed information acquisition is an important task for precision agriculture practices. And these data are main parameters of a field GIS and a field expert system. Many companies and universities have investigated field information acquisition system. HGIS(Handheld Geographic Information Systems TM, StarPal,US) was a Pocket PC capable of collecting GPS data, crop distributing and soil sample. ArcPad(ESRI, US) was a mobile GIS software for field mapping applications. AgGPS160 and EZ-map(Trimble, US) were also another two kinds of commercial products.

Modem agriculture demanded improved productivity and efficiency. Low cost, less time consuming were essential factors to compete in domestic and global markets. Positioning, wireless, and information technologies had changed the relationship of farms with the land. This paper intended to develop a data acquisition system based on the Samsung's S3C2410 embedded microprocessor.

HARDWARE

The field data acquisition system based on embedded MCU was composed of data acquisition, data transmission and human-machine interface. Data acquisition module was used to collect data from GPS, CMOS camera and other sensors. Data transmission module included wireless transmission units which transmitted data from data logger to PC or remote server. The human-machine interface was used to set and operate the data logger. Figure 1 is the structure of data logger.

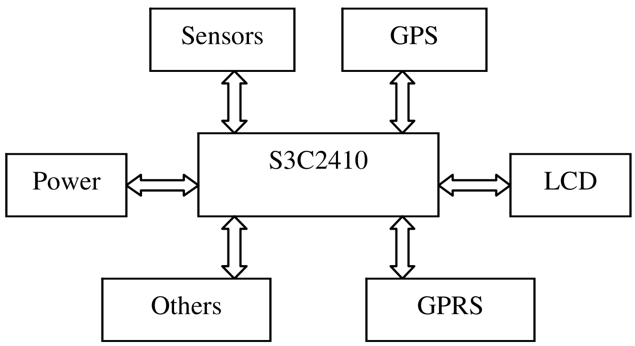

Figure 1 structure of data logger

Data Acquisition Module

Data acquisition includes three parts: data from sensors, data from GPS receiver and data from USB camera.

- Sensors data: there are analog and digital sensors, and analog data must be transformed into digital data before data processing. In this system, the data logger can collect data of six channels at the same time.
- GPS data: GPS module (GARMIN GPS25LVS) communicates with MCU through serial port. GPS module's output is NMEA0183 data format.

- Video data: video data from USB camera (Webeye V2000) will be captured as video image or image.

After an analog signal triggers ADC0809 and conversion is finished, an ADC end-of-conversion interrupt is pending. The system responds the request by reading the result of A/D conversion and starting the next conversion. To improve the accuracy of data acquisition, the system converts 1 analog signal for 10 times continuously, and then calculates the average of 8 middle values as the final conversion result after eliminating the maximum and minimum of the 10 values. S3C2410 has only three serial ports, so more serial devices communicate with MCU must through extending serial ports. TL16C554 is a chip which can support four serial ports. Each serial port communicates with MCU through interruption mode, and each has 16 bytes FIFO which can reduce interruption frequency.

USB interface is a very popular and usual interface today. S3C2410 has integrated USB controller, so the system can expand 2 USB host: one connects with USB camera, and the other connects with USB flash memory. When the data logger works in field, there are a mass of data to be acquired. So the memory of the data logger is not enough, an extended memory is necessary. At the same time data storage in USB flash memory is a backup when someone needs

Data Transmission Module

After data comes into data logger, there are two ways of dealing with them: one is storage, the other is transmission. In this system, data transmission has two kinds: ethernet network when in the office and GPRS network when in the filed. General Packet Radio Service (GPRS) is a new datum business developed from GSM. Its rate is up to 171.2kbs in theory, and it can get 30-50kbs in our applications. In China, every city even most of counties is covered with GSM network, and most of them offer GPRS service. The system can transmit data to a stable IP (server IP) what is known by the user. The system adopts simcom's SIM100-E GPRS module.S3C2410 communicates with GPRS module through serial port. The sketch of data transmission is shown as follow:

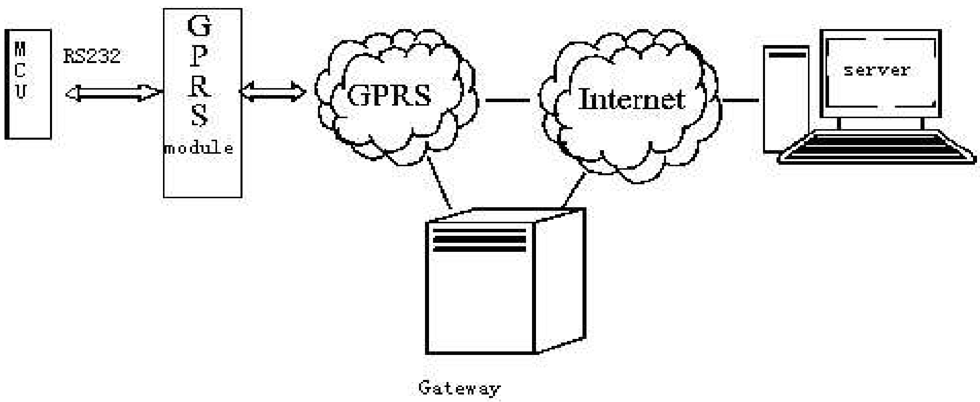

Figure 2 the sketch of data transmission (GPRS mode)

GPRS network is based on GSM network. The main hardware devices include GGSN(Gate GPRS Supporting Node) SGSN(Serving GPRS Support Node) HLR(Home Location Register) VLR(Visitor Location Register) BTS Base Transceiver Station and BSC(Base Station Controller).GPRS data flow shows as follow:

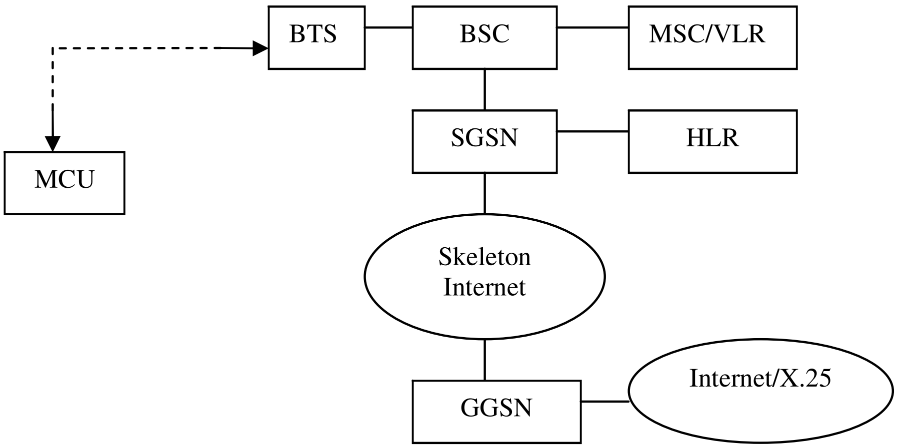

Figure 3 GPRS data flow

GPRS modem communicates with GSM base station. Then base station sends packets to SGSN. CGSN sends packets to destination network (Internet/X.25) after deals with packets from SGSN.

Human-machine Interface

Human-machine interface is an important part. It includes parameter setting, result display and the others. Keyboard is used to select function and input. LCD can display and tell users how to use it. LCD is 3.5 inch TFT displayer; keyboard includes “0-9” number keys, “.”, “Esc”, “Enter”, “Up”, “Down”, “back” and “close”.

DESIGN OF SOFTWARE

The software of the system adopts real-time operating system (RTOS) for free-embedded Linux operating system (armlinux). Compared with some other operating systems, Linux has the characteristic of multitask, stability, nice naturalization, excellent network. Furthermore, its original codes are open, so most users can use it according to their need. Because the system uses OS, the design of the software is composed of two main parts: device driver and application.

Device Driver

The driver is used to initialize a hardware device, such as the A/D conversion device, keyboard, LCD and so on. The user can not control the device directly in Linux system. Generally, the device needs to map into a file—driver, so the user can operate the "device file" like the other ordinary files. The driver hides the concrete details of the device and provides standard interface to different devices, such as read, write, open, close, ioctl. With these operations, applications can access to the hardware. The driver can be usually divided into three parts:

1. Auto-configure and initialization subprograms;
2. I/O requiring subprogram;
3. Interruption server subprogram.

The device has three functions: device initialization, data exchange between the device and kernel space, detect the errors that the device had made and deal with the errors.

The driver is used to detect the hardware's working condition. If the device works correctly, the driver initializes the device. The system transfers the relative interrupt server program in terms of the hardware's interrupt.

Application

The application programs include data acquisition, data save, data transmission and MiniGUI program. Because there are many programs must run at the same time, it is a good way of creating different threads to deal with them.

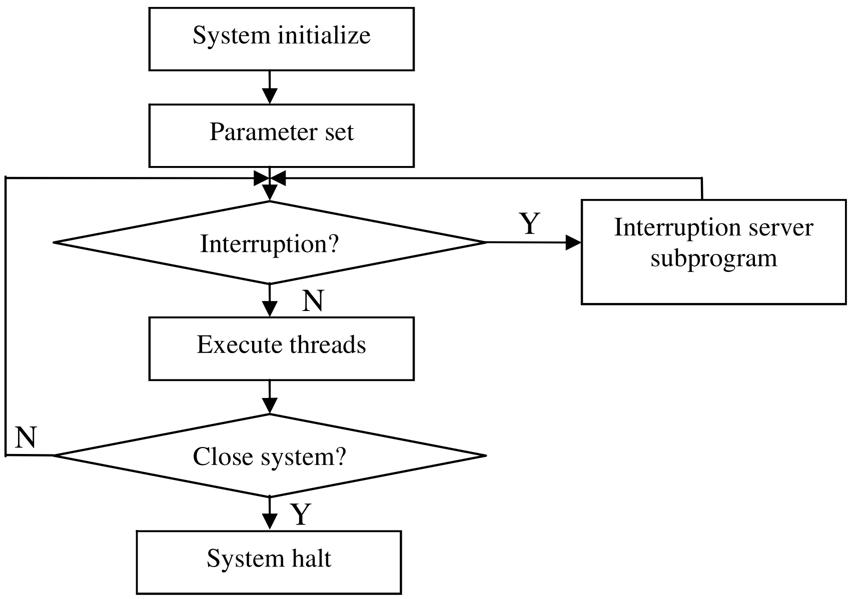

Figure 4 flow chart of application

Data acquisition: reads the data from driver and sends them to display; when data is read, save them in USB flash memory as a txt file; data transmission: reads the data file from USB flash memory and then transmits them through socket program. Armliux has embedded TCP/IP protocol, so the user can use conveniently. Figure 4 is a flow chart of the application.

CONCLUSION

The embedded system is based on the microprocessor ARM (S3C2410) which can collect many kinds of field information such as sensors, GPS signal. Moreover, it saves data by USB interface and transmits data through GPRS network. It has been proved that the system runs stably and reliably when worked in field; and the system had low-power, low-cost and high-performance. In addition, the hardware of the system is quite simple, and the program is convenient to be modified and updated. It is satisfied that the real-time response is quick enough in complex field surroundings.

But the system has some disadvantages which need to be improved. GPS precision lies on GPS OEM board. Now its precision is about 15m, which is not enough. We are adopting VRS (Virtual Reference Station) to improve its precision. And the system has different interfaces to adopt different sensors. In the future, we can design standard interfaces of sensors or wireless sensors, the data logger will be smaller and more feasible.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.42.05:681.11
Prethodno priopćenje
Preliminary communicaton

PRIMJENA TRAKTORSKE SONDE ZA UZIMANJE UZORAKA TLA UZ POMOĆ GPS- A

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SAŽETAK

Za intenzivnu proizvodnju potrebna je povoljna plodnost iz tog razloga analiza tla je nužna za modernu poljoprivredu. Do sada uzorci tla uzimani su ručno i zbog toga je Belje d.d. PC Ratarstvo, PJ Brestovac morao zapošljavati znatan broj djelatnika. Automatizacijom uzimanja uzorak tla postignuto je kvalitetnije uzimanje uzoraka tla s patentiranim strojem PHH-04 koji radi na dubini 30, 60 i 90 cm.

Na Belje d.d. PC Ratarstvo, na osnovu kronometriranja (2005. godine) rada traktorske sonde dobiveni su orijentacijski rezultati koji su promjenjivi ovisno od uvjeta rada. Najpovoljnije vrijeme uzimanja uzoraka tla je oko PVK tla, a masa cca 2 – 2,5 kg. Učinak stroja ovisi od dubine uzimanja uzoraka tla , da li se uzima uzorak 0 – 30 cm, od 60-90 cm dubine tla, dva uzorka od 0-30 cm i 30-60 cm ili tri uzorka na sve tri dubine 30, 60 i 90 cm. Od potrebnog broja uzoraka po mjestu uzorkovanja različit je učinak po satu rada stroja, odnosno broj uzoraka.

***Ključne riječi**: sonda, uzorak tla, kronometriranje, broj uzoraka*

UVOD

Bez analize tla nije moguće planirati maksimalni prinos, a ni odgovarajuću gnojidbu jer ne znamo što tlo sadrži. Za ostvarivanje maksimalnih prinosa potrebna je povoljna plodnost i iz tog razloga analiza tla je nužna. Vrijednosti kemijskih i fizikalnih analiza tla u laboratoriju ovise prvenstveno o pravilnom uzimanju uzoraka tla na terenu. Uzorci tla se uzimaju u razdoblju nakon žetve ili berbe do gnojidbe i pripreme tla za sjetvu narednog usjeva. Uzimanje uzoraka tla je potrebno obaviti u što kraćem vremenskom roku radi pravovremene analize tla. Da bi to bilo ostvarivo potrebno je izvršiti «automatizaciju» uzimanja uzoraka tla.

Sva dosadašnja rješenja «automatizacije uzimanja uzoraka tla», temeljila su se na sustavu pužnog transportera koji je kružno ulazio u tlo i samim tim poremetio strukturu uzorka tla.

MATERIJAL I METODA

Ispitivanje traktorske sonde provedeno je na Belje d.d. PC Ratarstvo, PJ Brestovac tijekom 2004. i 2005. godine uz pomoć GPS – a.

Tijekom 2003. godine praćeni su troškovi ručnog uzimanja uzoraka. Tom se prilikom cijev ručne sonde nabijala u tlo čekićem. To je dugotrajan, neučinkovit i skup proces. Iz tog razloga pristupilo se osmišljavanju bržeg i uspješnijeg uzimanja uzoraka tla strojno uz pomoć GPS – a. Na karti koja je bila podloga u omjeru 1 : 10 000 određene su točke na narušenoj mreži, a koje su prenesene na GPS Gauss-Krügerovom metodom Na osnovu ulaznih podataka (analiza tla i podataka sakupljenih anketom) dobiveni su rezultati proračuna gnojidbe u GIS-u (ArcMAP). U 2004. pristupilo se izradi traktorske sonde- PHH – 04 za koju je podnesena patentna prijava pod brojem 559-2/1-04-02 te je u istoj godini odrađen probni rad stroja. U 2005. godini pristupilo se kronometrijskom ispitivanju traktorske sonde.

Osnovne tehničke karakteristike sonde:

- dužina hidrauličnog dvoradnog cilindra: l=1300 mm,
- hod klipa hidrauličnog dvoradnog cilindra: l=1140 mm,
- promjer hidrauličnog cilindra Ø 110 mm,
- bešavna sonda za uzorkovanje dužine l= 1000 mm te promjera Ø 42 mm,
- spojnica između sonde za uzorkovanje i hidrauličnog cilindra dužine 127 mm promjera 60 mm.

Brzina ulaska sonde u tlo:

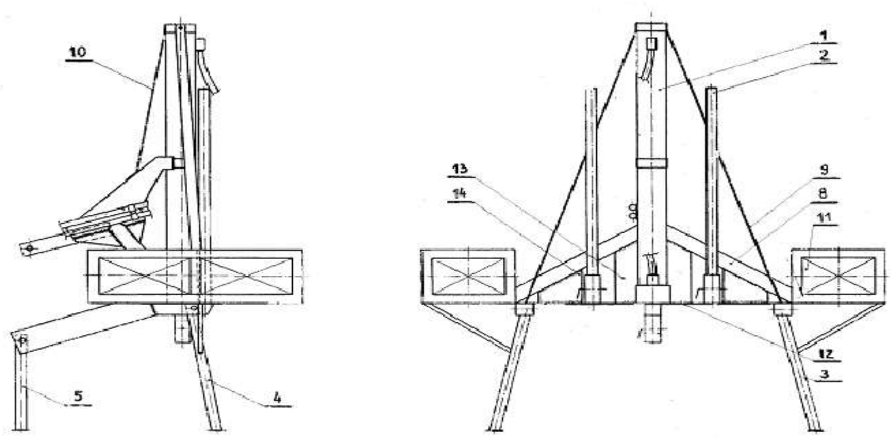
$$v = \frac{s}{t} = \frac{0,9}{30} = 0,03\ \mathrm{ms}^{-1}$$

Princip rada stroja za uzimanje uzoraka tla temelji se na bazi hidraulike, odnosno stroj radi uz pomoć dvoradnog hidrauličnog cilindra koji ima pravocrtno kretanje (gore- dolje), na taj način da utisne sondu u tlo, uzme određenu količinu tla te ga potom izvuče van.

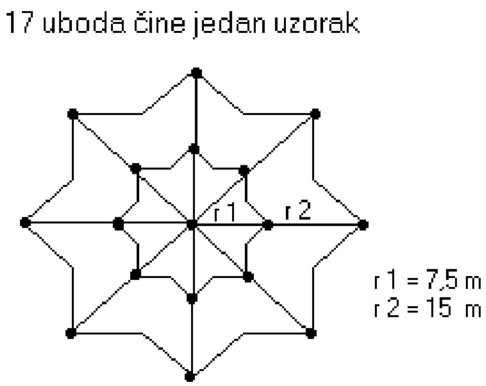
REZULTATI I DISKUSIJA

Na Belje d.d. PC Ratarstvo, PJ Brestovac od 2003. godine intenzivnije se počelo raditi na analizi tla, a samim tim i na uzimanju uzoraka tla. Uzorci tla uzimani su ručnom sondom (po kružnoj shemi od 17 uboda za jedan prosječni uzorak, Slika 2), uzorci su uzimani do dubine od 0 do 30 cm, za što je bilo potrebno 55 minuta pa do jednog sata. U istoj godini, ukupno je bilo utrošeno 746 sati rada djelatnika za uzimanje 31 uzorka tla za kemijsku analizu. Za navedeno bilo je potrebno 10 djelatnika u 10 radnih dana.

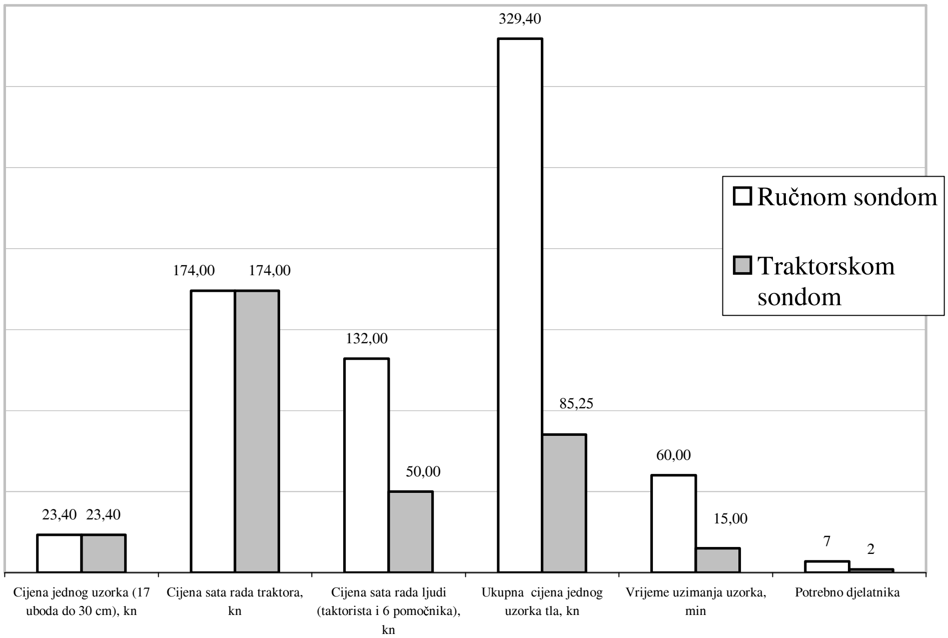
S obzirom na potrebu većeg broja ljudi, a i veći broj radnih dana potrebnih za uzimanje uzoraka tla što je neadekvatno dug period, pristupilo se ideji izrade traktorske sonde na hidraulički pogon (slika 1).



Slika 1 Skica traktorske sonde: 1 – hidraulični dvoradni cilindar, 2 - sonda za uzorkovanje, 3 - spojnica cilindar – sonda, 4 – zadnja noga, 5 – prednja noga, 6 – ruka sa polugama, 7 – poluga za toplink, 8 – piramida, 9 - bočni nosač cilindra, 10 – prednji nosač cilindra, 11 - kutija za uzorke, 12 – donja noseća ploča, 13 – prednje pojačanje piramide, 14 – srednje pojačanje piramide



Slika 2 Shema uzimanja uzoraka tla



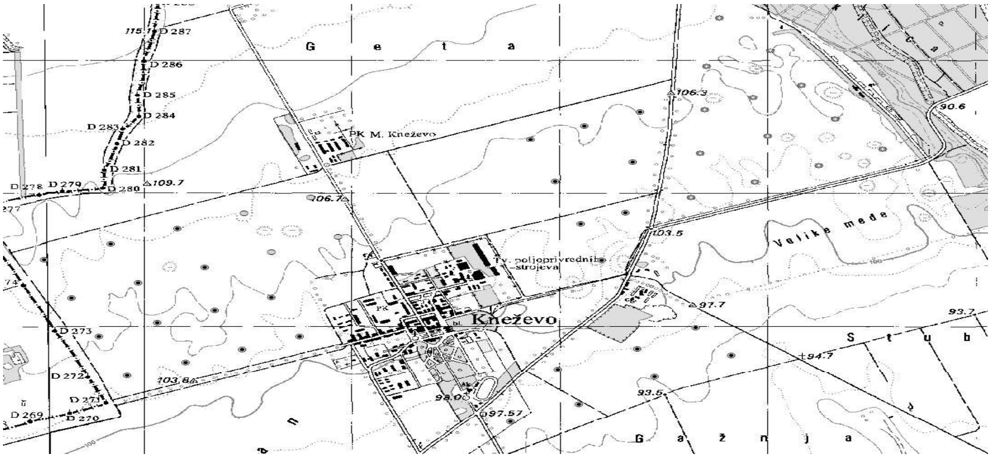
Slika 3 Odnos cijena uzimanja uzoraka tla ručnom i traktorskom sondom

U 2004. godini uzorci tla traktorskom sondom uzimani su samo na dubini od 0 – 30 cm. U istoj godini za analizu šećerne repe uzeto je 98 prosječnih uzoraka traktorskom sondom sa dva djelatnika u 42 radna sata na površinama koje su jedna od druge udaljene više od 5 km. U 2004. godini uzet je u prosjeku relativno mali broj uzoraka po satu jer je to bilo još uhodavanje stroja u radu, a i veća udaljenost površine od površine gdje su uzimani uzorci.

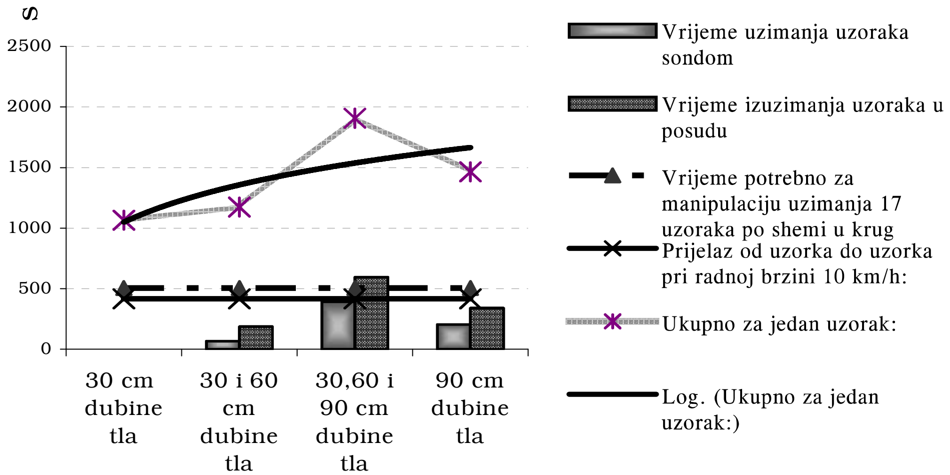
Izračunom ukupne cijene uzimanja uzoraka tla ručnom i traktorskom sondom dobivena je znatna razlika za cca 260 % (Slika 3.). Ovaj stroj bi mogli okarakterizirati kao poboljšanje i olakšanje uzimanja uzoraka tla jer je ljudski faktor skloniji pogreškama.

U 2004. godini pristupilo se suvremenijem načinu određivanja mjesta uzimanja uzoraka tla, GPS – om (Slika 4), uz pomoć Geodetske službe Belje d.d. čime se postiže ujednačenost uzimanja uzoraka tla jer se uzorci mogu uzimati na istom mjestu. Na taj način se postiže kontinuitet praćenja u sustavu tla, odnosno ispravnost i opravdanost dosadašnjih korektivnih mjera.

U 2005. godini pristupilo se detaljnijoj analizi iskorištenja traktorske sonde, tako da se pristupilo kronometrijskom ispitivanju stroja u četiri ponavljana. Na osnovu prosjeka dobivenih u mjerenjem trajanja uboda sonde u tlo, izuzimanja tla iz sonde u posudu, manipulacije traktora po shemi uzimanja prosječnog uzorka i vremena potrebnog da se dođe od «točke» do «točke» uzimanja uzoraka tla dobiveni su određeni rezultati (slika 5).



Slika 4 Karta točaka uzimanja uzorka tla GPS – om

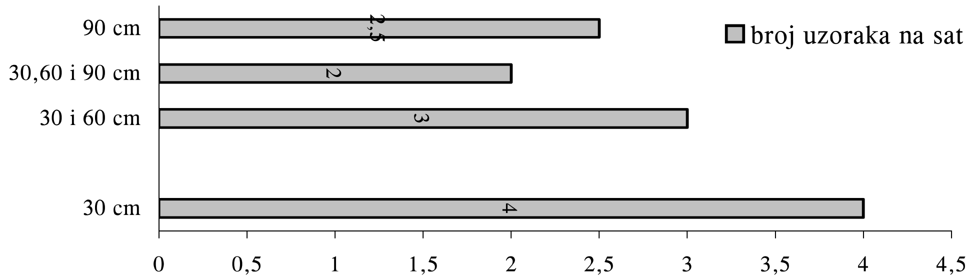


Slika 5 Vrijeme uzimanja uzoraka tla traktorskom sondom PHH – 04

Ispitivanjem traktorske sonde izmjereno je prosječno vrijeme ulaska sonde u tlo za jedan ubod do 30 cm dubine cca 3-4 s, do 60 cm cca 6,5 – 9 s, a za ubod na dubini od 90 cm potrebno je 10 do 14 s ovisno od strukture i vlažnosti tla. Vrijeme potrebno za vađenje uzorka tla jednog uboda iz sonde u posudu sa dubine 30 cm cca 4- 6 s, sa dubine 60 cm cca 8 – 12 s, a sa dubine 90 cm cca 18 do 22 s. Za manipulaciju traktora od uzorka do uzorka po shemi (Slika 2.) potrebno je cca 27 – 30 sek.

Na osnovi kronometriranja rada stroja dobiveni su orijentacijski rezultati koji su promjenjivi ovisno od uvjeta rada. Najpovoljnije vrijeme uzimanja uzoraka tla je oko PVK tla. Prosječan uzorak sa jedne dubine od 17 uboda teži cca 2 – 2,5 kg.

Učinak stroja ovisi od dubine uzimanja uzoraka tla , da li se uzima uzorak 0 – 30 cm, od 60-90 cm dubine tla, dva uzorka od 0-30 cm i 30-60 cm ili tri uzorka na sve tri dubine 30, 60 i 90 cm. Od potrebnog broja uzoraka po mjestu uzorkovanja različit je učinak stroja, odnosno broj uzoraka.



Slika 6 Prosječan broj uzoraka tla za 1 sat rada traktorske sonde

Za uzimanje jednog prosječnog uzorka tla od 17 uboda na 30 cm, za jedna sat rada prosječno je napravljeno 4 uzorka, kod prosječnog broja uzoraka 3 do 5 po tabli i prosječne udaljenosti od table do table do 5 km.

Za uzimanje dva prosječna uzorka tla od 17 uboda do dubine 30 i 60 cm, za jedan sat rada stroja prosječno je napravljeno 3 uzorka, kod prosječnog broja uzoraka 3 do 5 po tabli i prosječne udaljenosti od table do table do 5 km.

Za uzimanje tri prosječna uzorka od 17 uboda na tri dubine tla 30,60 i 90 cm, za 1 sat u prosjeku se napravi 2 uzorka, kod prosječnog broja uzoraka 3 do 5 po tabli i prosječne udaljenosti od table do table do 5 km.

ZAKLJUČAK

Ispitivanjem primjene traktorske sonde PHH – 04 za uzimanje uzoraka tla uz pomoć GPS – a ustanovili smo:

- Strojno uzimanje uzoraka tla dvostruko je isplativije i brže od ručnog uzimanja uzoraka tla.
- Stroj bi mogli okarakterizirati kao poboljšanje i olakšanje uzimanja uzoraka tla, jer je ljudski faktor skloniji pogreškama.
- Na osnovu kronometriranja rada stroja dobiveni su orijentacijski rezultati koji su promjenjivi ovisno od uvjeta rada.

- Najpovoljnije vrijeme uzimanja uzoraka tla je oko PVK tla.
- Prosječan uzorak sa jedne dubine od 17 uboda teži cca 2 – 2,5 kg.
- Od potrebnog broja uzoraka po mjestu uzorkovanja različit je učinak po satu rada stroja, odnosno broj uzoraka. Učinak stroja ovisi i od dubine uzimanja uzoraka tla.

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TRACTOR'S SONDE FOR TAKING SAMPLES OF SOIL WITH GPS

SUMMARY

For intensive plant production there is need for convenient rich soil so the soil analysis is necessarily for modern agriculture. Till now soil samples were taken manually and for that Belje d. d. PC Ratarstvo, PJ Brestovac had to employ many workers. Automation of soil sampling decreases costs of soil sampling. That was accomplished with this patent – Machine for soil sampling PHH-04 which works on 30, 60 and 90 cm depth.

On Belje d.d. PC Ratarstvo, PJ Brestovac on basis of chronometry (year 2005.) of work of the tractor sound, the orientational results were achieved, which are changeable depending on work conditions. The most favorable time for taking soil samples is around PVK of soil, which is 2-2,5 kg heavy. Performance of the machine depends on the depth of samples is the soil sample taken from depth of 0-30 cm, 60 – 90 cm two samples from 0-30 cm and 30-60 cm or three samples from all three depths 30, 60 and 90 cm. Performance of the machine, and number of samples depends on needed number of samples on the place of sampling.

Key words: *sound, soil sample, chronometry, number of samples.*

34. SIMPOZIJ
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MEHANIZACIJE
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628.8:631.234:631.344
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Expert paper

FUZZY ADAPTIVE CONTROL OF GREENHOUSE TEMPERATURE

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SUMMARY

Fuzzy controller has been successfully adopted to control greenhouse environment temperature. Since the principle of greenhouse environment temperature, under the influence of many factors, has the characters of nonlinear and non-stationary, it's necessary for control algorithm to have the capability of self-adaptability to get better control performance. This can be obtained by applying the algorithm of variable universe adaptive fuzzy controller. The algorithm adjusts the universes of fuzzy controller's inputs according to their value. If they are small the universes will expand and vice versa. In the paper, the design of the greenhouse temperature basic fuzzy controller is introduced, then, it's proved that basic fuzzy controller is in essence an interpolator, and the algorithm of variable universe in fuzzy controller is discussed in detail. An important concept, contraction-expansion factor, is discussed. The results of experiments carried out in a Venlo greenhouse indicate that the variable universe algorithm, compared with the basic fuzzy controller, improves the performance of the fuzzy controller entirely, the ITAE decreases about 80 percents, and it is feasible to use it on line since the algorithm is simple and need few system resources.

Key words: *variable universe, adaptive fuzzy controller, contraction-expansion factor, greenhouse, environment temperature control*

INTRODUCTION

Suitable environment temperature is very important for greenhouse-crops. There are lots of successful examples that using fuzzy control to regulate greenhouse environment temperature automatically [2][3][5][10][14]. Because greenhouses have the different scale, structure and climate, the dynamic processes of temperature are different. Even in the same greenhouse, there are different temperature dynamic processes along with the different season, that is to say, the nature of greenhouse temperature dynamic process is time-variance. Although a temperature fuzzy controller's parameters have been carefully adjusted and optimized when the controller is developed and installed, its performance is not optimal at all time after it starts to run. Sometimes this even makes the temperature cannot satisfy the demands of greenhouse-crop production. In order to solve the problem, it is necessary to apply adaptive fuzzy controllers.

Researches indicate that though time-variance exists in the greenhouse temperature dynamic process, the trend of temperature dynamic process is similar, and just the dynamic process parameters, namely time-constant etc, changed. In order to improve the control quality under the time-variance, the structure of fuzzy controller is needless to be changed, some controller's parameters modification is enough. In the paper, firstly, the design of basic fuzzy controller (BFC) of greenhouse environment temperature is introduced. Then, a kind of adaptive fuzzy controller, namely variable universe adaptive fuzzy controller (VUAFC) is applied to improve the system sensitivity and robustness in the chamber temperature regulation. And then, some experiments are carried out, and the control effects of BFC and VUAFC are compared.

DESIGN OF THE BFC OF ENVIRONMENT TEMPERATURE [9] [14]

Scholars have studied the greenhouse environmental temperature dynamic process, and find that though it is a non-linear process, the dynamic process can be approximately simulated by a delayed first-order or second-order process in a satisfying precision [1][15]. For different temperature regulation equipment, the time constant is different. On the basis of the above, the BFC of environmental temperature can be designed nearly without the expert's knowledge. So it can get the satisfactory result to use a two-dimensional fuzzy controller whose inputs are the temperature error and the change of error.

The schematic diagram of the BFC is as fig. 1. r is the set-point of environmental temperature that is given by the agricultural expert; y is the current chamber temperature. Between dashed lines is the BFC. The input e_1 is the error of temperature, and e_2 is the change of e_1. Then, $e_1 = r - y$, $e_2 = [e_1\,(\mathrm{k}) - e_1\,(\mathrm{k}-1)] / T$, T is the sampling interval. u is the output of the BFC.

E_1, E_2, U are the fuzzy variables corresponding to e_1, e_2, u respectively. The division of E_1, E_2, U is same, denoted by $\boldsymbol{A}$. $\boldsymbol{A}$ belongs to $\boldsymbol{X}$, $\boldsymbol{X}$ is the universe of E_1, E_2, U. Let $\boldsymbol{A}=\{A_i\}$={Negative-Big, Negative-Middle, Negative-Small, Zero, Positive-Small, Positive-Middle, Positive-Big}, or $\boldsymbol{A}$={NB, NM, NS, ZE, PS, PM, PB}. The membership functions of $\boldsymbol{A}_i$ are triangle function shown in Fig. 2. Let x_i is the peak point of A_i, $\boldsymbol{A}$ satisfies (1), (2) and (3) apparently.

$$(\forall i)(\exists x_i \in X)(A_i(x_i) = 1) \tag{1}$$

$$(\forall i, j)(i \neq j \Rightarrow x_i \neq x_j) \tag{2}$$

$$\left(\forall x\in X\right)\left[\sum_{i=1}^{n} A_i\left(x\right)=1\right] \tag{3}$$

We call ***A*** a family of normal fuzzy sets on ***X***.

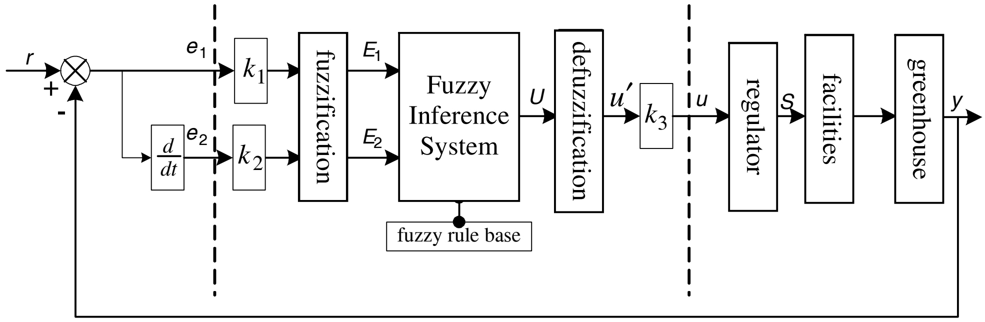

Figure1 Greenhouse environmental basic temperature fuzzy controller

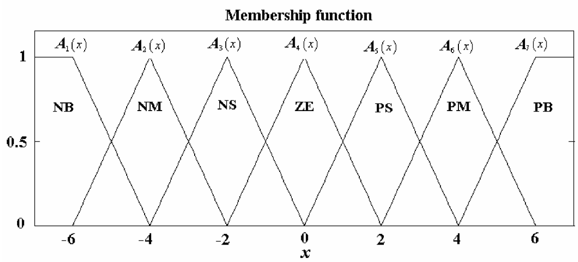

Figure 2 The membership function of E_1, E_2, U

According to the characteristics of the two-order system's dynamic process, the fuzzy rule base can be designed and reported in table1. Fuzzy inference rules are:

$R^{(j)}$: *if* E_1 *is* A_{1j} *and* E_2 *is* A_{2j} *then* U *is* G_j (4)

$$j=1,2,\ldots,M;\quad A_{1j},A_{2j},G_j\in A$$

In the paper, M = 49. If Spot fuzzification method, centroid defuzzification method and Mamdani-type inference are adopted, then the fuzzy logic system is:

$$u=k_u u'=k_u\frac{\sum_{j=1}^{M}\bar{U}_j\left[\prod_{i=1}^{2}A_{ij}(x_i)\right]}{\sum_{j=1}^{M}\left[\prod_{i=1}^{2}A_{ij}(x_i)\right]} \tag{5}$$

$\overline{U}_j$ is suitable for $G_j(\overline{U}_j)=1$. That is, $\overline{U}_j$ is the peak point of G_j.

Substituting equation (3) for equation (5), then

$$u = k_u u' = k_u \sum_{j=1}^{M} \overline{U}_j \left[\prod_{i=1}^{2} A_{ij}(x_i) \right] \tag{6}$$

Table 1 Fuzzy Control Rules Table

E_1	E_2						
	NB	NM	NS	ZE	PS	PM	PB
NB	PB	PB	PB	PB	PM	ZE	ZE
NM	PB	PB	PB	PB	PM	ZE	ZE
NS	PM	PM	PM	PM	ZE	NS	NS
ZE	PM	PM	PS	ZE	NS	NM	NM
PS	PS	PS	ZE	NM	NM	NM	NM
PM	ZE	ZE	NM	NB	NB	NB	NB
PB	ZE	ZE	NM	NB	NB	NB	NB

DESIGN OF VUAFC

The non-linear control by means of fuzzy controller is the non-linear mapping between input and output. The mapping is implemented by expert's experience and the linguistic rules [4]. The mapping is a non-linear function whose independent variables are the inputs of the fuzzy controller; the dependent variables are the output of the fuzzy controller. It has been proved that Fuzzy controller is a 'universal approach system' [11], and the output of a fuzzy controller can approach a certain non-linear function with a certain fuzzy base. Reference [6] proved that a fuzzy controller is in essence a binary piecewise interpolator, and the fuzzy sets, as antecedents of inference are just the base functions of interpolation. This means that the output of a fuzzy controller approximate a non-linear function by means of the mechanism of interpolation, and it can sufficiently approach the non-linear function if the interval of fuzzy sets' peaks is sufficiently short. In order to shorten the interval of fuzzy sets' peaks, more fuzzy rules are needed. Unfortunately, for the fuzzy controller that fuzzy base is obtained by inducing the experts' knowledge, it is difficult to gain more fuzzy rules. However, the aim of control is to keep the error round the zero. So, if there is a method to increase the base functions within the segment near the error to partially improve the approach precision will preferably solve the problem [7][8]. This is the idea of variable universe fuzzy control.

The so-called variable universe means that some universes such as X, can change with changing variables x, denoted by

$$X(x)=[-\alpha(x)E,\ \alpha(x)E] \tag{7}$$

where $\alpha(x)$ are contraction-expansion factors of the universe X. Being relative to variable universes, the original universes $X = [-E, E]$ are called initial universes. The situation of variable universes changing is shown as fig.3.

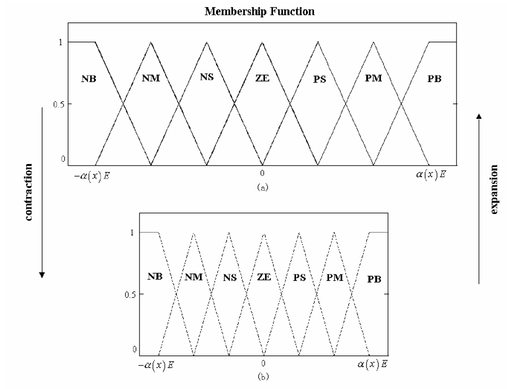

Figure 3 schematic of contracting /expanding universe

Several forms of $\alpha(x)$ are given as follow:

$$\alpha(x) = \left[\frac{|x|}{E}\right]^k + \varepsilon \quad 0 < k < 1 \tag{8}$$

$$\alpha(x) = \frac{1}{1-\varepsilon e^{-kE}}(1-\varepsilon e^{-k|x|}) \quad k > 0 \tag{9}$$

$$\alpha(x) = \frac{1}{1-\varepsilon e^{-kE^2}}1-\varepsilon e^{-kx^2} \quad k > 0 \tag{10}$$

Where k is a parameter that can be chosen by designers, and ε is a very small constant. A VUAFC based on table 1 can be represented by an piecewise dynamic interpolation function:

$$u = k_u u' = k_u \sum_{j=1}^{M} \bar{U}_j \left[\prod_{i=1}^{2} A_{ij}\left(\frac{x_i}{\alpha(x_i)}\right)\right] \tag{11}$$

EXPERIMENT AND ANALYSIS

Performance specification of system response

In order to evaluate the system performance roundly, three kinds of specifications were applied: dynamic performance specifications, stable-state performance specifications and synthetic performance specifications. The performance specifications adopted in this paper are: over-regulation, rise time, steady-state error and ITAE (Integral of product of Time and Absolute-value of Error) criterion [12].

System error is $e(t)= r(t) - y(t)$. Steady-state error is defined as

$$e_{ss} = \frac{2}{t_1 - t_0} \int_{\frac{t_0+t_1}{2}}^{t_1} e^2(t)dt \quad t_1\text{-}t_0 \text{ is the transient response time} \tag{12}$$

ITAE criterion is denoted:

$$J_{ITAE} = \frac{1}{t_1 - t_0} \int_{t_0}^{t_1} t\left|e(t)\right| dt \quad t_1\text{-}t_0 \text{ is the transient time of control system} \tag{13}$$

From (13), J_{ITAE} is the time weighting sum of system error, while error of steady system reduces gradually as time elapses. So it can be concluded that J_{ITAE} can reflect the dynamic and static performance of system. The smaller value of J_{ITAE} can indicate quick response speed, short regulation time, small over-regulation and small steady-state error. When J_{ITAE} reaches minimum, dynamic process of system response is optimized. It is very suitable to use this index to evaluate the dynamic response performance of greenhouse environmental temperature.

Experiments and analysis

The VUAFC has been used in the environment temperature control of an experiment greenhouse. The greenhouse is located on the campus of China Agricultural University. It is a North-China type multi-span greenhouse, an improved Venlo-type greenhouse. It is orientated south-north, and its covering material is two-layer polyethylene film. It has three spans that each span is 8m long. The inside ground area is 432m^2. It is equipped with heating system, ventilator and water pad. All these facilities are controlled by the greenhouse intelligent control system (GHICTLS) shown in fig. 4.

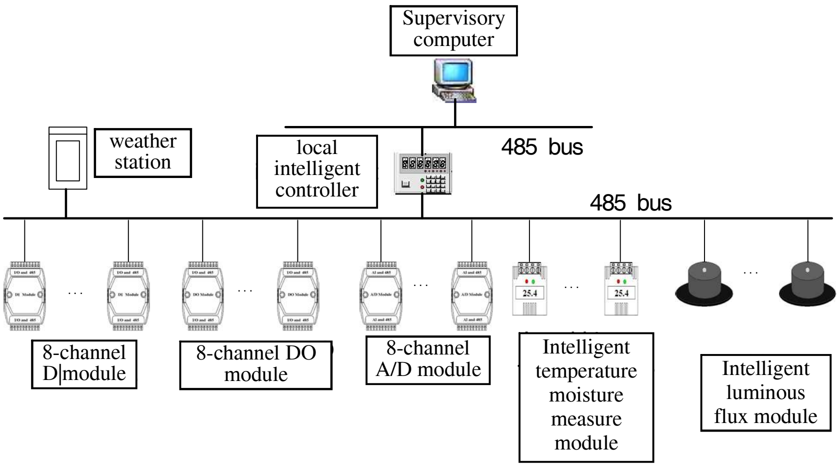

Figure 4 skeleton drawing of GHICTLS.

GHICTLS is a 3-layer distributed control system that consists of the supervisory computer, local intelligent controller, and measure-control module. 485-bus communication protocol is adopted between layers. The system software, greenhouse intelligent control software (GHICTLS Version 1.0), is run on the supervisory computer. The control algorithm is embodied in the system software in the form of DLL.

The chamber temperature is measured by the intelligent temperature-moisture measurement module. Its temperature measure accuracy is ±0.2 degree Celsius. There are 3 temperature-moisture measure points inside the greenhouse, 1 point each span and it is hung at the point that is 1.5m up away the ground and is in the middle of geometry plane of each span. The chamber temperature is the average of 3 measurement values.

In order to test the VUAFC, the chamber temperature control experiments were carried out in the greenhouse introduced above in Dec. 2003. First, the BFC was adopted, then, the VUAFC was applied and compared its control result with the BFC's. The chamber temperature depends on the hot water flow rate of the heating system, and the flow rate is related to the valve travel. The course of the experiment is that the supervisory computer firstly measure the chamber temperature and calculate 'e_1' and 'e_2', the inputs of the controller then, infer 'u', the output of the controller. 'u' is the time that the valve is powered, if $u > 0$ the valve position augments and vice versa.

During the experiment period some tomato plants were planted in the greenhouse, and began to be harvested. Because air temperature is low in the winter night, heater is needed to maintain the growth of tomato; the experiment is executed during the night. The chamber temperature set point is 13 degrees Celsius. When the temperature reduces to 8 degrees Celsius, the controller will be turned on to control the valve, when the temperature is fixed in the allowable error range that near the set-point value, the experiment end. The parameters of the BFC used in the experiment are set that k_1=2, k_2=20, k_3=30. The VUAFC is BFC +$\alpha(x)$ (contraction-expansion factor), the BFC is same as above, and $\alpha(x)$ adopt (10), ε = 0.8, k = 1. Fig.5 is the environmental temperature response curves of the BFC and VUAFC. Table 2 compares the main Performance specification of them. From fig. 5 and table 2, it is shown that VUAFC is better than BFC on dynamic performance specifications, stable-state performance specifications and synthetic performance specifications.

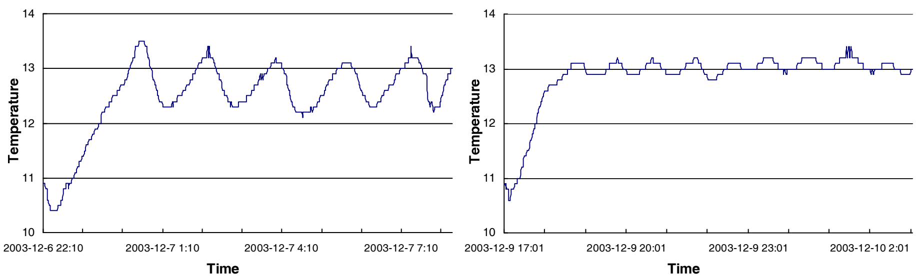

Figure 5 Response curve of BFC and VUAFC
(a)Response curve of BFC; (b) Response curve of VUAFC

Table 2 Comparison of Performance specifications of BFC and VUAFC

	Over- regulation / %	rise time / min	steady-state error	J_{ITAE}
BFC	3.8	132	0.27	150.1
VUAFC	3	98	0.02	31.05

CONCLUSIONS

By the experiments, we learn that variable universe adapted fuzzy control algorithm is a powerful tool for greenhouse temperature control, a nonlinear process. It has some good characteristics such as short settling time and rise time, little over-regulation, very small stable error, strong and globally asymptotically stable robustness. This algorithm is easy to be implemented and, since it will not occupy too much resources, it not only can be used on normal computer, but also can be used on single-chip microcomputer system. Because of the non-stationary of temperature dynamic process, the basic fuzzy controller as a temperature controller will not always be the optimal, and sometimes it is improper. Variable universe adaptive fuzzy controller has very strong robustness, so it can solve the problem excellently.

The performance of variable universe adaptive fuzzy controller depends on the performance of basic fuzzy controller and the contraction-expansion factor. Apply parameter on-line self-tuning algorithm [13] in environmental temperature basic fuzzy controller can optimize the performance of fuzzy controller efficiently. Otherwise, How to choose a proper contraction-expansion factor is a problem that should be studied in the future.

ACKNOWLEDGEMENTS

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Preliminary communication

ON DOUBLE LEVEL FUZZY CONTROL TECHNIQUE OF TRACTOR AUTOMATIC STEERING

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SUMMARY

This paper mostly introduces steer control of tractor automatic driving, and the double level fuzzy control technique is put forward, in addition fuzzy control formula is designed, which is evaluated by using simulink software. The result reveals that the double level fuzzy control technique produces the behaves very similar to driver, and is suitable for tractor automatic steering system

Key words: *tractor; autonomous driving; fuzzy control*

INTRODUCTION

Autonomous tractors are believed to be one of the driving forces for precision farming, since they can perform farming operations accurately and automatically and assure precision task, such as holding space of ridge in a field, in addition taking from technique request of operator and decreasing overlap operation, and accelerating rate of progress and economize cost. Document[1] indicates proficiency tractor driver can plough in 10cm precision, but after a day's work, precision will recede much more; whereas autonomous tractors based on GPS, which cost is 42% more than general tractors', can maintain operation in 3cm precision all time, avoid overlap operation, save fuel consume and cut down dosage of pesticide; So they can enhance 40% profit of farm. Autonomous tractors have been reached in worldwide, which reach keystone is Autonomous steering, namely yaw control.

Navigation control, which will firstly be designed based on control point, in according to operate mode, is sticking point of autonomous tractor, for example it is selected in front when tractor used in reaping which dead stocks are equipped; it is selected in rear when tractor used in plough which dead stocks are equipped. Front control point that may be select at front axes and rear control point may be select at rear axes herein putting up vehicle dynamic model. Although there are many navigation control methods, control parameters are all yaw error and yaw angle error, which are limited in permit bound in order that autonomous tractor runs along desire route[2□3], at the same time data fuse that can make two parameters change into one parameter reinforces data nicety; last navigation control is confirmed. In the context vehicle dynamic model based on center of mass is putted up, and a sort of complex fuzzy control technique of tractor automatic steering is put forward, which suits for autonomous tractors.

Dynamics Model of Tractor Steer Control

In order to realize tractor auto driving which is key for navigation control, firstly control point should be selected, for example, control point should be selected in tractor rear when it perform plough or planting, whereas control point should be selected in tractor front if tractor carry out reaping. Taking into account convenience of setting up tractor model the front control point generally be lied in the front axes, the rear control point generally be lied in the rear axes or COM(center of mass)[2]; secondly control parameter should be made certain, generally which are yaw error and yaw angle. If yaw error and yaw angle are controlled, tractor will driving along expectation route.

If steering machine is predigested by first-order inertia system, the tractor yaw angle was chosen as a state variable in order to compare it for emulation. The tractor dynamics was then represented in matrix form to determine tractor slip angle, yaw rate, steer angle and yaw angle:

$$\begin{bmatrix} \dot{\beta} \\ \dot{\omega} \\ \dot{y} \\ \dot{\psi} \\ \dot{\delta} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & 0 & 0 & B_1 \\ A_{21} & A_{22} & 0 & 0 & B_2 \\ v & 0 & 0 & v & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -\frac{1}{\tau} \end{bmatrix} \begin{bmatrix} \beta \\ \omega \\ y \\ \psi \\ \delta \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ \frac{1}{\tau} \end{bmatrix} \delta_d$$

where $A_{11} = -\frac{k_1 + k_2}{mv_c}$, $A_{12} = -1 + \frac{k_2 l_2 - k_1 l_1}{mv_c^{\ 2}}$, $A_{21} = \frac{k_2 l_2 - k_1 l_1}{M}$, $A_{22} = -\frac{k_2 l_2^{\ 2} + k_1 l_1^{\ 2}}{Mv_c}$, $B_1 = \frac{k_1 - F_{x1}}{mv_c}$, $B_2 = \frac{l_1 (k_1 - F_{x1})}{M}$. m is mass of tractor, kg. M is the turning inertia with regard to tractor COM, kg·m^2. l_1 and l_2 are the distance of the front and rear wheel to tractor COM, m. V_c is velocity of tractor-body, km/h. F_{x1} and F_{x2} are resistance of the front and rear wheel, N. F_{y1} and F_{y2} are the side forces at the front and rear wheel, N. F_W is the side force of side wind, N. M_W is the moment of side wind, N·m ρ is curvature of tractor steering, m^{-1}. $R = \frac{1}{\rho}$. ψ is yaw angle, rad. β is slip angle of tractor, rad. δ is tractor steering angle, rad. τ is inertia time constant of steering system. δ_d is expectation tractor steering angle.

Yaw Double Level Fuzzy Control

Since action of wheel of the tractor is complex in allusion to characteristic of tractor task: low speed and no way, and a precision tractor model is not mostly putted up, besides speed change of tractor-body impact the frequency region response, tractor navigation control will avoid depending on tractor dynamics model. However expert knowledge can be expression using fuzzy rule which can judge state of controlled object real time without precision math model in fuzzy control that has characteristic of robust and applicability spontaneously[3,4]. In this paper the double level control is used in tractor yaw control, so drivers' knowledge is introduced.

Double level control (figure 1) has strong control function, its principle is that when language variable is great than zero section, the first fuzzy is work; the other way round when language variable is small than zero section, the second fuzzy control work alone, in order to enhance system stabilization performance.

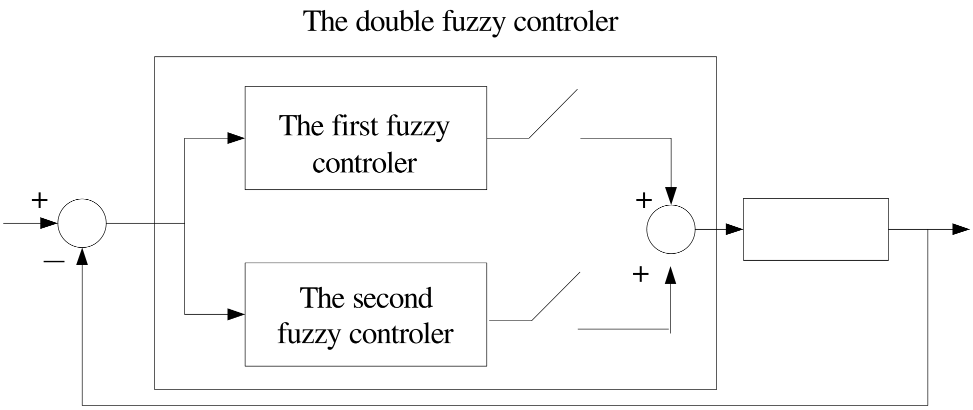

Figure 1 Complex fuzzy control system

In this research, the first fuzzy controller is selected, which there are two input, yaw error (y) and yaw angle(ψ), and one output(δ). $y \in$ [-1 1] and y ={ *NB NM NS 0 PS PM PB* }; $\psi \in$ [-1.57 1.57] and ψ ={ *NB NM NS 0 PS PM PB* }; $\delta \in$ [-0.5233 0.5233]and δ ={ *NB NM NS 0 PS PM PB* }; Mamdani rule is used, subjection function of language variable is trapezium and triangle, then control rule is showed in table 1, and relation between input and output is show in figure 2.

Table1 First fuzzy control rule

ψ δ y	*NB*	*NM*	*NS*	*O*	*PS*	*PM*	*PB*
NB	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
NM	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
NS	*NB*	*NB*	*NM*	*NM*	*NM*	*NS*	*NS*
O	*NB*	*NM*	*NS*	*O*	*PS*	*PM*	*PB*
PS	*PS*	*PS*	*PM*	*PM*	*PB*	*PB*	*PB*
PM	*PM*	*PM*	*PM*	*PB*	*PB*	*PB*	*PB*
PB	*PM*	*PM*	*PB*	*PB*	*PB*	*PB*	*PB*

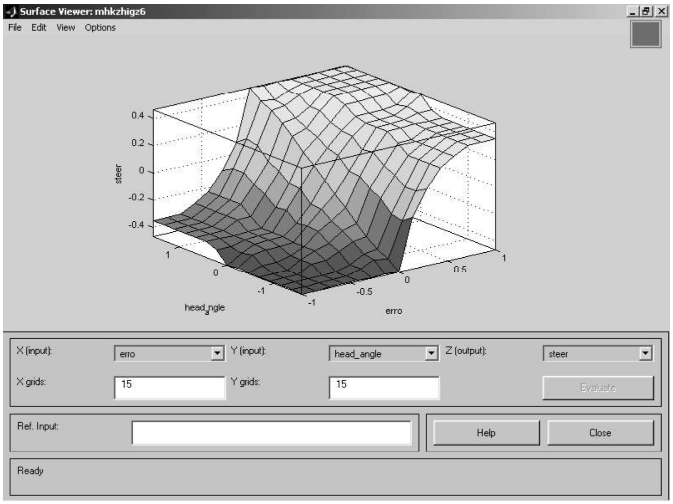

Figure 2 Relation between input and output of first fuzzy control

The second fuzzy controller is selected, which there are also two input, yaw error (y) and yaw angle(ψ), and one output(δ). $y \in$ [-0.3 0.3] and y ={ *NB 0 PB* };$\psi \in$ [-0.3 0.3] and ψ ={ *NB 0 PB* };$\delta \in$ [-0.5233 0.5233] and δ ={ *NB 0 PB* }; Mamdani rule is used, subjection function of language variable is trapezium and triangle, then control rule is showed in table 2, and relation between input and output is show in figure3.

Table 2 Second fuzzy control rule

ψ / U / δ	*NB*	*O*	*PB*
NB	*NB*	*NB*	*NB*
O	*NB*	*O*	*PB*
PB	*PB*	*PB*	*PB*

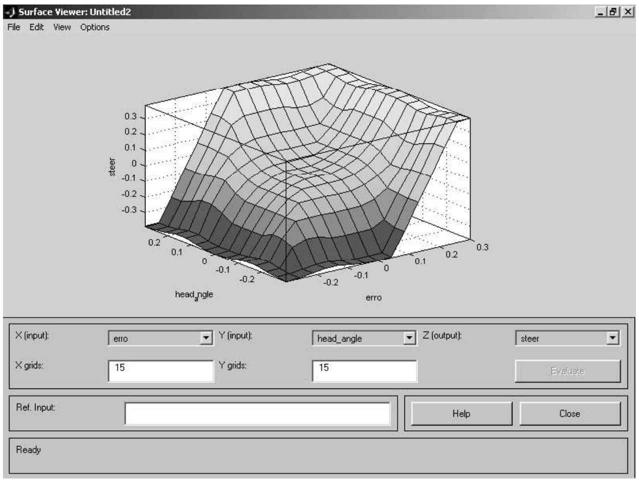

Figure 2 Relation between input and output of second fuzzy control

RESULTS AND DISCUSSION

A tractor character parameter, such as $l_1 = 1.575$m $l_2 = 0.86$m, k_1=80kN/rad, k_2=100kN/rad, $v = 3$m/s, M =4834kg·m^2. valve of fuzzy control is yaw error is 0.2 and yaw angle is 0.157 when yaw error and yaw angle are more than valve, the first fuzzy control works, which will enhance output but it can not exceed max output($\pm$0.5233rad); when yaw error or yaw angle is less than valve, the first fuzzy control will be cut down, then the second fuzzy control work by oneself. In order to advantage, Original yaw error is 0, finally yaw is 0.3, namely Original yaw error is 0, finally yaw is 0.3, and original yaw angle is 0, in order that change route of tractor is simulated. Results are shown in figure 4, and the results that fuzzy control work alone are shown in figure 5. The simulation results indicate that representation of double level fuzzy control is better than single fuzzy control, and embodiment driver knowledge which is suitable for tractor automatic steering system.

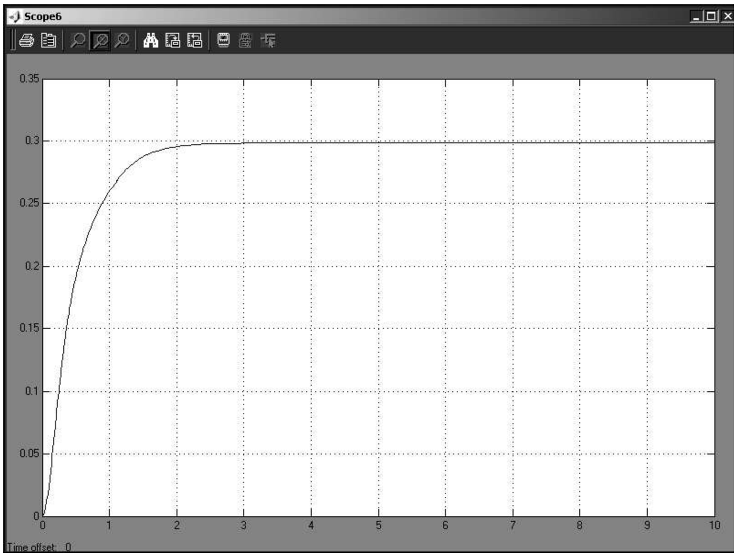

Figure 4 Results of double level fuzzy control

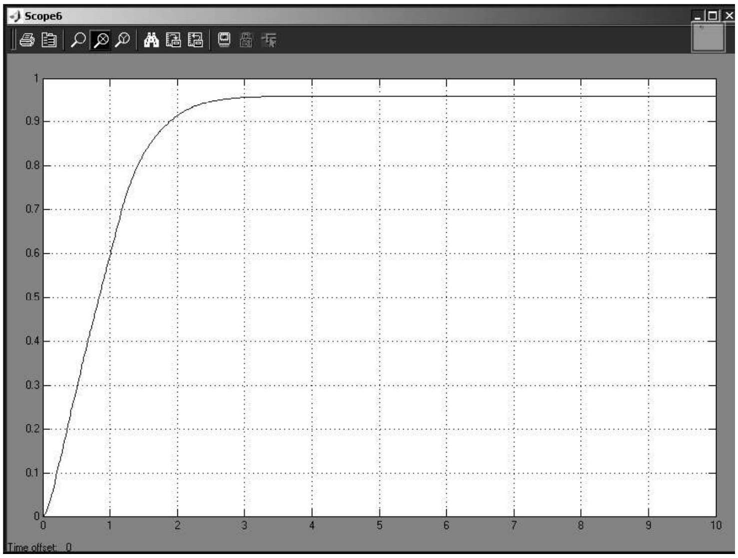

Figure 5 Results of single fuzzy control

CONCLUSION

The main goal of this study was to develop a new method that can enhance navigation capable of autonomous tractor. Such a double level fuzzy control is put forward based on single fuzzy control, and tractor dynamics model is set up, which is dased for simulation. Computer simulation analyses demonstrate that the double fuzzy control can enhance control performance, such as reducing stabilization error and improving response speed besides realizing personification drive.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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ECONOMIC OF THE MECHANISATION OF FIELD ROOT VEGETABLES PRODUCTION TECHNOLOGY

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SUMMARY

The total growing area of root vegetables in Hungary is ca. 3-4 thousand hectares including 2-2,5 thousand hectares of carrot growing area. Carrot is a very important vegetable for fresh consumption as well as for the deep freezing and for the canning industry. The carotin content (α and β 5-30 mg/100mg) of the carrot is the highest among all root vegetables and its sugar (4-6 %), ascorbic acid and potassium contents are also remarkable what makes carrot play a major role in nutrition in general, but first of all in infant nutrition. In Europe the total carrot production is about 4,5 Million tons on ca. 150 thousand hectares. The greatest producers are Great Britain, Poland and France. In Hungary carrots are grown all over the country, but the most important growing areas are South-Hungary, the Kisalföld, Fejér county and the north-eastern part of the Alföld.

Due to the many different ways of its use, different methods are applied in carrot production. Early spring carrots are offered in bundles, later on washed, defoliated carrots are offered for fresh consumption. The late varieties are produced either for prompt procession for the canning industry or for long term storage. In accordance with the growing methods there is a wide selection of varieties and different production technologies are applied.

Hereinafter we are focusing on the production technology of carrots meant for fresh consumption or for the canning industry. This is a field which can easily be mechanized and which plays the most important part in the domestic production. The technology specified below can also be applied in parsley growing.

The present essay presents the up-to-date mechanized production technology of carrot production from ridge preparation till harvesting including packaging to a certain extent as well.

The aim of the evaluation and presentation of experiences together with the performance and economic data of machines necessary for production is to

promote the spreading of modern carrot growing technology. (Dimény-Fenyvesi-Hajdú 2004) [1]

Key words:

Picture 1 Root vegetable harvesting machine type ASA-LIFT-COMBI 1000

THE MOST IMPORTANT MACHINES OF THE TECHNOLOGY

The studied technology is based on the drag picking (*ASA-LIFT-COMBI-1000*) (**Picture 1**) and digging system (*GB-02*) **(Picture 2**) harvesting machines which worked in ridge cultivation mode on the territory of RÓNA MgSz in Szabadszállás and CAROTA Bt. in Soponya. For the individual arable land operations the following machines were used: the *RUMPSTAD FHAX5 RSF 2000 ridge forming machine* for ridge forming (**Picture 3**), for seeding the *AGRICOLA ANT-3-290 precision driller* (**Picture 4**), for the renewal of ridges the *BADALINI VARIAX EP/85W 1400 GLS ridge spacing machine* (**Picture 5**). For manipulating carrots the *SCHNEIDER SWF 500 grader* (**Picture 6**) was used.

Picture 2 root vegetable harvesting machine type GB-02

Picture 3 Ridge forming machine type RUMPSTAD FH4X75 RSF 2000

Picture 4 Precision driller type AGRICOLA ANT-3-290

Picture 5 Ridge spacing machine type BALDINI VARIAX EP/85W 140

Picture 6 Grader type SCHNEIDER SWF 500

PRESENTATION OF THE PRODUCTION TECHNOLOGY

The machine technology of production is presented on the basis of **Table 1**. The table shows the denomination of operation, the machine applied for the certain operation, and the type of the power machine connected to it together with the shift performance of the connected machines and the calculated shift performance of the working machine for the given economic year. Some of the economic data are also included: the selling price of the working machine and the power machine in the year 2004, the operational cost of the same per shift hour together with the operational cost of the connected machines. (**Gockler-Hajdú 2004**) [3]

Stubble stripping by disc-harrow is unavoidable in order to work the stem remains of the forecrop into the soil and to prevent weeding. The next operation is deep ploughing. The ploughing processing is realized in the form of dragging. The subsequent delivery of nutrients is ensured through the transport and spreading of fertilizers. This is followed by the preparation of ridge beds, sowing and later on by the renewal of ridges. Plant protection is applied once as a pre-emergence treatment and three times afterwards as a post-emergence treatment. Stock treatment is applied six times. In the vegetation period of cultivated plants irrigation is necessary in order to achieve a high quality final product and a better crop yield. This is done by a linear irrigation system.

In case the final product is meant for canning purposes harvesting is done by a digging-system root vegetable harvesting machine type **GB-02,** in case it is meant for fresh consumption by a root vegetable harvesting machine type **ASA-LIFT-COMBI-1000** which can be considered the major machine of the technology and by which picking and stalk removal is done in one course.

If the goods are meant for the fresh market it makes the application of a grader necessary. Four-fraction grading can be realized by a **SCHNEIDER SWF 500** type grading machine.

The well proved production process and technology by which outstanding quality can be produced for several years ensures the optimal use of the machinery.

RESULTS OF THE ECONOMIC SURVEY

The results of the economic survey of carrot production on a 20 hectare area are shown in **Table 2**. Apparently, the machine working time necessary for the cultivation of the 20 hectare growing area in case of connected machines has been stipulated related to the individual operations. On this basis the direct operational cost of the connected machines can easily be calculated by multiplying the *direct operational cost of the machine per hour* (Table 1) with the effective working time. Furthermore, the additional cost of connected machines has also been stipulated which is affected by the capital return on fixed and current assets as well as by the general costs of farming. As a result the cost of the individual operations related to 20 hectare growing area has been defined the total of which equals the total production costs of carrot production on 20 hectares, and also the specific costs per hectare of the different harvesting methods for fresh consumption or for the canning industry have been stipulated.

It can be stated on the basis of the results that in case of ***carrot production for canning purposes*** the operational cost of the power machines (6631 EUR) is less than the half of that of the working machines (14.979 EUR). The total operational cost amounts to 21.610 EUR, 1080 EUR per hectare. In case the ***goods are meant for the fresh market*** the above indexes are as follows: the operational cost of the working machines (16.790 EUR) is nearby equal to the operational cost of the power machines (17.812 EUR). The total operational cost is 34.602 EUR, 1730 EUR per hectare.

It can be stated that the drag picking method harvesting for fresh consumption causes an extra cost of about 500 EUR per hectare plus the 200 EUR/hectare cost of grading.

In view of the operational cost relations it can be stated that in case the final product is meant for industrial use the cost of road transport is about 35 %, and the delivery from the field to the depot by tractor about 10 % of the total cost. It is followed by the harvesting operation with 19 %. Considering the cost of the other operations of the technology the significant ones are the plant protection with 11 %, the ridge bed preparation with 7,5 %, the deep ploughing and the renewal of ridge beds with 3 % each, while the cost proportion of the remaining operations is often less than 1 %. In case the final product is meant for the fresh market this order is different. The major cost factor is harvesting with 40 %, road transport and delivery by tractor follows with 22 % resp. 5 %, the proportion of grading is about 11,5 %, and in this case the cost of plant protection is 7 %, of ridge bed preparation 5 %, of deep ploughing 2,5 % and of the renewal of ridge beds 2 % of the total cost.

The figures of the present survey are calculated on the basis of high quality and mostly valuable power machines which ensure effective performance. Consequently the acquisition and operational costs of the power machines are also substantial. The prescribed operations can naturally be realized by using power machines of a lower technical level under strict control and in this case the operational cost of the machines can be less than that figuring in the survey.

Table 1: The basic economic data of carrot production

Denomination of operation	Type of machine applied in the technology: working machine	Type of machine applied in the technology: power machine	Shift Perfor-mance (ha/h)	Price of working machine (EUR)	Price of power machine (EUR)	Direct cost of operation working machine (EUR/h)	Direct cost of operation power machine (EUR/h)	Direct cost of operation total (EUR/h)
Stubble stripping	Kühne 770 - 7,2 disc harrow	NH G 190 DT	3	19164	109048	10	27	37
Deep ploughing	VN Euromat 3S Var.5blade upright	NH G 190 DT	1	18000	109048	7	27	34
Ploughing-processing	S-2H/M	NH G 190 DT	4,8	7452	109048	7	27	34
Transport of fertilizer	MBP 6,5	MTZ 82	4	6016	13516	2	11	13
Fertilizer spreading	Tornado 5	Fendt 309 CA	4	9604	82000	6	20	27
Ridge bed preparation	Rumpstadt FH4x75 RSF 2000 T	NH G 190 DT	0,6	15200	109048	13	27	40
Sowing	Agricola ANT-3-290	Fendt 309 CA	1,5	6400	82000	9	20	30
Renewal of ridge beds	Badalini Variax EP/85W 140 GLS	Fendt 309 CA	1	6600	82000	6	20	26
Spray transport	DETK-115 tanker	MTZ 82	4,8	6800	13516	4	11	15
Plant protection–pre-emergence	HARDI Commander Plus 2200/18	Fendt 309 CA	4,8	21600	82000	12	20	32
Spray transport × 3	DETK-115 tanker	MTZ 82	4,8	6800	13516	4	11	15
Plant protection-post-emergence×3	HARDI Commander Plus 2200/18	Fendt 309 CA	4,8	21600	82000	12	20	32
Spray transport × 6	DETK-115 tanker	MTZ 82	4,8	6800	13516	4	11	15
Plant protection-stock treatment×6	HARDI Commander Plus 2200/18	Fendt 309 CA	4,8	21600	82000	12	20	32
Irrigation	Valmont Linear		1	98000		17		17
Harvesting	GB-02	Fendt 309 CA	0,4	66000	82000	44	20	64
Crop transport	MBP 6,5	MTZ 82		6016	13516	2	11	13
Lodging, loading		Manitou MT 835			76000		22	22
Road transport	HL 92.02 road	IFA L 60 1218 DSK		7536	33720	3	20	22
The basic economic data of the operations of harvesting and manipulating of carrots meant for fresh consumption								
Harvesting	ASA LIFT Combi - 1000	Fendt 309 CA	0,1	59060	82000	34	20	54

Denomination of oper.	Applied machine acc. to technology: type	Applied machine acc. to technology: engine-capacity	Shift performance (t/h)	Price of the Machine (EUR)	Cost of electricity (EUR/kWh)	Direct cost of operation (EUR/h)	Cost of energy (EUR/h)
Grading	Schneider SWF 500	1,1 kW	0,5	24000	0,09	4,2	0,10

Table 2: The economic index numbers of the operations of carrot production on 20 hectares

Denomination of operation	Machine working hours (h)	Direct operational cost of connected machines (EUR)	Additional operational cost of connected machines (EUR)	Total operational cost (EUR) working machine	Total operational cost (EUR) power machine	Cost of operation (EUR)
Stubble stripping	6	221	44	74	191	265
Deep ploughing	20	679	135	175	639	814
Ploughing-processing	4	136	28	37	127	164
Transport of fertilizer	5	65	10	12	63	75
Fertilizer spreading	5	134	27	39	122	161
Ridge bed preparation	33	1316	309	571	1054	1625
Sowing	13	385	82	148	319	467
Renewal of ridge beds	20	528	112	149	491	640
Spray transport	4	61	9	20	50	70
Plant protection–pre-emergence	4	129	33	65	97	162
Spray transport × 3	12	184	30	62	152	214
Plant protection-post-emergence × 3	12	388	101	195	294	489
Spray transport × 6	24	370	61	125	306	431
Plant protection-stock treatment × 6	24	777	202	390	589	979
Irrigation	20	336	108	444	0	444
Harvesting	50	3220	887	2878	1229	4107
Crop transport	150	1973	326	380	1919	2299
Lodging, loading	20	435	80	0	515	515
Road transport	300	6730	959	867	6822	7689
Canning industry technology - total	**726**	**18067**	**3543**	**6631**	**14979**	**21610**
Cost per hectare (EUR/ha)						**1080**
The economic index numbers of the harvesting and manipulating operations of carrot production for fresh consumption on 20 hectares						
...	...	...	...	...	...	...
Harvesting	200	10824	3202	9097	4929	14026
Grading	700	2940 + 68 (Cost of electricity)	1008		4016	4016
Fresh consumption technology - total	**1.526**	**27849**	**6753**	**16790**	**17812**	**34602**
Cost per hectare (EUR/ha)						**1730**

The investment cost of the machines applied in the production technology amounts to 543 thousand EUR *(554 thousand EUR*[1]), out of which the purchasing price of the working machines amounts to 288 thousand EUR, which equals about 48 % of the total investment cost *(292 thousand EUR – 53 %)*, while the purchasing price of the power machines is 314 thousand EUR, about 52 % of the total cost of machines *(262 thousand EUR – 47 %).* In case of power machines it can be stated that one power machine with an engine capacity of 140 kW is needed for the hard cultivation works, while the tasks of nutrients delivery, plant protection and crop cultivation, sowing, harvesting tractor delivery are fulfilled by 70 kW main and a 60 kW aid machine. For moving the goods in the depot a telescopic loader is also required, first of all in case of root vegetables meant for industrial use. For the road transport of the crop a low-cost trailer can be used. With the above method of applying power machines lower acquisition costs and a more effective utilization of power machines can be achieved.

Carrot production on 20 ha demands 726 shift hours of machine work, out of which the two lower capacity tractors represent a great proportion due to delivery of nutrients, sowing, ridge bed renewal, crop protection and harvesting and transport by tractor and the shift hour performance of the high capacity power machine in the course of cultivation is also significant. Road transport with its 300 shift hour capacity demand is the most time-demanding operation.

In case of production meant for fresh consumption the 70kW tractor works even more shift hours due to the time-demanding harvesting. Furthermore, the grading of the crop produced on 20 has demands about 700 shift hours of machine work according to our calculation. In this case the total number of the shift hours performed in the course of the technology is 1526.

CONCLUSIONS AND PROPOSALS

The surveys conducted have proved that the machine work costs of field root vegetable production are high. Taking into consideration the extra work connected to grading and consumer packing substantial additional costs arise which can lead to specific costs per hectare exceeding 1700 EUR. In case of a 60 t/ha yield it can easily be calculated that operational costs of machines themselves exceed 3 EURO Cent/kg, and we have to take into consideration the costs of seeds, fertilizers, pesticides, labour and irrigation water. These figures are characteristic of large-scale production costs and they grow further in case of smaller production units with less effective automation.

Considering machine costs it is advantageous if, as in the studied cases, harvesting is done by tractor-pulled working machines instead of expensive self-propelling harvesting machines with high operational costs, as the acquisition cost of connected working machines is more favourable and a better utilization and lower specific operational costs of power machines can be achieved by the use of tractors.

[1] Investment cost values in case of technology when the goods are meant for the fresh market.

It can be stated that special attention is to be paid to the following operations: harvesting, transport, cultivation and plant protection works which are the most costly ones and which represent about 95-97 % of the total machine operational costs.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Preliminary communication

TRAVEL DISTANCE AND FIELD COSTS

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SUMMARY

A calculation method is composed to compute plant production costs, depending from travel distance between certain field and farm centre. In the paper is presented overview about this method and done example calculations with data from a cereal production technology.

To compute costs, are calculated

1. *transportation costs of field operation equipment;*
2. *how transportation duration of field operation equipment affects deviation of work time from most suitable work time and thus income from the field;*
3. *transportation costs of materials (fertilizers, yield, seed etc.), related to field;*
4. *driving costs of service teams and plant production manager.*

The method enables to find out in complex, field area – travel distance – costs, depending on travel distance, a value of one component, if values of other two components are given. For example, if area of field would be 5 ha and upper limit of costs, depending on travel distance should be 64,5 €/ha, then by sample calculation travel distance must not exceed 13,27 km. By limited value of costs proved also that increasing area of field causes also growth of maximum travel distance in the beginning until certain value of area and then starts to decrease again.

***Key words**: transportation costs, loss of yield, travel distance, operation performance, duration of operation, decision support system, PC application.*

INTRODUCTION

Many cereal producers are trying to increase area of arable land, while it's generally known, that bigger area enables decrease the cost price of production and maximize the capacity of profit. But it is also quite clear, that area of arable land can't to be enlarged to endless, because the further are fields, the bigger is portion of travel costs in total costs. There are known several methodic [2, 3, 4, 5, 6] to find out average travel distance and total transportation costs of farm, what in turn are used to determine optimum area of arable land in farm.

Now, if the farm manager knows the value of farms optimum area, we have question, how (s)he will use this knowledge? (S)he should decide now, which fields leave out from usage and where to try take new lands into use. Deciding to sell or buy some defined field, or changing the technology or crop rotation, it is always good to know, how it affects production in economical point of view. Therefore is needed to estimate profitability of production on this field, whereas one important estimation criteria would be travel distance between transport centre of the farm and this field. It is quite common to calculate transportation costs of materials, but costs of transportation of field operation equipment and organizational drives are often not taken into account or are calculated very approximately, while there is no certain method to make these calculations. We can see that fuel prices tend to rise on the world market and therefore we should consider with travel costs more and more.

The travel distance between transport centre of the farm and field affects:

1. transportation costs and daily performance of field operation equipment;
2. duration of whole operation, which in one's turn affect deviation of work time from most suitable work time and this acts on output from the field;
3. transportation costs of materials (fertilizers, yield, seed etc.), related to field;
4. driving costs of service teams and plant production manager.

The objective of this paper is to introduce methodic, which is used to calculate these costs and estimate influence of travel distance to production costs on certain field.

METHODS

Transportation costs of field operation equipment

Aggregates should move for field operations from farm center to field and in the end of work day or after accomplishment of operation back to centre. The further is field from farm centre, the more time and resources are needed for transportation of machines.

Travel costs of field machinery, within whole production year, all operations together

$$K_s = \frac{du_t}{F}\sum_{i=1}^{n}\frac{P_i\sum_{j=1}^{o}Z_{i,j}}{v_i}, \tag{1}$$

where

K_s– travel costs of field machinery by defined field, within whole production year, €/ha;

d – travel distance from farm centre to field, km;

u_t – number of drives between field and machine centre within one workday (e.g. if in the morning drive to field and in the evening back, then u_t=2);

n - number of aggregates, working on the field within whole production year;

o - number of operations, that aggregate i performs on the field through the year.

P_i – hourly cost of idle drive of aggregate, EEK/h;

v_i – average travel speed of aggregate, km/h;

$Z_{i,j}$ - integer number of days, that aggregate i should use regarding to operation j and

F - area of field, ha.

Formula (1) considers also cases, when one operation will be done with several aggregates and if more than one work day is needed, to perform a single operation on defined field.

If equipment is rented with driver, then rent charge is used as hourly cost P_i. In case of own machines the cost for fuel, oil, labor and maintenance are considered as hourly cost of transportation of aggregate. Other costs like depreciation, interest, insurance and housing cost are considered in field operation cost, which is contained in hectare costs and are thus presented well enough in cost price of production, to be compensated.

Number of days needed to perform operation j

$$z_{i,j} = \frac{F}{\sum_{i=1}^{n} w_i \tau \left(T_i - \frac{du_t}{v_i} \right)}, \tag{2}$$

where

$z_{i,j}$ - fractional number of days needed to perform operation j;

w_i - operation performance of aggregate i;

τ - coefficient, considering time loss;

n - number of aggregates, performing operation j and

T_i - duration of work day of aggregate i, h/day.

If $z_{i,j} > \lfloor z_{i,j} \rfloor$ i.e. fractional number of days is bigger than integer form that number, then integer number of work days of aggregate i, performing operation j is

$$Z_{i,j} = \lfloor z_{i,j} \rfloor + 1 \tag{3}$$

If $z_{i,j} = \lfloor z_{i,j} \rfloor$, then $Z_{i,j} = z_{i,j}$.

Income dependence on transportation distance

Yield is main source of income in plant production. Yield depends on duration and time of accomplishing of operation. The faster the operation will be completed, the minor are timeliness costs [7, 8, 9]. The longer is transportation distance the more time is needed to drive to field and back. And just as much shortens pure operation time in workday, used for performing of operation and that means that there is needed bigger number of work days, to complete operation on the field. Bigger number of work days causes higher timeliness costs. Thus we have to find out, how travel distance affects average yield on the field. Having mostly experiences with functions describing yield dependence on sowing time, we will clarify effect of transport of seedbed preparation and seeding machines to average yield.

In the situation, where machinery contains only one tractor and farm has only one operator, then all seedbed preparation and seeding operations are done in sequential order. In that case we should consider with transportation time of all aggregates involved to those operations:

$$t_{s,r} = \frac{du_t}{T_{t,k}} \sum_{i=1}^{n} \frac{\sum_{j=1}^{o} Z_{i,j}}{v_i}, \tag{4}$$

where

$t_{s,r}$ - transportation time in case of sequential operations, days.

If machinery has several tractors and farm has several operators, then probably field works are organized in the way where seeding aggregate should wait for other aggregates performing previous operations only in first day of seeding season and after that operations are made parallelly in different fields and sowing duration is mostly affected from seeding aggregate(s).

In that case transportation time of seeding aggregate is calculated with formula:

$$t_{s,k} = du_t \frac{Z_k}{v_k T_{t,k}} \tag{5}$$

where

Z_k - integer number of work days, needed to perform seeding operation on defined field (will be computed with formulas (2) and (3));

v_k - transportation speed of seeding aggregate, km/h and

$T_{t,k}$ - duration of work day of seeding aggregate, h/day.

Timeliness costs depending on transportation distance

$$\Delta T = \frac{bhrt_s}{3000}\left(t_s + 2t_k\right) \tag{6}$$

where

t_s - transportation time computed with formula (4) or (5), days;

t_k - estimate duration of seeding season in whole farm without transportation times on defined field, days;

h - yield from farm area, seeded in best day (yield is highest), kg/ha;

r - sell price of cereal, €/t and

b - regression coefficient.

Transportation costs of materials (fertilizers, yield, seed etc.), related to field

Transportation (one cycle) costs of a material is computed with formula

$$K_{v,s} = \frac{2dP}{v} \tag{7}$$

In the transportation cycle of vehicle is one drive with load and other idle

$$K_{v,s} = K_{v,s,loaded} + K_{v,s,empty} \tag{8}$$

where

$K_{v,s,loaded}$ – cost of loaded drive, €/h and

$K_{v,s,empty}$ – cost of idle drive, €/h.

And

$$K_{v,s,loaded} = \frac{dP_{loaded}}{v} \tag{9}$$

$$K_{v,s,empty} = \frac{dP_{empty}}{v} \tag{10}$$

Difference of hourly costs P_{loaded} ja P_{empty} is caused by different waste of fuel and oil on loaded and idle drive of aggregate. It means that we have to separate costs for fuel and oil from hourly costs to get possibility to calculate these costs differently.

Thus we have to calculate hourly costs in two parts:

1) P_f [€/h] - costs for fuel and oil per one work hour, if carrying capacity of vehicle is totally used and
2) $P_{m.}$[€/h] - sum of other components of hourly costs of vehicle.

According to our line of reasoning

$$P_{loaded} = P_m + \mu P_f \quad \text{and} \tag{11}$$

$$P_{empty} = P_m + \mu_0 P_f \tag{12}$$

where

μ - factor, considering consumption of fuel depending on usage of carrying capacity;

μ_0 - μ, if vehicle is making idle drive.

It is clarified on the bases of literature [1], that relation between carrying capacity of vehicle and change of fuel consumption is quite well described with linear regression model.

$$\mu = ax + b, \tag{13}$$

where

a, b - regression coefficients and

x - factor, considering carrying capacity of vehicle, between 0…1.

To find out values of coefficients *a* and *b* in linear regression (13) we only have to know fuel consumptions by idle drive of and fully loaded drive of vehicle.

In that case

$$a = \frac{Q_k - Q_t}{100} \qquad b = Q_t \tag{14}$$

where

Q_k – fuel consumption, if carrying capacity of vehicle is totally used, l/h and

Q_t – fuel consumption, if vehicle is making idle drive, l/h.

Transportation costs of all materials handled in one production year and on defined field are calculated with formula

$$K_v = \sum_{s=1}^{l} K_{v,s} = \frac{d}{F}\sum_{s=1}^{l}\sum_{i=1}^{n}\frac{\left(2P_{m,i} + P_{f,i}\mu_{0,i}\right)\left(\lfloor Y_{i,s}\rfloor + 1\right) + P_{f,i}\left(\mu_{t,i}\lfloor Y_{i,s}\rfloor + \mu_{j,i}\right)}{v_i} \tag{15}$$

where

K_v – transportation costs of all materials related to the field in one production year, €/ha;

l - number of materials related to the field in one production year and

n - number of vehicles, carrying one sort of material.

Number of transportation cycles of one vehicle, needed to transport one sort of material

$$Y_{i,s} = \frac{p_s F \lambda_{i,s}}{\rho_s g_i} \tag{16}$$

where

g_i - carrying capacity of vehicle *i*, kg;

ρ_s - coefficient, considering carrying capacity of vehicle if transporting material *s*;

p_s - amount of material *s*, kg/ha;

$\lambda_{i,s}$ - factor showing, how big portion of material *s* is transported with vehicle *i*; if whole material *s* is transported by vehicle *i*, then $\lambda_{i,s} = 1$.

For one vehicle

$$\lambda_{i,s} = \frac{w_{i,s}}{\sum_{i=1}^{n} w_{i,s}} \tag{17}$$

where

$w_{i,s}$ - performance of vehicle *i* on transporting material *s*, t/h;

Performance of vehicle

$$w_{i,s} = \frac{g_i \rho_s}{g_i \rho_s \left(\frac{1}{w_{pl,s}} + \frac{1}{w_{ml,s}} \right) + \frac{2000d}{v_i}} \tag{18}$$

where

$w_{pl,s}$ - performance of loading material s onto vehicle, t/h and

$w_{ml,s}$ - performance of loading material s from vehicle, t/h.

Driving costs of service teams and plant production manager

In addition to transportation of materials immediately related to field is practical by large and outlying fields to organize transportation of materials needed for field machines, like oil, fuel and spare and also food for operators. Often agronomist or plant production manager has to visit the field with aim, to clarify condition of field and to check quality and quantity of work of field machines.

For prognostication of transportation costs of service machines, the user of this calculation method has to look on the bases of own experiences, what is probability of need for service drive for some operation. Same way is needed to think about probable reasons, why plant production manager has to visit the field and thus count how many times the field will be visited within one production year.

Cost of one visit to field is

$$k_{o,1} = \frac{2dP_t}{v_t} \tag{19}$$

And cost of all organizational drives to the field within one production year

$$k_o = \frac{2d}{F} \sum_{i=1}^{c} \frac{\eta_i P_{t,i}}{v_{t,i}} \tag{20}$$

where

K_o - cost of all organiz. drives to the field within one production year, €/ha;

$P_{t,i}$ - hourly cost of vehicle used for type *i* of organizational drive, €/h;

$v_{t,i}$ - speed of vehicle used for type *i* of organizational drive, km/h;

η_i - number of drives, needed to do under type *i* of organizational drive;

c - number of types of organizational drives

RESULTS

For calculations author composed software "Field distance". As bases of calculations conventional technology of cereal production was taken. In the tables 1, 2, 3 and 4 are results in case, when field area is 5 ha and travel distance between field and farm centre is 13,27 km. Hourly costs of machines are computed by calculations methods, composed in Estonian Research Institute of Agriculture. Fuel price is 0,63 €/l.

Table 1 Initial data and results for calculating of transportation costs of field machinery

Machine	τ	T_t h	v km/h	w ha/h	P €/h	t^* h	Z	Ks, €/ha
Plough	0,85	8	30	0,9	12,78	0,88	1	2,26
Cultivator	0,85	8	30	6	12,78	0,88	1	2,26
Fert.distrib.	0,85	8	30	5	9,84	0,88	1	1,74
Cultivator	0,85	8	30	6	12,78	0,88	1	2,26
Drill	0,85	8	30	5	12,78	0,88	1	2,26
Harrow	0,85	8	30	5	12,78	0,88	1	2,26
Sprayer	0,85	8	30	8	12,78	0,88	1	2,26
Sprayer	0,85	8	30	8	12,78	0,88	1	2,26
Combine	0,85	8	20	1,5	24,54	1,33	1	6,51
Total								24,07

t* - duration of one drive to back and forth (in all tables)

Table 2 Initial data and results for calculating of transportation costs of field materials

Material	p kg/ha	ρ	Vehicle	v km/h	g t	P_m €/h	w_{pl} t/h	w_{ml} t/h	Q_t l/h	Q_k l/h	P_f €/h	w t/h	t^* h	Y	K_v €/ha
Fertil.	400	1	Wagon	30	10	18,0	28	15	11,9	17,5	11,4	5,24	0,88	0,2	3,4
Seed	200	1	Wagon	30	10	18,0	28	20	11,9	17,5	11,4	5,74	0,88	0,1	3,4
Water	300	1	Tank	30	5	11,5	40	20	9,8	15,1	9,8	3,97	0,88	0,3	2,2
Yield	3500	1	Wagon	30	10	18,0	40	1800	11,9	17,5	11,4	8,77	1,77	1,8	7
Total															16

By calculation of timeliness costs is considered, that farm has several tractors and several operators are working in sowing season. Thus operations are performed simultaneously and sowing time is affected only from time needed for transporting of drill to field and back. This time is recalculated to sowing days (Table 3.).

Table 3 Initial data and results for calculating of timeliness costs

r €/kg	b	t_k day	h kg/ha	t_s day	ΔT €/ha	t_s day
95,87	0,00115	14	3500	0,111	0,4	0,111

Table 4. Initial data and results for calculating of organizational drives

Reason	Vehicle	P €/h	v km/h	η	t^* h	K_o €/ha
Work inspection	Car	19,17	60	7	0,442	11,9
Field inspection	Car	19,17	60	1	0,442	1,7
Measuring	Car	19,17	60	1	0,442	1,7
Fuel transport	Fuel tank	25,56	50	3	0,531	8,1
Total						23,4

Costs affected from travel distance between field and farm centre are all together 64,5 €/ha.

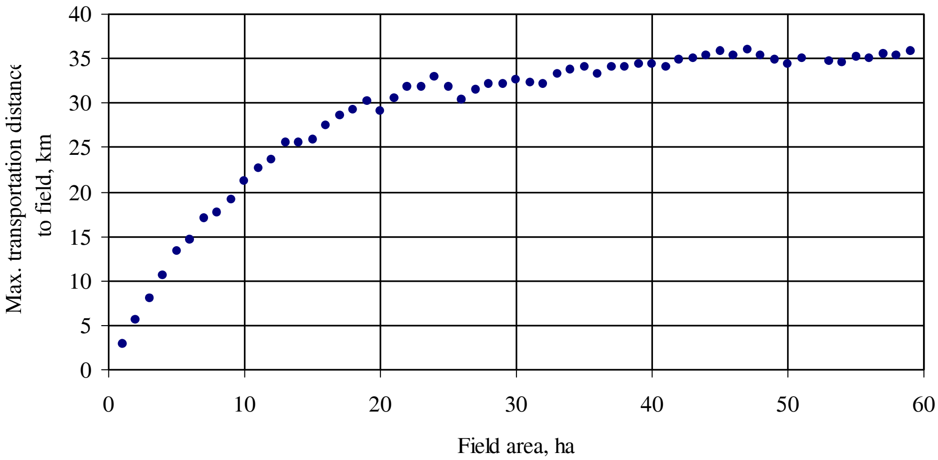

Figure 1 Maximum travel distance by some defined area (under 60 ha) of field and cultivation technology, in condition, that travel distance dependent costs do not exceed 63,9 €/ha

Often are production costs and incomes prognosticated by some defined technology. It is possible to calculate costs such way, that computed are only costs, not depending on travel distance and costs depending on travel distance are equal with some defined value, which must not exceeded. Now we have to find out, what are limit values of field area and travel distance in condition, that costs depending on travel distance does not exceed value, defined above.

Software, composed for computing travel distance dependent costs, enables to find out maximum travel distance by some defined area of field so, that costs depending on travel distance does not exceed some defined limit value. In sample calculation is that limit 64,5

€/ha. On the figure (1) is shown, what would be maximum travel distance by some area of field. And same time we can also see from this figure the minimum area of field by some predefined travel distance. Also we can see from figure (1) that on a defined value of travel distance increasing of area of field does not help anymore – distance must not be longer, else costs will exceed defined value.

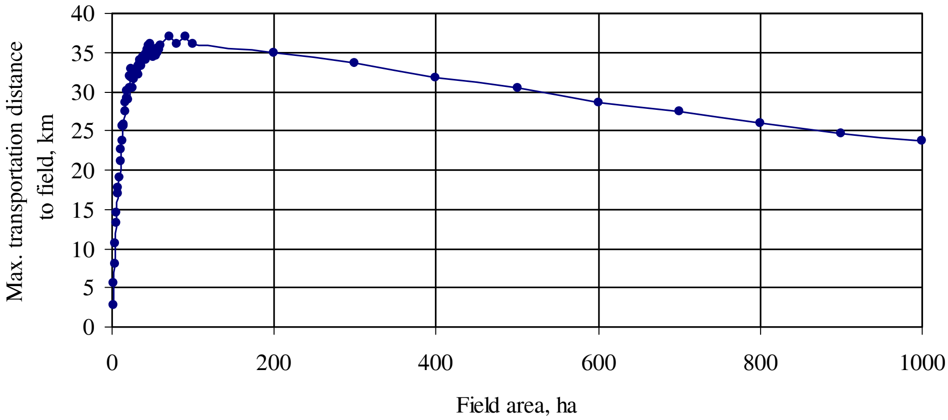

Figure 2 Max. travel distance by some defined area (under 1000 ha) of field and cultivation technology, in condition, that travel distance dependent costs do not exceed 63,9 €/ha

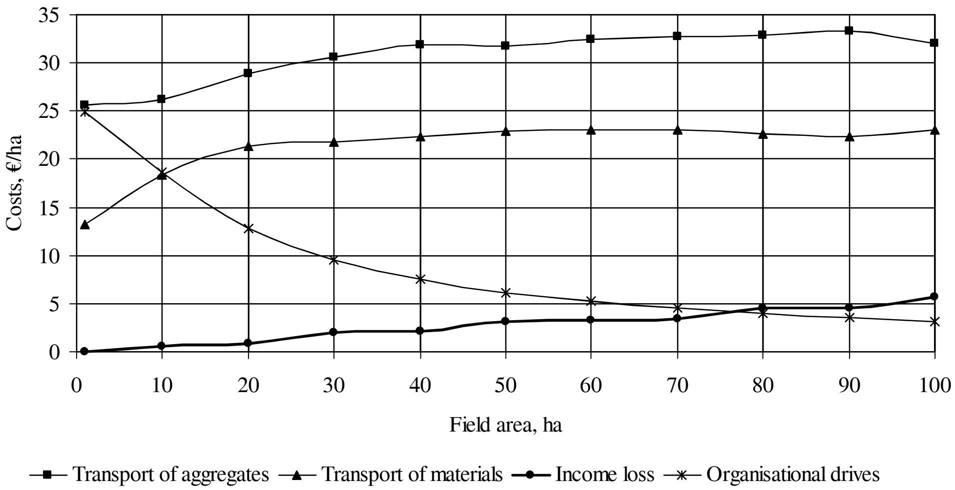

Figure 3 Change of costs depending on travel distance according to conditions of Fig. 1.

Interesting is situation if we use same technology by very large fields. On the figure (2) is shown that on beginning of a defined field area the max. travel distance starts do decrease. The reason is significant grow of timeliness costs if area of field increases (Fig. 3.) and that's why travel costs and therefore travel distance of other cost components has to decrease. From the figure (3) we can see also that beginning on a defined value of field area costs for transportation of machines and materials dos not change much, because number of drives depends on area of field. But number of organizational drives is fixed in given sample and that's why organizational costs decrease per hectare if area of field is increasing.

CONCLUSIONS

Calculation method is composed to calculate costs depending on travel distance considering cultivation technology used on field, organization of works, area of field and travel distance between field and farm centre.

While usually in different years are grown different crops on same field and there is possibility to choice between different technologies, then it would be good to make calculations with several production scenarios on one field. While one farm can have lot of fields anyway, then this work with pen and paper would be very time consuming and danger of mistakes would be significant. Therefore author composed PC application, what can be used by plant production managers, advisors and researchers to estimate cost of fields, whereas under main attention are transportation costs.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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NATURALNI I EKONOMSKI REZULTATI PRI PROIZVODNJI KRASTAVACA

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SAŽETAK

Za proizvodnju krastavaca namjenjenih preradi u Hrvatskoj postoje idealni uvjeti i osigurano tržište, a u isto vrijeme to je kultura za kojom postoji i veliki interes na inozemnom tržištu. Proizvodnja je radno intezivna i visoko dohodovna te kao takva interesantna za obiteljska gospodarstva koja obrađuju relativno malu oraničnu površinu.

U radu je dan prikaz rezultata istraživanja organizacije i ekonomike proizvodnje krastavaca na obiteljskom gospodarstvu. Rezultati su svedeni na površinu jednog hektara. Na temelju praćenja obavljanja radova utvrđen je utrošak 48,03 sati/ha rada strojeva i 524 sata/ha rada ljudi. Ukupni troškovi iznose 23.932,20 kn/ha. Prinosom od 20.700 kg/ha ostvarena je vrijednost proizodnje u iznosu 39.675,00 kn/ha, a nakon podmirenja troškova dobit od 15.742,80 kn/ha. Najveći udjel u ukupnim troškovima predstavlja primjena polietilenske folije i naknada za utrošenih 524 sata/ha rada ljudi, što čini više od 55,1% ukupnih troškova. Na temelju koeficijenta ekonomičnosti čija je vrijednost 1,65 zaključuje se da je ova proizvodnja ekonomična. Na 100 kn ukupnih troškova uloženih u proizvodnju ostvareno je 65,7 kn dobiti.

Pri sadnji krastavaca utrošen je 1,5 kg sjemena/ha za čiju nabavu je izdvojeno 1.170,00 kn/ha. Za mineralna, organska i folijarna gnojiva utrošeno je 2.869,95 kn/ha, a za sredstva za zaštitu 771.00 kn/ha. Troškovi za nabavu 350 kg/ha polietilenske folije iznose 4.900,00 kn/ha. Srednji traktori korišteni su 21,37, a laki 26,66 sati/ha.Ukupni troškovi korištenja sredstava mehanizacije iznose 5.490,70 kn. Od 20.700 kg/ha krastavaca ubrano je 16,7 % I. klase, 50 % II. klase i 33,3 % čine krastavci III. klase.

Ključne riječi: *dobit, krastavac, tehnika, tehnologija, troškovi.*

UVOD

Krastavci pripadaju porodici tikava (Cucurbitaceae) i predstavljaju povrćarsku kulturu koja se uzgaja zbog mladih plodova u kojima se sjeme nalazi u početnoj fazi razvitka (Lešić i suradnici, 2002). Za proizvodnju krastavaca namjenjenih preradi u Hrvatskoj postoje idealni uvjeti, osigurano tržište, a isto tako je kultura za koje postoji veliki interes i na inozemnom tržištu. Proizvodnja je radno intenzivna i visoko dohodovna te prikladna za obiteljska gospodarstva koja obrađuju relativno male oranične površine, a mogu osigurati dovoljno radne snage posebice tijekom srpnja i kolovoza kada dospijeva berba koja treba biti temeljita i redovito organizirana svakog svakog dana (Jurišić, 2005). Ovim se osim većeg prinosa ostvaruje i bolji odnos klasa, a time i veća profitabilnost proizvodnje.

Organiziranost tržišta je izuzetno bitan preduvjet za uspjeh u proizvodnji krastavaca. Krastavci u svježem stanju imaju visok sadržaj vode i kao takvi neprikladni su za skladištenje i duže čuvanje. Uputno je obimniju proizvodnju ugovoriti sa nekim od distributivnih centara. Oni bi kontinuirano preuzimali urod, a proizvođača snabdjevali potrebnim repromaterijalom te mu pomagali pri provođenju agrotehničkih mjera te savjetovali i nadzirali tijek proizvodnje (Vagner, 2000).

Prema podacima zvanične statistike krastavci se u Hrvatskoj uzgajaju na oko 3.300 hektara. Veći dio proizvodnje čine krastavci uzgojeni u vrtovima i namjenjeni za korištenje u svježem stanju i konzerviranje. Iako se oko 80% prerađenih krastavaca može izvesti u druge zemlje oko 4.300 obiteljskih gospodarstava još uvijek krastavce proizvodi na prosječnoj površini od oko 900 m^2 po gospodarstvu.

ORGANIZACIJA RADA PRI PROIZVODNJI KRASTAVACA

Organizacija osnovne obrade, predsjetvene pripreme tla i sadnje i gnojidbe

Na obiteljskim gospodarstvima u Hrvatskoj krastavci se najčešće uzgajaju na površinama najbližim ekonomskom dvorištu te je njihova učestalost na istim površinama velika. To je nepoželjno, jer se oni ne ponovo uzgajati barem četiri godine na istoj površini.

Dobri predusjevi za krastavce su kulture koje tlo napuštaju u ljeti, najkasnije u ranu jesen. Nakon žetve strnih žitarica, graška ili paprike tlo je tanjuračom radnog zahvata 3,1 m prašenjem obrađeno na dubinu između 8-12 cm.

Pri brzini kretanja od 12 km/h pri odlasku i povratku na parcelu uz brzinu rada od 8,5 km/ha te 15 minuta utrošenog na održavanje ostvaren je učinak 10,5 ha u jednoj smjeni.

Budući da krastavci dobro uspijevaju na tlu pognojenom organskim gnojivom početkom rujna obavljeni su utovar, prijevoz i rastresanje 21 t/ha stajnjaka. Isti je zaoran na dubinu 30-35 cm. Oranje je obavljeno dvobrazdnim plugom radnog zahvata 0,7 m. Ovisno od dužine table od 200-400 m i udaljenosti iste između 1-3 km od ekonomskog dvorišta, ostvareni učinak kreće se između 1,6-2,0 ha pri čemu se po jedinici površine troši od 3,5-4,37 sati/ha rada ljudi i traktora.

U rano proljeće kada su to dopustile vremenske prilike obavljeno je zatvaranje zimske brazde tanjuračom. Prije sadnje tlo je pognojeno sa 400 kg/ha mineralnog gnojiva formulacije NPK 7:14:21, te potanjurano i fino podrljano.

Tablica 1 Projekt normi za prašenje strništa tanjuračom i oranje plugom (ha)

Dužina parcele (m)	Tanjurača			Plug		
	Udaljenost do parcele (m)			Udaljenost do parcele (m)		
	1.000	2.000	3.000	1.000	2.000	3.000
200	9,7	9,4	9,1	1,7	1,7	1,6
300	11	10,7	10,4	1,9	1,8	1,7
400	11,8	11,5	11,1	2,0	1,9	1,8

Norme su izračunate na temelju dužine tabli, uobičajenih na manjim obiteljskim gospodarstvima i njihove udaljenosti od ekonomskog dvorišta uz uvažavanje stanja poljskih puteva te brzine kretanja pri radu.

Sadnja je obavljena početkom druge dekade svibnja. Neposredno prije sadnje ručno je položena crna polietilenska folija debljine 0,04 mm i širine 120 cm. Pri sadnji su u sredini folije oštrim vrhom metalne cijevi (promjera 5 cm) izbušene rupe sa razmakom 30 cm. U svaku rupu polažu se 3-4 sjemenke i prekriju slojem tla debljine do 2 cm. Pri sjetvi je utrošeno 1,5-1,8 kg sjemena.

Tablica 2 Projekt normi učinka pri zatvaranju zimske brazde tanjuračom, drugom prohodu tanjurače i finu pripremu tla drljačom pred sjetvu (ha)

Dužina parcele (m)	Tanjurača (prvi prohod) Udaljenost do parcele (m)			Tanjurača (drugi prohod) Udaljenost do parcele (m)			Drljača Udaljenost do parcele (m)		
	1.000	2.000	3.000	1.000	2.000	3.000	1.000	2.000	3.000
200	5,6	5,4	5,2	7,0	6,7	6,5	6,8	6,5	6,3
300	6,1	5,9	5,7	7,6	7,4	7,1	7,4	7,2	6,9
400	6,4	6,1	5,8	8,0	7,6	7,2	7,8	7,4	7,8

Organizacija mjera njege krastavaca

Zaštita protiv korova obavljena je ručnom prskalicom pri čemu je sa 1,5 l/ha Reglona tretirana samo staza između folija. U fazi pojave prvog lista u prvoj dekadi lipnja sa 2,5 l/ha Dithane obavljena je i zaštita protiv plamenjače. Sljedeće tretiranje protiv bolesti obavljeno je u fazi 3-4 lista sa sredstvom Ridomil u količini 2,5 kg/ha pri čemu je istovremeno protiv štetnika primjenjeno 0,4 kg/ha Dotan-a.

Sredinom lipnja nasad je prihranjen sa 3 l/ha tekućim gnojivom Folifertil-T. Litra Folifertila-T sadrži 120 g N, 40 g P_2O_5, te 60 g K_2O.

Tablica 3 Projekt normi učinka pri rasipanju mineralnog gnojiva, kemijskoj zaštiti usjeva i folijarnoj gnojidbi (ha)

Dužina parcele (m)	Rasipač Udaljenost od parcele (m)			Prskalica Udaljenost od parcele (m)		
	1.000	2.000	3.000	1.000	2.000	3.000
200	9,7	9,3	9,0	4,1	4,0	3,9
300	10,5	10,2	9,8	4,4	4,7	4,2
400	11,0	10,5	9,9	4,7	4,5	4,3

Organizacija berbe krastavaca

Berba krastavaca započela je 5. srpnja i trajala do 10. kolovoza. Zbog činjenice da plodovi krastavca brzo rastu i nižu klasu, nužno je svakodnevno ručno branje. Za berbu je utrošeno ukupno 410 sati rada ljudi po hektaru. Za pripremu i prodaju plodova na tržištu utrošeno je ukupno 44,77 sati.

TROŠKOVI I REZULTATI PROIZVODNJE KRASTAVACA

Ukupni troškovi proizvodnje krastavaca na istraživanom poljoprivrednom gospodarstvu iznose 23.932,20 kn/ha (Tablica 4.). Najveći dio u iznosu od 9.710,95 kn/ha ili 40,6% ukupnih troškova predstavljala su ulaganja u troškove sirovine i pomoćnog materijala. Pri proizvodnji je utrošeno ukupno 48,03 sati/ha rada strojeva čiji troškovi iznose 5.491,70 kn/ha, a njihov udjel u ukupnim troškovima bio je 22,9%. Kao radon intenzivna kultura proizvodnja krastavaca u ovakvim uvjetima proizvodnje zahtijeva oko 524 sata/ha rada ljudi, a uz današnju cijenu rada njegova vrijednost je 8.277,00 kn/ha te predstavlja 34,6% ukupnih troškova. Ostali troškovi, primjerice kao vodni doprinos te pripadajući opći troškovi na istraživanom gospodarstvu iznosili su 455,00 kn/ha.

S ukupno 20.700 kg/ha proizvedenih krastavaca ostvarena je vrijednost proizvodnje od 39.675,00 kn/ha, a nakon podmirenja ukupnih troškova dobit u iznosu 15.742,80 kn/ha.

Tablica 4 Troškovi i rezultati proizvodnje krastavaca po hektaru

Redni broj	Stavka	Jed. mj	Količina	Cjena kuna	Vrijednost (kn)
1.	Sjeme	kg	1,5	780,00	1.170,00
2.	Polietilenska folija	kg	350	14,00	4.900,00
	Mineralna gnojiva				
3.	NPK 7:14:21	kg	400	1,89	756,00
4.	Folifertil-T	l	6	65,00	390,00
5.	Stajski gnoj	t	21	82,09	1.723,95
	Pesticidi				
6.	Reglone	l	1,5	100,67	151,50
7.	Dithane	l	2,5	99,00	247,50
8.	Ridomil	kg	2,5	137,10	342,75
9.	Dotan	l	0,8	36,56	29,25
	Rad sredstava				
10.	Laki traktori	sat.	26,66	88,15	2.350,00
11.	Srednji traktori	sat.	21,37	146,97	3.140,70
12.	Rad ljudi	sat	524	15,50	8.277,00
13	Vodni doprinos	-	-	-	80,00
14.	Dovoz gnojiva	-	-	-	75,00
15.	Opći troškovi	-	-	-	300,00
UKUPNI TROŠKOVI					23.932,20
VRIJEDNOST PROIZVODNJE					
Klasa I.		kg	3.450	3,50	12.075,00
Klasa II.		kg	10.350	2,00	20.700,00
Klasa III.		kg	6.900	1,00	6.900,00
UKUPNO		kg	20.700	-	39.675,00
DOBIT					15.742,80

Tablica 5 Tehnološka karta za obavljanje radova pri proizvodnji krastavaca

Popis poslova	Jed. mj.	Agrotehnički zahtijev	Vrijeme rada od-do	Sredstva mehanizacije		Učinak-norma	Sati po hektaru	
				Stroj	Oruđe		Strojeva	Ljudi
Prašenje strništa	ha	8-12 cm	5.7-25.7	ST	Tanjurača 3,1m	10,5	0,7	0,7
Utovar stajnjaka	t	21 t/ha	1.9-20.9	ST	Utovarivač	1,0	7,0	7,0
Prijevoz i rastresanje stajnjaka	t	21 t/ha	1.9-20.9	ST	Rasipač	1,0	7,0	7,0
Oranje	ha	30-35cm	20.09-1.10	ST	Plug 2 br. 0,7m	2,0	3,5	3,5
Zatvaranje zimske brazde	ha	-	5.3-15.3	ST	Tanjurača 2,6m	10.4	0,7	0,7
Utovar mineralnog gnojiva	t	400 kg/ha	15.4-25.4	-	Ručno	35	-	0,2
Prijevoz mineralnog gnojiva	t	NPK 7-14-21	15.4-25.4	LT	Prikolica 3t	20	0,35	0,35
Rasipanje mineralnog gnojiva	t	NPK 7-14-21	15.-25.4	ST	Rasipač 6m	11,0	0,64	1,28
Tanjuranje II. prohod	ha	-	15.4-25.4	ST	Tanjurača 2,6m	7,7	0,91	0,91
Drljanje	ha	-	25.4-1.5	ST	Drljača 4m	7,6	0,92	0,92
Polaganje folije	ha	Razmak 70cm,350kg	5.5-20.5	-	Ručno	-	-	16,0
Sadnja	ha	4-6 biljaka na m2	5.5-20.5	-	Ručno	-	-	24,0
Zaštita od korova	ha	Reglone 1,5 l/ha	1.6-5.6	-	Ručno	-	-	7,67
Zaštita od bolesti	ha	Dithane 2,5 l/ha	10.6-15.6	LT	Prskalica	4,5	1,56	1,56
Zaštita od štetnika	ha	Dotan 0,4 kg/ha	10.6-15.6	LT	Prskalica	4,5	1,56	1,56
Folijarna gnojidba	ha	Folilertil 3 l/ha	10.6-15.6	LT	Prskalica	4,5	1,56	1,56
Zaštita od bolesti	ha	Ridomil 2,5 kg/ha	20.6-5.7	LT	Prskalica	4,5	1,56	1,56
Zaštita od štetnika	ha	Dotan 0,4 kg/ha	20.6-5.7	LT	Prskalica	4,5	1,56	1,56
Folijarna gnojidba	ha	Folifertil 3 l/ha	20.6-5.7	LT	Prskalica	4,5	1,56	1,56
Berba	t	25 t/ha	5.7-10.8	-	Ručno	-	-	410
Priprema za tržište	ha	-	5.7-10.8	LT	Ručno	-	16,95	34,41

EKONOMSKI POKAZATELJI USPJEHA PROIZVODNJE

Na temelju troškova i rezultata proizvodnje izračunati su sljedeći pokazatelji uspjeha proizvodnje: proizvodnost rada ljudi, ekonomičnost i rentabilnost proizvodnje.

Proizvodnost rada ljudi – izračunata je na temelju ostvarenog prinosa krastavaca (kg/ha) i utrošenih sati rada i ljudi po jedinici površine kako slijedi

$$P = \frac{Q}{T} = \frac{20700}{524} = 39{,}5 \text{ kg/sat}$$

i(li) obrnuto

gdje je Q prinos krastavaca u kg/ha i T utrošeno vrijeme u sati/ha.

$$P = \frac{T}{Q} = \frac{524}{20{,}7} = 25{,}3$$

gdje je T utrošeno vrijeme u sati/ha i Q prinos krastavaca u t/ha.

Ekonomičnost proizvodnje – izračunata je na temelju elemenata obračunske kalkulacije. Ona predstavlja odnos vrijednosno izražene količine i cijene sirovine I pomoćnog materijala, usluga te iznos ostalih troškova. U ovom slučaju ona je izračunata prema sljedećem obrascu:

$$E = \frac{V}{U} = \frac{39675{,}00}{23932{,}20} = 1{,}65$$

gdje je V vrijednost proizvodnje kn/ha i U ukupni troškovi kn/ha.

Rentabilnost proizvodnje – izražena stopom rentabilnosti (%) a izračunata je iz odnosa dobiti i ukupnih troškova. Rentabilnost proizvodnje pokazuje koliko se kuna dobiti ostvaruje na 100 kn uloženih tijekom procesa proizvodnje.

$$R = \frac{D \cdot 100}{U} = \frac{15724{,}00 \cdot 100}{23932{,}20} = 65{,}7\%$$

gdje je D dobit kn/ha i U ukupni troškovi kn/ha.

ZAKLJUČAK

U radu su prikazani rezultati istraživanja proizvodnje krastavaca na obiteljskom poljoprivrednom gospodarstvu sa područja Slavonije. Proizvodnja je bila organizirana na otvorenom uz primjenu konvencionalne tehnologije na polietilenskoj foliji.

Istraživanjem je utvrđeno da se pri proizvodnji ukupno troši 48,03 sati rada strojeva. Od tga laki traktori su korišteni 26,66 a srednji 21,37 534 sati/ha. Ova, radno intenzivna, proizvodnja obavljena je s utroškom 524 sati/ha rada ljudi. Sa 9.710,95 kn/ha I udjelom od 40,6% u strukturi ukupnih troškova koji iznose 23.934,20 kn/ha najzastupljeniji su troškovi sirovina i pomoćnog materijala. Za troškove rada sredstava mehanizacije izdvojeno je 5.491,70 kn/ha ili 22,9% ukupnih troškova. Na površini od 1 ha proizvedeno je ukupno od 20.700 kg ploda. Pri prodaji 16,7 % pripadalo je I. klasi, 50,00 % II. a 33,3 % III. klasi.

Prodajom krastavaca ostvarena je vrijednost proizodnje u iznosu od 39.675,00 kn/ha, a po odbitku ukupnih troškova dobit je bila u inosu od 15.742,80 kn/ha.

Na temelju odnosa vrijednosti proizvodnje i ukupnih troškova izračunat je koeficijent ekonomičnosti, a njegova vrijednost je 1,65 prema kojem je proizvodnja ekonomična. Po satu rada ljudi proizvedeno je 39,5 kg ploda, a za proizvodnju jedne tone proizvoda utrošeno je 25,3 sati rada ljudi. Prema stopi rentabilnosti na 100 kn ukupnih troškova ostvareno je 65,7 kn dobiti. Ovo je znatno veća rentabilnost u odnosu na većinu drugih ratarskih kultura najzastupljenijih u strukturi sjetve. U uvjetima velike nezaposlenosti proizvodnja povrća jedna je od mogućnosti riješenja socijalnih poteškoća na našem agrarnom području.

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ECONOMIC RESULTS OF CUCUMBER PRODUCTION

SUMMARY

This paper deals with a cucumber production organization research on 1 ha where 48.03 machine work and 524 human labor hours were consumed based on the computed standards and developed technological map. Total costs amount HRK 23.932,20 where profit of HRK 15.742,80 was achieved with yield of 20.700 kg and product value of HRK 39.675,00 being rather satisfactory for a family farm. The highest expenditure intake refers to a human labor and polyethylene sheet accounting for 55.1 % expenditures. Calculation of economic indicators showed that the economy coefficient of 1.65 leads to a conclusion that the production is cost effective. While seeding cucumbers one needs 1.5 kg seed/ha requiring HRK 1.170,00/ha. Mineral fertilizers, manure and foliar fertilizers cost HRK 2.869,00 /ha whereas protection agents HRK 771,00 /ha. Polyethylene sheet cost HRK 4.900,00 /ha. Medium tractors were used for 21,37 and light ones 26,66 hours with total tractor work expenditure of HRK 5.490,70 . Yield obtained was 20.700 kg/ha of which approximately 15 % I. class, 45 % II. class and 35 % III. class cucumbers.

***Key words**: Costs, Cucumber, Profit, Technique, Technology*

34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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ENERGETICAL PARAMETERS OF TRACTOR-IMPLEMENT UNIT FOR ADDITIONAL TILLAGE IN HIGHLY INTENSIVE ORCHARDS

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SUMMARY

Subjects of this paper are energetical characteristics of tractor-implement unit, consited of tractor of tractor »Rakovica 65« with »OMMAS Magnum« rotary cultivator, for inter-row tillage in orchards. Regarding obtained results, recommendations for potential users will be given.

Working width of the machine is 0.6 – 0.8m and it is suitable for all types of palmettes, slender spindle, etc.

Optimization of sophisticated systems highlights the necessity of optimal aggregate concerning the elementary exploitation possibilities that must be studied in interaction with financial effects in fruit production.

***Key words**: tractor-implement unit-implement, rotary cultivator, soil cultivation, orchard.*

INTRODUCTION

Highly intensive fruit production, besides cultivar characteristics, is directly influenced by usual practice operations among them mainly soil cultivation that is carried out on time and certanly in adequate conditions. This agro-technical practice, if it is timely done, with reciprocal effects of other agro-technical practices, results in high fruit quality, regular and high yields and lower production costs. Vitality, fruitfulness and long life of fruit trees, its fruit quality and shelf life are in direct correlation with primary and additional tillage. Considering this, it must not be forgotten that soil cultivation is one of the highest energy consumers in fruit production, where soil cultivation is using 25 to 35 % energy. With soil cultivation, soil physical properties are changed which influence to biological and chemical, too. Soil cultivation has basic assignment to create and maintain cultivated areas that will able crop production.

Subject of this paper is establishing energy parameters of soil cultivation with rotary cultivator in orchard inter-rows. Based on results analysis, system optimization will be done.

MATERIAL AND METHOD

In accordance with set goal, tractor »Rakovica 65« with »OMMAS Magnum« rotary cultivator is subject of this investigation.

Measurements were done in real conditions for the peach production in Experimental Station `Radmilovac` that is property of Faculty of Agriculture in Belgrade. The Station is 8 km to the South-East of Belgrade along the motorway to Smederevo. Investigation included:

- drawbar force (measured by Amsler dynamographom),
- driving speed
- hourly fuel consumption
- specific fuel consumption
- bulk density of soil (cylinders after Kopecky)
- fuel consumption per area unit (obtained as a quotient of hourly fuel consumption and aggregate productivity),
- torque on tractor power take-off shaft with measuring system TRC - MMN1 with impulse transmitter *2kNm* and impulse transmitter TD2. Control measurements of impulse transmitter TD2 was done by oscilloscope Tektronix 2230.
- soil structure analysis was done by Savinov method.

Tab. 1 Technical characteristics of investigated machines

Technical characteristic of tractor		Technical characteristic of rotary cultivator	
Engine power [kW]	47	Number of working elements	16
Speed engine at max. power [min^{-1}]	2300	Working width [cm]	80
$M_{max.}/n_{Mmax}$ Nm/ min^{-1}	185/1200	Machine width [cm]	160+80
q [g/kWh]	282	Tillage depth [cm]	15
Energy supply for nominal weight [kW/t]	20,33	Length of machine [cm]	168
Specific weight without ballast [kg/kW]	49,16	Maximum height[cm]	100
Specific weight with ballast [kg/kW]	75,00	Type of machine	Mounted
Weight without ballast with ballast	2360 3600	Weight [kg]	524

List of symbols:

Eha – specific energy consumption	[kWh/ha]	Q - hourly fuel consumption	[l/h]
Fv - drawbar pulling force	[kN]	Qha - fuel consumption per area unit	[l/ha]
k_t – specific soil resistance	[N/cm^2]	v – driving speed	[km/h]
M_{max} – max. torque	[Nm]	Wh – productivity	[ha/h]
n_{Mmax} - speed of engine at M_{max}	[min^{-1}]	φ – adherence	[-]
Pv - output power	[kW]	λ - – slip of wheels	[%]
q – specific fuel consumption	[g/kWh]	η – efficiency coefficient	[-]

Dominant soil type of Experimental Station `Radmilovac` is eutric cambisoil. From table 2 can be seen that conditions for soil cultivation, considering soil moisture, were ideal. Considering bulk density of soil, it belongs to the `heavy soils` group.

Tab. 2 Soil moisture and soil bulk density

No.	Sampling layer	% moisture	Bulk density of soil *(g/cm^3)*
1.	Surface	21.77	1.364
2.	Depth 5 cm	22.96	1.489
3.	Depth 10 cm	22.69	1.420

RESULTS AND DISCUSSION

Pulling characteristics of tractor

Potential pulling characteristics of tractor on stubble filed with and without ballast are shown in tables 3a and 3b.

Tab. 3a Potential pulling characteristics of tractor without ballast

Gear	Pv (kW)	Fv (kN)	v (km/h)	λ (%)	Qh (l/h)	q (g/kWh)	ή (-)
I	7.22	9.29	2.15	14.20	7.02	0.807	0.151
II	11.29	9.51	3.29	19.40	8.23	0.605	0.236
III	18.89	9.03	5.81	16.41	11.53	0.506	0.395
IV	24.15	9.02	7.43	21.50	13.18	0.452	0.505
V	31.10	6.75	12.79	8.88	14.84	0.396	0.650

Tab.3b Potential pulling characteristics of tractor with ballast

Gear	Pv *(kW)*	Fv *(kN)*	v *(km/h)*	λ *(%)*	Qh *(l/h)*	*q* *(g/kWh)*	*ή* *(-)*
I	9.90	15.69	1.75	27.7	7.68	0.643	0.207
II	15.40	15.07	2.83	27.1	9.88	0.532	0.322
III	26.69	14.21	5.21	21.9	13.92	0.433	0.558
IV	32.29	11.35	7.90	11.8	15.28	0.392	0.675

Driving speed (7.9 km/h), where drawbar power (with ballast) showed maximum results, was in optimal limits for 75kg/kW specific tractor weight. Utilization capacity of tractor weight, without ballast and with power wheels slipping of 8.9 %, with maximal engine power, was 0.50. If ballast is present, and slipping of the wheels is 11.8%, weight utilization increases up to 0.62. This characteristic is under the great influence of tractor centre of gravity and axis height of power activity. Distribution of tractor weight on rare axis with and without ballast was 0.52 up to 0.60, respectively. Based on this, optimal maintenance range of drawbar traction power was between 6.75 and 11.35 kN, with power wheels slipping of 20%.

Tractor-machine aggregate, made of tractor and rotary cultivation for inter-row soil cultivation, in perennial plantation, showed following results (table 4.):

Tab. 4 Energetic characteristics of aggregate

No.	M (Nm)	n (o/min)	Pv (kW)	v (km/h)	Fv (kN)	Qh (l/h)	Qha (l/ha)	Wh (ha/h)	Eha (kWh/ha)
1.	500	230	14.02	2.22	2.5	7.38	19.42	0.38	36.91
2.	501	250	15.20	2.31	3.20	7.40	18.33	0.40	37.99
3.	502	376	23.30	2.41	4.10	7.20	17.10	0.42	55.47
4.	490	240	14.66	2.18	3.00	7.25	19.53	0.37	39.62
5.	480	246	13.70	1.22	3.10	7.30	34.69	0.21	65.28
6.	300	400	14.97	1.31	5.00	7.40	32.75	0.22	68.04

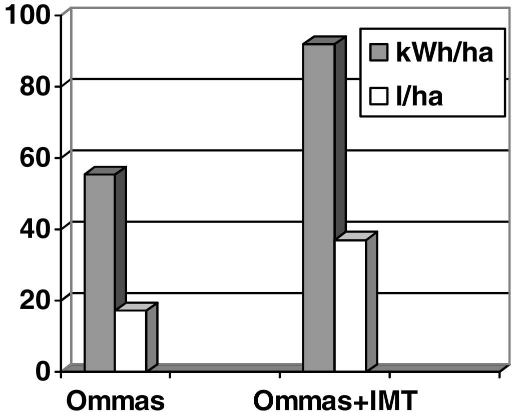
Fuel consumption, in the best case was up to 17.10 *l/ha,* with 0.42 *ha/h* productivity and specific energy consumption of 55.47*kWh/ha.* Considering the best case in soil breaking, specific energy consumption was from 39.62 up to 68.04 *kWh/ha.*

Like cited before, papers` subject was only inter-row soil cultivation. Considering tillage of the whole arable land of the plantation, energy balance, Đević *et al.* (2001), is increasing (table 5).

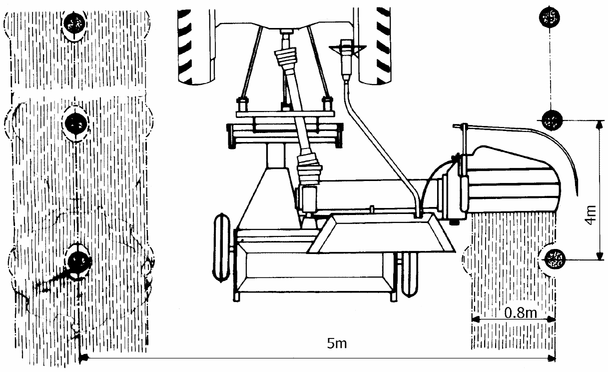
Tab. 5 Energetic characteristics of TMA with rotary cultivator IMT 612.732

No	M (Nm)	n (o/min)	Pot (kW)	V (km/h)	Fv (kN)	Qh (l/h)	Qha (l/ha)	Wh (ha/h)	Eha (kWh/ha)
1.	249	558	16.06	1.33	4.12	10.40	56.50	0.13	89.22
2.	368	548	22.97	1.35	4.90	10.20	53.87	0.19	120.08
3.	250	563	19.81	3.61	5.05	10.80	19.95	0.54	36.59

In the best case, it is needed 19.95 *l/ha* more, with productivity of 0.54 *ha/h* and energy consumption 36.59 *kWh/ha.* Considering energy, this type of cultivation is very expensive because of large fuel consumption (picture 1), but considering quality of tillage, very satisfactory (table 5).



Pict. 1 Fuel consumption in inter-row ant total arable land tillage with rotary cultivator



Pict. 2 Scheme of rotary cultivator during work

Table 6 Index of rotary cultivator Ommas Magnum work

Aggregate size (mm)	*Measurement I*		*Measurement II*	
	Weight (g)	*Soil particles distribution in the sample (%)*	*Weight* (g)	*Soil particles distribution in the sample (%)*
>50	-	-	-	-
25-50	600	13.48	200	3.6
19-25	200	4.49	200	3.6
16-19	250	5.61	250	4.58
9,5-16	450	10.11	500	9.17
5-9,5	500	11.22	800	14.67
1-5	1750	39.32	2600	47.77
>1	700	15.73	900	16.51
Total	***4450***	***100***	***5450***	***100***

CONCLUSION

Based on presented, following can be concluded:

- Soil cultivation is improving soil conditions because it creates better environment for root development of perennial crops by regulating water, air and heat relationship in soil, provide better soil particle mixing with plant residue and evens distribution of fertilizers through soil profile.
- Regular soil cultivation affects the growth and fruitfulness of the fruit cultivars.
- Inter-row soil cultivation uses 36-68 kWh/ha, in dependence to working regime of the aggregate, but by tillage of the whole arable land in perennial plantations total energy balance was between 92 and 180 kWh/ha.
- By using rotary machines with horizontal rotation of axis, with changeable rotors, with different shapes, geometric and position of working elements with high energetic costs, but with high quality tillage and decreasing of manual work, profitable production is possible.
- All types of palmettes and slender spindle are training system that allows using of this machine that has working grip width 0.6-0.8 m.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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PROBLEMS AND TASKS IN THE MECHANISATION OF SMALL AND MEDIUM-SIZE FARMS IN HUNGARY

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SUMMARY

In connection with general problems, most of the Hungarian small and medium-size agricultural enterprises have serious problems of the field of mechanisation.

The tasks of developing the mechanisation of these farms are dual:

- *The improvement of coverage of agricultural machinery and the increase of their density. The establishment of such machinery output which is capable of meeting the demands of the new structures of technology and property. This makes the increase of machine coverage essential, especially small and medium-sizes farms.*
- *The replacement of amortised and overused machines with new ones. The meeting of the demands of the technological modernisation. The supply of the market of agricultural machinery must facilitate the realisation of these objectives in such a way that it offers both technically and financially suitable range for the farms willing to invest.*

Key words: *the role of agricultural production, farm mechanisation, small and medium-size farms*

INTRODUCTION

The agriculture was a prosperous sector of the national economy till the middle of the 80's in Hungary. The great changes of the Hungarian economic and society has created a new situation for the agricultural production. The importance and the role of agriculture in the national economy have been decreasing. The development of agriculture has not stumbled world-wide, but in Hungary the production dropped by 30 %. The export of food industry and the foreign exchange surplus decreased as well.

In connection with the general problems, most of the Hungarian small and medium-size agricultural enterprises have serious problems of the field of mechanisation. The difficulties have started in the 1980's when the earlier possibilities of development were narrowed and the machinery investments slowed down. As a consequence of it several decades the balance of machinery investments and replacements tipped over at the enterprises. The rate of depreciated but used means and their time of life increased nearly on all areas. The aged tractor stock causes Hungary serious concern. The average age of tractors in 2000 was 15.3 years. In individual farms this value was 16.1, in case of joint farmers 12.4 years. The greater part of individual farmers is forced to operate on the used, worn-out machines of former agricultural co-operatives.

The main objective of the research and this presentation is to systemise the present technical development tasks of the Hungarian agriculture, especially focusing on the mechanisation tasks in small and medium-size farms.

METHOD

Statistical analysis was performed on the basis of data collected from the Hungarian Central Statistical Office and from the Hungarian Institute of Agricultural Engineering. The results of analysis were completed with information from personnel connection with farmers.

RESULTS AND DISCUSSION

The present situation and role of agriculture

Agriculture and food industry in the Hungarian economy are traditionally important. The ecological conditions of the country and the traditions provide a very good base for agricultural production. The data summarised in **Table 1** refer to the role of agriculture in the national economy.

Table 1 Share of agriculture in the Hungarian national economy (%)
(*Source*: Hungarian Central Statistical Office)

Year	GDP	Investment	Exports*	Employment
1960	22,3**	16,2	22,1	36,6
1970	21,2**	17,5	22,8	20,5
1980	18,6	12,1	23,3	15,1
1990	15,3	8,6	23,1	11,1
2000	4,2	5,0	2,6	6,6

*: With food industry
**: Net income

The **importance** and the **role** of agriculture in the national economy have been decreasing. It is particularly obvious after the change of regime. While the development of agriculture has not stumbled world-wide, the production dropped by 30 % in Hungary. The export food industry and the foreign exchange surplus decreased as well.

The sector employed 850 thousand people granting secure living for a great number of families. It used to have more than 1.5 billion HUF (cc. 5,9 mil. €) foreign exchange surplus that covered the energy and raw material import of the country. The standard of the cultivation was near to the standard of the most developed countries. The sector produced goods and basic material for the food industry in significant quantity.

The **development of Hungarian agriculture** is important for several reasons. Among these, the following two reasons should be emphasised:

- There was some confusion in the agriculture due to the changes in the political regime and in the social-political-economic environment, resulting strong decrease of output in several sectors.
- Joining the European Union will probably be realised in the next couple of years. However, based on the present state of development we cannot expect that the competitiveness of the Hungarian agriculture will meet the requirements.

Problems in the mechanisation of the Hungarian agriculture

While we often emphasise the significance of **complexity** in connection with the agricultural technical development that is the necessity of harmony among effective factors, most experts accepts that "Mechanisation is the **backbone** of the technical development".

The work of machines substituting both for animal and human work became a production factor in the course of time. It is already unimaginable to produce agricultural product in volume without machines. The economic significance of mechanisation became a decisive issue, as high proportion of the agricultural production costs is in connection with the use of machines.

Most of the Hungarian agricultural enterprises have serious problems of the field of mechanisation. The difficulties have started in the 1980's when the earlier possibilities of development were narrowed and the machinery investments slowed down. As a consequence of it several decades the balance of machinery investments and replacements tipped over at the enterprises.

The rate of depreciated but used means and their time of life increased nearly on all areas.

Some **other problems:**

- the technically obsolete and used machines injure the environment very much,
- the maintaining and repairing basis were partly disintegrated and the remain part can hardly keep up with the wearing out of machines,
- the lack of infrastructure and the condition of the available one – e.g. the poor quality of agricultural roads – influences the technical state of the too heavy machines and at the same time increases the cost of repair and causes considerable losses at the transported products.

As other conditions were getting worse and because of the above mentioned facts the expected economic advantages of mechanisation were not realized efficiently. The lack of capital and the uncertainty of transformation worsened the problems. It wasn't really difficult to forecast the present situation of the Hungarian agriculture: one of the main limits of the international competitiveness is the stock of obsolete means.

We can get a picture on the characteristics of the mechanisation in the Hungarian agriculture from the recent data of HCSO (**H**ungarian **C**entral **S**tatistical **O**ffice). In the frame of the **G**eneral **A**gricultural **R**egister in 2000 (GAR 2000) CSO surveyed the stocks of agricultural machines, buildings and structures in Hungary. I refer to the data of this survey in this paper. (**Table 2)**

According to the data between 1991-2000 the **mechanical drawing power** increased by 1.6 % in Hungary. Inside this figure, the drawing power capacity of tractors rose by 35.6 %; the engine performance of combines by 5.6 %.The performance of lorries decreased a lot, to 58.5 % and the performance of other self-moving machines to 80.6 %. As a result of this, the inner performance structure of the power machines has been changed. The drawing power proportion of tractors increased from 44.7 % to 59.5 %, the combines' ratio from 13.9 to 14.4 %. The proportion of lorries decreased from 32.1 % to 18.5 %, and the proportion of the self-driven machines from 8.9 to 7.0 %.

Only 26.9 % of the total power machine capacity was in the possession of individual farms in 1991. This figure increased to 56.8 % by 2000. The proportion of engine performance in the farms rose from 29.4 % to 67.2 % in the same period.

Table 2 Some characteristics of the mechanisation in the Hungarian agriculture

Title	1991	2000
Machinery power (1000 kW)	9 733	9 888
From this: tractor	4 347	5 884
Tractor stock (pc)	92 000	113 000
From this: in private farms	46 000	87 000
in organisations	46 000	26 000
Average tractor capacity(kW/pc)	47	52
From this: in private farms	28	45
in organisations	66	74
Av. tractor-age (year)	..	15,3
From this: in private farms	..	16,1
in organisations	..	12,4
Cereal harvester stock (pc)	10 400	12 113
From this: in private farms	559	6 453
in organisations	9 841	5 660
Av. age of harvesters (year)	..	14,5
From this: in private farms	..	18,3
in organisations	..	11,5

Source: GAR 2000.

The changes in average engine performance show up interesting connections as well. The nation-wide average value was 47.3 kW/pc in 1991 and 52.1 kW/pc in 2000. At joint farming these figures changed from 66.8 kW/pc to 74.1 kW/pc, while in case of individual farming from 27.7 kW/pc to 45.6 kW/pc.

The previous figures say that the characteristics of the individual farming prevail the national situation. In piece number, 78.7 % of the tractors are in the possession of individual farmers. The number of tractors per field unit is threefold higher in individual farming than in joint one. It means at the same time that machine utilisation is more favourable at the joint farmers. It is particularly true if we additionally consider the fact that a significant proportion of individual farms are cultivated by joint farmers. The unfavourable utilisation of machines puts up the cost of production.

There is **significant difference** in the composition of the power machines as well. At individual farmers the proportion of tractors with less engine performance (fewer than 40 kW) is much higher than at joint farmers.

It is a general trend that the average utilisation time of the machines has got longer. The machines of individual farmers are older and consequently their maintenance is more expensive, their reliability is less favourable than in case of joint farmers. The proportion of power machines with favourable age, below ten years, is 40.1 % at joint and 37.1 % at individual farmers.

In agreement with other experts, I also think, that in the task of mechanisation of the Hungarian agriculture, **quantitative** and **qualitative** measures need to be taken. I see reasons in improving the availability of farm machinery and the reasonable increase of the machinery density. From the point of view of competitiveness, it is also important to replace old and worn machinery with modern technology. This is a prerequisite for compliance with the more restrictive qualitative requirements.

Work to do in the sphere of mechanisation development

The **mechanisation** of Hungarian agriculture and the technical standard of the machine park fall behind the ones of developed countries. It is worrying, because efficient and quality production can be realised only by up-to-date technology. The tractor-frequency index of Hungary is 1.49 tractors/100 hectares, that are 67 hectare agricultural fields, get to one tractor on average. The index in international comparison is not too encouraging, as in each Western European country this value is substantially more favourable and even more Eastern European countries are ahead of us in this field. The data are professionally not unambiguous, even they are disputable, but nevertheless they grant good references to judge our tractor stock internationally.

The **aged tractor stock** causes Hungary serious concern. The average age of tractors in 2000 was 15.3 years. In individual farms this value was 16.1, in case of joint farmers 12.4 years. The greater part of individual farmers is forced to operate on the used, worn-out machines of former agricultural co-operatives.

Tractor stock requires enlargement, its age structure should be improved. At the same time the tractor park should be modernised, especially as more than three quarter of the Hungarian tractor park consist of out-of-date Easter European types.

The situation is not much better at **combines**. The combine park today is 12500 combines, out of this figure 53 % work in individual farms. Nation-wide, on average the agricultural area per combine index is 250 hectares and this figure is three times higher than the average of the European Union. The combine park is also too aged, the average is 13.6 years. We could meet the consequences of the aged park last years, when cereal harvesters lasted 55-60 days compared with the optimal 25-28 days. It causes lower quality and high proportion of harvest losses.

We can find very similar facts and conclusions at **other groups** of agricultural machines.

By today, difficulties and problems of mechanisation have become the **limits** of modernisation of agricultural production. It should be realised that the technical "push" can not meet the users "pull" in the innovation model, namely farmers are unable to select machines according to their demand. We hope that changes in social-political-economic environment will be able to help in this field as well.

The farm-machinery market is **supply-led.** Today, if somebody likes to buy an agricultural machine, can choose from almost 60 thousand different models. The offer of tractors includes 1350 tractor types and their variants from 58 manufacturers (19 Easter European and 39 Western European). The range of cereal combine harvesters includes 252 different types and their variants from 10 manufacturers (3 Eastern and 7 Western European). We can find 1815 types of ploughs and 1872 types of seeding machines on the market. The number of spraying machines is even higher, 2664 types are on offer. These data demonstrate that most of the world's agricultural machinery manufacturers are present on the Hungarian market. The main data supporting this can be seen in **Table 3.**

Table 3 Farm machinery market supply

Machine type	Number of types	Manufacturers	Hungarian+Eastern+Western
Tractor	10 350	58	1+18+39
Harvester	252	10	0+3+7
Plough	1 815	61	19+11+31
Sowing machine	1 872	74	2+12+60
Sprayer	2 664	53	5+13+35
Total (2001)	**55 800**	**1 900**	

Source: Hajdú, 2003.

It is apparent that the enlarged selection on offer requires expert knowledge for the procurement decision-makers. It is not only that it is more difficult to choose from 100 models than from 10. It is also decisive question, whether it is possible to follow the large number of different technical parameters on a daily basis. Additionally, under the competition pressure manufactures modernise at a faster pace than before, so that they put more new models faster on the market, not taking into account whether the consumers are able to adjust – technically and financially – to this pace.

The data show that the supply on the Hungarian farm-machinery has changed a lot from the former 1/3-1/3-1/3 ratio. It is now evident that western supply is dominant, as shown by the figures in **Table 4.**

Table 4 Ratios of farm-machinery procurement by region

Region	Number of machines	Value of procurement
Hungarian	28,49	13,83
Eastern	4,33	16,31
Western	67,18	69,86

Source: Hajdú, 2004.

The domination of **western supply** alone could be welcomed, because these machines are usually of higher quality. However, it is not indifferent, what is the price is of the higher quality. The Hungarian agricultural community is very sensitive to the cost of development, as the "agricultural scissors" are opening permanently making critical the development of efficiency and the rate of return and at the same time it limits the fulfilment of the classic principles of self-financing. The small and medium-size farms with short of capital often face with the unsolvable challenge of synchronising the force of machine procurement with their lack of capital. It is not a surprise that the most frequent motivation for their buying a farm-machine is the existence or the non existence of investments supports. Except for last year, development funding was rather **limited**.

The data related to this can be seen in **Table 5.**

The data clearly show that the ratio of **own risk** resource is above 70%, which again calls for the importance of a careful decision analysis before the procurement. The largest part of the financial resources used for purchasing machinery was made of the farmers' own liquid resources.

Table 5 Sources of farm-machinery investments in 2001

Source	*Total amount (MHUF)*	*Ratio (%)*
Own resource	37 836,8	42,28
Subsidy	24 530,7	27,41
Credit	26 713,3	29,45
Other	418,6	0,47
Total	**89 499,4**	**100,00**

Source: Hajdú, 2003.

The **largest value** of investments (58 %) was made up by tractors and cereal combine harvesters. The remaining part was used for purchasing farm implements, irrigation systems, fodder processing machines, materials-handling equipment and equipment for animal husbandry. Over 80 % of purchased machines was for crop production, machinery for animal husbandry made 8 %, while the remaining made by other divisions.

Table 6 Farm-machinery investment per sector in 2001

Economic sector	*Area of land (%)*	*Average area (hectares)*	*Investment ratio (%)*
Private farms	51,7	4,05	43,2
Economic societies	32,2	582,4	46,6
Co-operatives	15,1	1 226,9	9,5
Total	**100,0**	**8,1**	**100,0**

Source: Hajdú, 2003.

Knowing the previous figures it is also advisable to look at the ratio of sector procurement in Hungary in the last few years. The data related to this is shown in **Table 6.**

Table 7 The organisational structure of Hungarian agriculture

Name	Forms of production			
	Number (pieces)	Ratio (%)	Number (pieces)	Ratio (%)
	1990		1998	
Enterprise with legal entity	1 990	64,0	7 703	19,7
Out of which: Economic societies	445	14,3	4 932	12,6
Co-operatives	1 362	43,8	1 715	4,4
Producers without legal entity	1 118	36,0	31 339	80,3
Out of which: Private farmers	..	..	27 832	71,3
Total	**3 108**	**100,0**	**39 042**	**100,0**

Source: HCSO

The table clearly show that the private farms and the co-operatives **have a lower ratio** of investment per area than the economic societies. This fact could serve as a basis for further analyses. It seems probable, that economic societies – due to their ownership structure – still have development funds to improve their technical capability, while the individual producers and the co-operatives have already spent their reserves. This is an existing question, as new organisational structures are developing nowadays, which is the next decade could be decisive for the international competitiveness of Hungarian agriculture. The development of new organisational structure is illustrated in **Table 7.**

The economic problems of the using of farm-machinery

A machinery investment decision is a complex economic problem in itself and furthermore it influences the economic characteristics of the machine use, particularly the machine utilisation and its economic effect-mechanism.

During both planning and utilising the capacities we face the problems of efficiency. Efficiency is a relative category; it shows the ratio of the theoretically possible and the real utilisation. In case of capacity it shows in what degree we use the capacities. Efficiency has a direct effect, the better we utilise the production capacity the less machinery we need for a given production and vice versa.

After the transition in Hungary the land-structure has changed significantly. The new conditions are unfavourable for the economic machine utilisation as the land sizes do not make the economically reasonable utilisation possible. This is the reason we have to deal with this problem further on.

Based on the actual situation, the **tasks of the agricultural technical development** can be determined, paying attention to:

- the fact that the concrete tasks and possibilities of the development are influenced by the current social-political-economic characteristics, which change over time;
- the need to solve the development of the active components in a complex and harmonised way because there is a special “minimum-law” implied in the development, i.e. the success of the development is determined by the developing factor that is present in minimum level.

The **level of mechanisation** in the Hungarian agriculture is lower than it used to be. Our research is dealing with the tasks of the mechanisation development, emphasising the following key-factors:

From the **farmer’**s point of view:

- improvement of professional skills/knowledge,
- paying attention to quality and quantity, assurance of financial liquidity,
- validation of the system-oriented approach and determination of the economic optimum.

From the social-political-economic environment’s point of view:

- strengthening the security of agricultural production,
- providing economic preferences and state support,
- improving the information supply to the producers, development of extension and customer service.

CONCLUSIONS

The technical development of the agriculture is a multi-component, **complex** task. Among the current tasks, the development of mechanisation can be emphasised which forms the main part of the technical development.

I found that the designated development tasks **cannot be postponed** because the absence of the developments can weaken the international competitiveness of the Hungarian agriculture and threaten the future of the sector.

The **main conclusions** are following:

- The mechanisation **indexes** of our agricultural enterprises considerably lag behind the similar indexes of EU member states. At the same time our economic possibilities do not permit and our structural characteristics do not justify a strained machinery investment. The limited financial sources ought to be spent circumspectly, and therefore deep preparations are to be done before investment decision. The decision preparations are particularly difficult because the scope of supply has been enlarged significantly on one hand and on the other hand the professional knowledge is not always adequate.

- At judging the economic position of the sector one must consider that **self financing** is seldom possible nowadays which occasionally can cause development inability.
- The high value of most agricultural machines is a **big burden** not only to the investment cost but it influences to a great degree the costs of utilisation as well.
- Under the present circumstances of the Hungarian agriculture there are more possibilities worth while to be considered for **decreasing the cost** of utilisation, such as:
    - Creating the conditions that a volume oh the tasks should be reasonably given that makes an **optimal utilisation** possible. We can claim it sure enough that a farm with a couple of hectares is suitable to it only if there is a possibility to utilise the surplus capacity.
    - To work out the **amortisation policy** in order that fixed cost can be divided reasonably.
    - It is practical to rethink the possibilities of utilising **used** or **amortized** machines. The obvious advantage in this case is that the large ratio of fixed cost falls off. However we must consider that the repairing cost increase and we must face if the used machine can still meet the quality requirements of the work.
- A farmer in order to get a unit of performance at the **lowest** possible **price** ought to know the level of utilisation where the specific cost the machine use is minimal. According to our trial calculations and observations we can claim that the present utilisation values are far below the economic expectations in the most of small and medium-size Hungarian farms.

ACKNOWLEDGEMENTS

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

ORGANIZACIJSKO-EKONOMSKI KONCEPT ZADRUŽNE MREŽE HLADNJAČA ZA VOĆE I POVRĆE S OBITELJSKIH GOSPODARSTAVA U HRVATSKOJ

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SAŽETAK

Proizvođači s malim proizvodnim površinama nemaju ekonomskog opravdanja za koncept "hladnjača u svako dvorište". Taj koncept ne može se opravdati niti ekonomijom razmjera, niti visinom društvene cijene investicije, niti kroz učinkovitost potpora kapitalnim ulaganjima u poljoprivredu, a najmanje zbog visokih fiksnih troškova po objektu. Proizvodno usitnjena i infrastrukturno neorganizirana obiteljska poljoprivreda gospodarstva nemaju mogućnost ozbiljnijeg tržišnog nastupa i natjecanja. Primjerice kod jabuka, preko 66 % ukupne površine smješteno je na posjedima ukupne veličine do 5 ha. Četiri petine (80,4 %) površina i proizvodnje jabuke odvija se na gospodarstvima veličine do 10 ha, a svega 20 % ukupnih površina pod jabukom imaju gospodarstva veličine preko 10 ha. Tek se ova gospodarstva, u našim uvjetima, mogu organizirati kao samostalna poduzeća odnosno kao tehnološko i tržišno zaokružena cjelina. Ova bi se gospodarstva zbog svoje proizvodne snage mogla opskrbiti i hlađenim prostorom kao samostalna voćarska poduzeća. Ostali se, po kapacitetima i proizvodnji manji proizvođači, trebaju organizirati u sustav mreže hladnjača kako bi kroz sustav sinergije povećali svoju pojedinačnu konkurentnost. Mreža hladnjača je najprihvatljivije sustavno rješenje problema povezivanja velikog broja gospodarskih jedinica razasutih na širokom proizvodnom prostoru. Nacionalnom mrežom hladnjača troškovno bi se optimizirala opskrbno-prodajna logistika voćara i povrćara s obiteljskih gospodarstava. Također bi se smanjili opći troškovi pojedinačne izgradnje, standardizirala bi se tehnologija i kvaliteta čuvanja proizvoda, osigurala mogućnost licenciranja hladnjače kao preduvjet za uvođenje skladišnice kao kolaterale za kredite proizvođača u obrtna sredstva te omogućilo skupno strateško istraživanje tržišta i uvođenje «brand name-a» za određenu vrstu voća i povrća. Nacionalnom mrežom hladnjača pojačala bi se kontrola ekološki incidentnih situacija s jednog mjesta, olakšalo uvođenje e-trgovine voćem i povrćem kao i olakšalo druge servisne poslove u ime i za račun voćara i povrćara vezanih uz zajedničku hladnjaču.

Ključne riječi: *Obiteljska poljoprivredna gospodarstva, voće, povrće, hladnjače*

UVOD

Hladnjače za voće i povrća zajedno s ostalim uslužnim kapacitetima u poljoprivredi čine poljoprivrednu infrastrukturu. Uspješnost organizacije i s tim u vezi ekonomike korištenja ovog dijela infrastrukture biti će temeljno pitanje buduće konkurentnosti na globaliziranom EU tržištu i nužna pretpostavka za osvajanje novih tržišta. U većini rasprava o pristupu hrvatske poljoprivrede EU, govori se i o potrebnoj infrastrukturi, najčešće deklarativno, bez koncepta i osnovne organizacijske sheme.

Aktualna agrarna politika Hrvatske zagovara stajalište o potrebi izgradnje hladnjača za voće i povrće, no bez cjelovitog i sustavnog pristupa. Bez definiranja tehnoloških standarda, bez osmišljene organizacije i ekonomike održavanja, bez definiranog centralnog nadzora mogućih ekoloških incidenata, bez kriterija prostorne lociranosti sadašnje te budućeg širenja proizvodnje i tržišta voćem i povrćem; tada hladnjača kao neophodna u sustavu proizvodnje, može biti samo nepotrebni element «zidanja» ukupnih troškova u obiteljskom voćarstvu i povrtlarstvu.

Ostali elementi o kojima se mora voditi računa na mikro razini su veličina i struktura proizvodnje voćarskih i povrtlarskih gospodarstava, rasparceliranost i dislociranosti voćnjaka unutar jednog OPG-a. Na makro razini su regionalizacija dospjelosti, logistika prikupljanja voća i povrća s OPG-a, osmišljavanje uloge hladnjače u rješavanju lokalne i sezonske zaposlenosti te ostaloj potpori za funkcioniranje mreže hladnjača. Sve su to bitni elementi koje se mora uvažavati u ostvarenju pune tehnološko-ekonomsko-tržišne učinkovitost ove proizvodnje u Hrvatskoj i njezine uklopivosti (proizvodnje i čuvanja) u konkurentske sposobnosti zemalja članica EU-a. Bez nje odnosno bez prethodne organizacije i ekonomike korištenja ne postoji stvarna mogućnost tržišne utakmice OPG-a, a time i cjelovite hrvatske voćarske i povrtlarske proizvodnje (izuzetak su monopolizirana voćarska i povrtlarska poduzeća).

Voćarsko-povrtlarsku infrastrukturu hladnjača treba graditi u formi interaktivne mreže koja će tržišno i proizvodno afirmirati manje proizvođače te koji će se zbog svoje veličine proizvodnje lakše i brže prilagođavati tržišnim promjenama nego veliki, samodostatni i tromi proizvodni sustavi.

OSNOVNE POSTAVKE I OPRAVDANOST KONCEPTA MREŽE HLADNJAČA

Ako kapaciteti hladnjača nisu dovoljni i/ili nedovoljno organizirani da prihvate od proizvođača željenu količinu voća i povrća na čuvanje, voćarska i povrtlarska proizvodnja biti će izložena sezonskim oscilacijama cijena, velike, trenutačne rizičnosti i dugoročno razvojne nesigurnosti. Isto tako, ako su organizacijski i funkcionalno vezane uz trgovinu a ne voćarsku i povrtlarsku proizvodnju na OPG-a, tada hladnjače postaju servis u službi distribucije i trgovine, a ne željenog infrastrukturnog poticanja proizvodnje. Smještene u trgovini kao grani odnosno izvozno-uvoznom nacionalnom servisu za voće i povrće, tada se potencijalna dobit kroz sezonalnost cijena odlijeva izvan voćarske i povrtlarske proizvodnje. Stoga servis čuvanja u hladnjačama za manje proizvođače treba izgraditi kao njihov vlastiti servis (infrastruktura) potpore voćarsko-povrtlarskoj proizvodnji te vlasnički i organizacijski uz njih vezati. Budući su kao proizvođači u stanovitom privilegiranom položaju raspolaganja vlastitom proizvodnjom i ponudom neposredno poslije berbe, valja im omogućiti korištenje slobodnih kapaciteta uvozno-izvoznih hladnjača (u trgovini) samo onda kada za to postoji poslovni interes (čuvanje i prodaja radi izvoza), a ne kao nužnost. To će biti moguće postići ako se sustavom potpore i adekvatnom organizacijom hladnjača kroz kapitalna ulaganja u poljoprivredu, osigura sustavna i kontinuirana izgradnja i nadogradnja mreže hladnjača u zajedničkom vlasništvu proizvođača.

Sezonske se pojave mogu definirati kao periodičke pojave s ciklusom unutar jednog razdoblja i to najčešće jedne godine. U analizi gospodarskih kretanja vrlo je važno uočiti zakonitosti pojava u vremenu, odnosno u tom kretanju odjeliti utjecaj trenda i rezidualne komponente.

Metodološki, ekonomske vremenske pojave u načelu od sistemskih komponenti, osim sezonskih, sadrže i trend-komponentu, koja je prikazana u grafu 2.

Od dva regresijska modela, aditivnog i multiplikativnog, u analizi sezonskog utjecaja na gospodarsku politiku, iskustvo nam potvrđuje prikladniju primjenu multiplikativnog modela, koja je primijenjena u ovom istraživanju. Stoga je zadaća ove analize izračunati utjecaj vremena berbe jabuka (vremena tehnološke zrelosti) na njezinu izvan sezonsku, prosječnu, mjesečnu veleprodajnu cijenu, tijekom godine i primjenom multiplikativnog modela od *n* članova serije:

$$Y_t = T_t * I_{Ct} * I_{St} * I_{\varepsilon t}$$

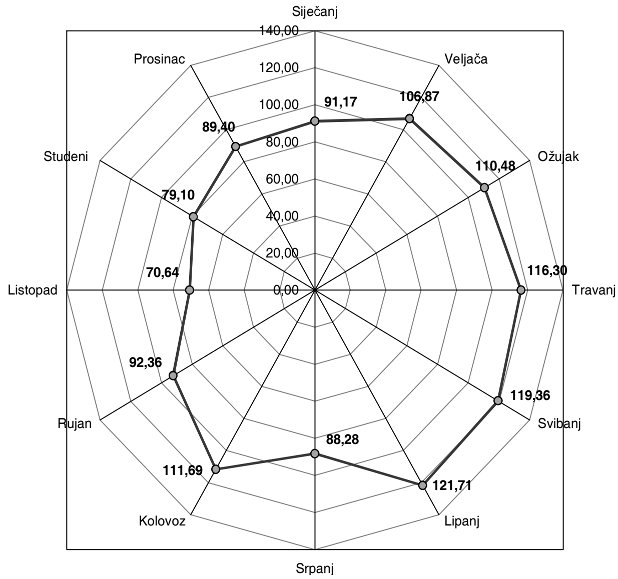
gdje je T_t trend komponenta, I_{Ct} indeks cikličke komponente, I_{St} indeks sezonske komponente i $I_{\varepsilon t}$ indeks rezidualnog ostatka modela.

Značajne razlike u prosječnim mjesečnim cijenama jabuke uvjetovane sezonalnošću ponude tijekom mjeseci u godini, dovoljan su razlog za osmišljavanje i provedbu koncepta izgradnje mreže hladnjača u organizaciji i pod kontrolom proizvođača jabuka odnosno hladnjača namijenjenih OPG-ima.

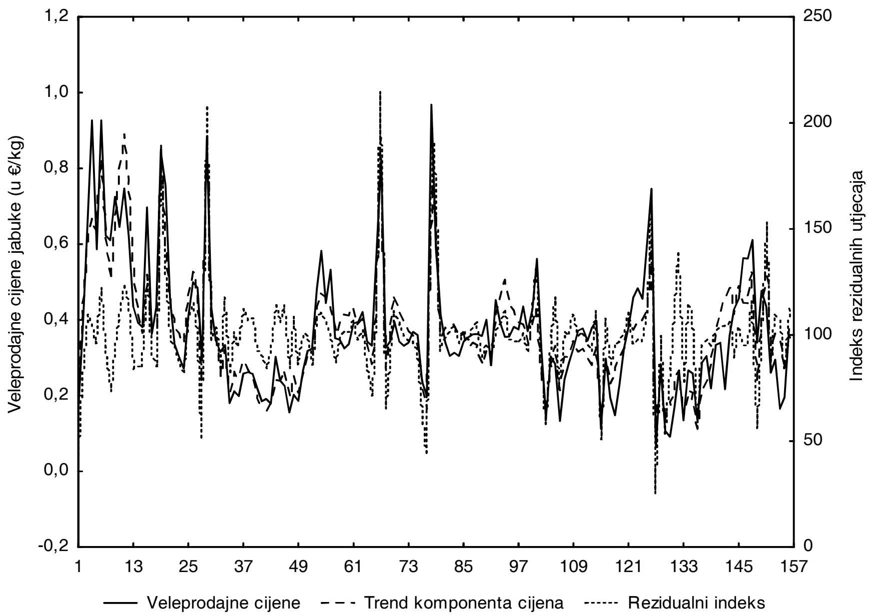
Kroz izračun indeksa sezonalnosti cijena jabuke izračunavaju se vrijednosti pojave očišćene od sezonskih utjecaja. Tako je npr. sezonski indeks prosječne mjesečne veleprodajne cijene jabuke na hrvatskom tržištu u siječnju 1990. godine bio 87,30 i pokazuje razinu cijene u istom mjesecu za 12,7 % **manju,** zbog sezonskog utjecaja.

Promatrano na prosječnoj razini za analizirano razdoblje (od 1990. do 2002. godine), prosječna je cijena za siječanj mjesec bila je 8,81 % **manja** s naslova sezonskog utjecaja. Istodobno, mjesec lipanj u prosjeku je zbog sezonskog utjecaja imao 21,71 % veću cijenu.

Ovu razliku u načelu je «konzumirala» trgovina budući su OPG-a bez vlastitih rashladnih kapaciteta. To svakako govori o odljevu dobiti od poljoprivrednih proizvođača prema trgovcima, a sve temeljem sezonskog utjecaja na cijene. Na taj je način moguće vrlo lako izračunati dobit koja je «uskraćena» proizvođačima kao razvojno poticajna s jedne strane i monopolski, realizirane ekstra dobiti trgovaca u distribucijskom lancu jabuke, s druge strane.



Graf. 1 Indeksi sezonskog utjecaja cijena jabuke za razdoblje 1990. do 2002.



Graf 2 Grafički prikaz prosječnih mjesečnih veleprodajnih cijena jabuke (€/kg), trenda i rezidualne komponente cijena

Proizvođači s malim prosječnim površinama nemaju ekonomsko opravdanje razvijati koncept i logiku "hladnjača u svako dvorište" jer se to ne može opravdati niti ekonomijom razmjera, niti visinom društvene cijene investicije, niti kroz učinkovitost potpora kapitalnim ulaganjima u poljoprivredu, a najmanje visokom razinom fiksnih troškova po objektu i sl. U prilog tome nam govore i podaci o usitnjenosti proizvodne strukture proizvođača jabuka, kao najzastupljenije voćne vrste na OPG-ima, u nas.

Tablica 1 Distribucija veličine obiteljskih poljoprivrednih gospodarstava pod jabukom u Republici Hrvatskoj

Veličina gospodarstva prema razredima	Površina pod jabukom (plantažni i neplantažni uzgoj preračunato) (ha)	Struktura (%)	Udjeli (%)	Proizvodnja jabuka (tona)	Udjeli (tona)
Ukupno	**2452**	**100,0**		**98080**	
do 0,10 ha	98	4,0		3928	
0,11-0,50 ha	348	14,2		13939	
0,51-1,00 ha	232	9,5		9275	
1,01-2,00 ha	344	14,0		13779	
2,01-3,00 ha	261	10,6		10430	
3,01-5,00 ha	**337**	**13,8**	**66,1**	**13498**	**64851**
5,01-10,00 ha	**349**	**14,2**	**80,4**	**13975**	**78826**
10,01-20,00 ha	278	11,3		11116	
Preko 20,00 ha	**204**	**8,3**	**19,6**	**8155**	**19270**

Izvor: Vlastita obrada iz podataka Popisa poljoprivrede, DZS RH, Zagreb 2003.

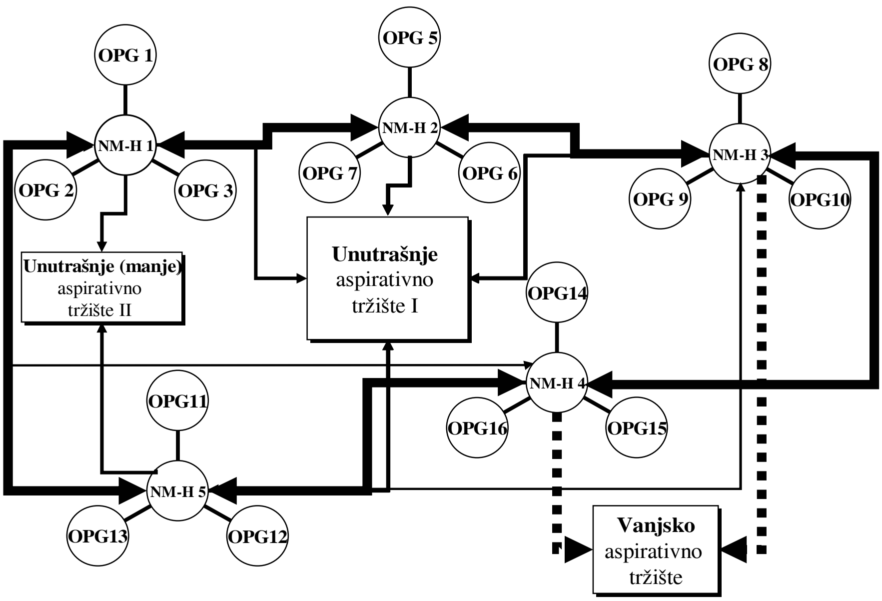
Prema Popisu poljoprivrede iz 2003. godine u posljednjih se desetak godina, voćarska i povrtlarska proizvodnja u Hrvatskoj seli na obiteljska poljoprivredna gospodarstva (OPG). Proizvodno usitnjena i infrastrukturno neorganizirana, obiteljska poljoprivreda gospodarstva nemaju mogućnost ozbiljnog tržišnog nastupa i natjecanja. Ilustrativno se to može prepoznati kroz proizvodnju jabuka na OPG-ima, gdje je 66,1 % ukupne površine pod jabukom smješteno na posjed ukupne veličine do 5 ha. Četiri petine (80,4 %) površine ali i proizvodnje jabuke odvija se na gospodarstvima do veličine od 10 ha. Svega 20 % površine pod jabukom imaju gospodarstva razreda preko 10 ha. Tek se ova gospodarstva u nas mogu organizirati kao samostalna poduzeća u voćarstvu i povrtlarstvu kao tehnološko i tržišno zaokružena cjelina. To znači kako bi se takova gospodarstva zbog svoje proizvodne snage mogla opskrbiti i hlađenim prostorom kao samostalna voćarska poduzeća. Ostali se manji proizvođači trebaju organizirati u sustav mreže hladnjača kako bi kroz sustav sinergije povećali svoju pojedinačnu konkurentnost.

PARAMETRI MREŽE HLADNJAČA

Mreža hladnjača je najprihvatljivije sustavno rješenje problema povezivanja velikog broja gospodarskih jedinica razasutih na širokom prostoru, nejednakomjerno dispergiranih. Disperzija proizvođača voća i povrća uvjetovana je neravnomjernim nacionalnim razmještajem agroekoloških uvjeta proizvodnje voća i povrća te su zbog toga proizvođači po skupinama različite gustoće raspoređeni na proizvodnom prostoru. Agroekološki uvjeti proizvodnje, osim zemljišnih i mikroklimatskih uvjeta, dobrim dijelom određeni su i tradicijom u proizvodnji voća i povrća. Tako će u kvalitetom istim agroekološkim uvjetima za voće i povrće biti različiti broj voćara i povrćara, te sa stanovišta mreže možemo govoriti o različitoj aspirativnoj gustoći proizvođača prema «čvoru mreže».
U organizacijskom smislu mreža ima svoje vrhove ili čvorove mreže. Prostorno gledano, oni (čvorovi) su točke optimalno postavljene a kapacitetom hladnjače su određene granice gravitacijskog područje proizvodnje jednog ili više agroekoloških područja.

Shema 1

Shema organizacije nacionalne mreže (NMH) hladnjača za OPG-a



OPGn =Obitljska poljoprivredna gospodarstva **NM-Hn**=Čvor nacionalne mreže hladnjača

Mreža je organizacijski sustav, protočan cijelim svojim tijekom odnosno korespondentan između pojedinih vrhova mreže koji su ovdje definirani kao lokacijske točke hladnjača nacionalne mreže (H-NM).Vrhovi mreže odnosno NM-H su težišne točke u prostoru prema rojevito raspoređenim skupinama proizvođača voća i povrća na OPG-ima. Time mreža dobiva osnovnu organizacijsko-ekonomsku optimizaciju prema prostornoj disperziji proizvođača.

Prometno parametriranje vrhova NM-H–a prema aspirativnom domaćem i izvoznom tržištu drugi je organizacijsko-ekonomski kriterij definiranja mreže.

Treći parametar optimiranja NM-H-a je vrijeme kao varijabla, točnije protočnost mreže između južnih i sjevernih proizvodnih područja ranijeg i kasnijeg vremena dospijeća berbe. NM-H-a treba organizacijski parametrirati prema učestalosti alternativne rodnosti kao i razlikama u strukturi voćarske i povrtlarske proizvodnje juga i sjevera Hrvatske.

Promjena je glavno obilježje svakog dinamičkog sustava tako i mreže kao sustava. To je bit funkcioniranja te smisao i svrha upravljanja sustavom. Upravljati sustavom, znači imati zadatak proučavati promjene te tražiti mogućnosti za optimalno reguliranje i usmjeravanje tog sustava odnosno mreže sustava.

UPRAVLJANJE SUSTAVOM MREŽE HLADNJAČA

Na razini koncepta sustav NM-H razmatra dvije mogućnosti upravljanja i vlasništva. Sukladno konstataciji kako izgradnja mreže mora biti u funkciji infrastrukturne potpore voćarima i povrtlarima s OPG-a, koncepcijski je neminovno to kao uslugu vezati uz sustav proizvodnje. Stoga je mogući koncepcijski pristup upravljanja vezan uz status vlasništva nad pojedinim hladnjačama u mreži. Prva mogućnost bila bi vlasničko organiziranje na načelima dioničarstva od strane korisnika pojedine hladnjače (voćarskih i povrtlarskih gospodarstava), a druga mogućnost je zadružne organizacije korisnika hladnjače utemeljene na temeljnim zadružnim načelima.

Koncept daje prednost zadružnom načinu ustrojstva smatrajući ga manje opasnim za majorizaciju prava i vlasništva pojedinih korisnika nad drugim manjeg vlasničkog udjela. To smatramo ozbiljnom mogućnošću ugrožavanja motivacije za skupno korištenje mreže a što je koncepcijsko polazište.

ZAKLJUČAK

Konkurentnost u globaliziranom tržištu razumijeva količinom i kvalitetom sigurnu ponudu. Voćarska i povrtlarska proizvodnja s OPG-a niti kvalitetom a niti količinom ne može osigurati stalnu opskrbu tržišta velikih kupaca. Stoga, kvalitetnu i količinom sigurnu opskrbu tijekom godine moguće je pronaći u sustavu mreže hladnjača ustrojenu kao nacionalnu mrežu hladnjača (NM-H) za proizvodnju s OPG-a.

Vlasničko-upravljački ustroj treba temeljiti na zadružnoj organizaciji proizvođača voća i povrća OPG-a jer bi se uvažavanjem zadružnih načela izbjegla majorizacija površinom jačih voćara i povrtlara nad onim slabijim.

NM-H troškovno bi se optimizirala opskrbno-prodajna logistika voćara i povrćara s obiteljskih gospodarstava, smanjili bi se opći troškovi pojedinačne izgradnje, standardizirala bi se tehnologija i kvaliteta čuvanja proizvoda, osigurala mogućnost licenciranja hladnjače kao preduvjet za uvođenje skladišnice kao kolaterale za kredite proizvođača u obrtna sredstva, omogućilo skupno strateško istraživanje tržišta i uvođenje «brand name-a» za određenu vrstu voća i povrća. Kontrola ekološki incidentnih situacija s jednog mjesta, uvođenje E-trgovine voćem i povrćem, doradu i preradu voća i povrća kao alternativni i odteretni kanal plasmana voća i povrća pri velikoj alternativnoj rodnosti kao i ostale servisne poslove u ime i za račun voćara i povrćara vezanih uz zajedničku hladnjaču.

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ORGANIZATIONAL-ECONOMIC CONCEPT OF CO-OPERATIVE COLD STORAGE NETWORK FOR FRUIT AND VEGETABLE FROM FAMILY FARMS

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SUMMARY

Farmers with small production areas cannot find economic judiciousness for the concept «cold storage in every backyards». Primary due to the high fixed costs, mentioned concept can not be justify neither by the economy of scale, level of social price of investment not by the investment support in agriculture. Small and unorganized family farms do not have possibility for entrance and competition on the market. For example, in apple production, above 66% of the total production is placed on the farms with production areas to 5 hectares. About 80% of orchards and apple production take place on the farms to 10 hectares large and only about 20% of apple orchards have family farms bigger then 10 hectares. Under Croatian conditions, only these types of farms can organize themselves as autonomous company or complete technological (including cold storage) and marketing units. Other, smaller farms need to organize in the system of cold storage networks and use synergy effect in raising competitiveness. It is also the most suitable solution for large number of small units on the diversified in space. Input-output logistic of the fruit and vegetable produces would be optimized by the national network of cold storage. It would also lower overhead costs of construction, standardized technology and quality of storing. Additionally it opens possibilities for licensing cold storage in the process of warehouse receipt introduction, joint marketing research and introduction of "brand-names". National cold storage networks will enforce control of ecologically incident situations, make introduction of e-trade easier as well as other connected works that goes with cold storage.

***Key words**: family farms, fruit, vegetable, cold storage*

34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

DESIGN AND DEVELOPMENT OF SIMPLE HARVESTER FOR SWEET SORGHUM

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SUMMARY

Sweet Sorghum is a short-day and annual plant which belongs to Gramineae. This plant is similar to racemose maize with about 3m height and 0.5-3cm thickness of stalk. Sweet Sorghum has sweet flavor stalk, which is used for sugar production. Because of the importance of whole-stalk of Sweet Sorghum after harvesting to increase the sugar extraction efficiency, we cannot use from similar crops harvester (like corn or sugarcane chopper). With due attention to Sweet Sorghum stalk properties, rotating cutting system was selected. This system has a simple bar mechanism guiding the whole-stalk at one side. The test of the machine was achieved by two series of blades with 30°and 45° blade sharp angle on stalk. The results showed stalk cutting surface with 30° blade sharp angle was smooth and without fracture on filaments and vasculums, better than that of with 45° blade sharp angle. Blade penetration was accomplished very well with 30° blade sharp angle. After the farm tests, the efficiency of this harvester for small farms or research farms of Sweet Sorghum has been evaluated well and inexpensively.

Key words: *Design, Development, Rotating Cutting System, Sweet Sorghum, Harvesting Machine*

INTRODUCTION

Sweet Sorghum belongs to *Gramineae*, and it is similar to racemose maize. Its water need is less than other plants because of its deep development. Therefore, Sweet Sorghum is planted at warm and low water areas of the world in all of the soils. The Period of planting till harvesting for this plant is short (90-120 days) and now Sweet Sorghum is planted in the 95 countries of the world [8].

This plant is sensitive to cold weather, and the minimum temperature for its life is 7-10°C. Suitable soil PH for its growth is 5-8.5, that is why Sweet Sorghum is semi-sustained to saltiness [9].

Sweet Sorghum has sweet taste stalks, and it can be used for sugar production the same as sugarcane. In weather condition of Iran, we can acquire sugar by 4 ton/hectare. In addition, production of Alcohol from this plant is four times of sugar beet molasses. The developed countries in this industry prepare alcohol from Sweet Sorghum syrup. For example in 1985, Brazil prepared 3387 liter Ethanol from 33.7 ton stalks in one hectare. Refused stalks can be used in cellulose industries, fiberboard production and animal food (delicious because having sugar) [2].

In kinds of Sweet Sorghum, 7-15.9 percent of expressed juice is formed from sugar (Glucose, Fructose, Sucrose and Starch) in which 50 percent of that pure sugar is Sucrose [12]. Sweet Sorghum planting is more advantageous than sugarcane and sugar beet (Because of less water need, maximum sugar production per hectare and short growing period) [6].

Table 1 Comparison between Sugarcane, Sugar beet and Sweet Sorghum [5, 6].

Suitable soil PH	Minimum temperature for growth (°C)	Sugar production	Water need (m^3/hectare)	Duration of growth (month)	Product
extensive	2-3	4.5	18000	8-9	Sugarcane
neutral	20	10	30000-50000	12-18	Sugar beet
5-8.5	7-10	4	8000	4-5	Sweet Sorghum

Sweet Sorghum is planted on the mound by 10 cm distance, 3-4 cm depth and 75 cm between mounds by planting machine. So far, special commercial harvester for this plant hasn't been presented yet. However, a few researches on this harvester were accomplished in U.S.A Moisture of Sweet Sorghum stalks during harvesting time is about 80-90%. When moisture is low, stalk syrup amount decreases, and more cutting force is needed for cutting stalks [3].

Harvesting of Sweet Sorghum at three hectares in research farm of Isfahan University has been accomplished by special sickles called "Dastghaleh" yet. With extension of planted areas, the necessity to a special harvester for Sweet Sorghum was necessary.

It was not possible to use maize chopper to harvest Sweet Sorghum, because the experiments show that cut and chopped stalks of Sweet Sorghum with a chopper must be utilized for syrup extraction within several hours. Otherwise in a short time more existing sugars in the stalks will be changed to Alcohol, because microorganism activity and efficiency of sugar extraction will be decreased. However, after 30 days keeping of whole-stalks of harvested Sweet Sorghum, fermentation of stalk sugar is little [4].

Some U.S.A. researchers have designed a research harvester for Sweet Sorghum. It cuts stalks from low point by means of special cutting disk, and a chained mechanism transfers whole-stalks of Sweet Sorghum to its accumulator [11]. It was as a research harvester, and it hasn't been presented to bazaar. Therefore, due to necessity needed mechanized harvesting in our country, we decided to design and develop the special harvester for Sweet Sorghum. In the near future, we will complete this harvester for more rows and with transferring mechanism for whole-stalks of Sweet Sorghum to accumulator.

METHODS

Cutting system selection

The first stage was the design of special cutting system for this plant with due attention to physical properties of Sweet Sorghum stalk. All of the used mechanisms in the harvesting machines have been designed according to two systems: Cutter-bar Cutting System (with the help of scissor method) (CCS) and Rotating Cutting System (with the impact method) (RCS).

CCS is used for cutting of annual plants stalks (thin stalks). RCS is used more often for more thick stalks (up to 0.5 cm) with more cutting resistance. RCS uses inertia force and impact force for cutting of stalks, but CCS uses come and go movement of blade for cutting of stalks. With due attention to specification of those systems and physical properties of Sweet Sorghum stalk, RCS was selected.

Cutting mechanism selection

Mechanisms that work on the basis of RCS are: Saws Cutting Mechanism (SCM), Coulter Cutting Mechanism (CCM) and Disk Cutting Mechanism (DCM).

SCM has main problems in that it cannot work under the condition of harvester trembling while the harvester is moving on the ground; therefore, manufacturing of special toothed disks (like saw) is very expensive [7]. CCM is made of two small disks with sharp edges functioning as scissors. This method is used for 2 cm diameter stalks.

The only mechanism which can cut all kinds of thick stalks more than 2 cm diameter is DCM with different blade shape, different number of blades and different blade angles for different plant with thick and juicy stalks and with different cutting resistance; therefore, for Sweet Sorghum stalks, rotating cutting system (impact) with the kind of disk cutting mechanism was selected.

Design information

At first, for designing of cutting system, maximum cutting force for cutting of Sweet Sorghum stalk is used the same measured amount for maize stalk with 87% moisture (maize stalk is exactly similar to Sweet Sorghum stalk). For thick stalks like maize, sunflower and etc., blade linear velocities were allowed with 25-30 m/s, and advance velocities are recommended with 4.5-9 km/h [10].

According to design calculations, for better continuous cutting in rows, the number of blades in cutting disk four blades was considered. Used blades in farm machinery for cutting blades (rotating and impact implements) must be made from special heat treated steel (with hard surface and soft pith).

Recommended blades for rotating cutting of maize stalk with sharp angles of 23-45°, need minimum cutting force. According to needed power calculation for one thick stalk, a one phase electromotor (1.1 kw and 1420 rpm) was selected. In the future, tractor power (PTO shaft) will be used for completing of harvester power section.

Harvesting machine test

Harvesting tests in Sweet Sorghum farm with advance velocity of 5 km/h and two series of blades with sharp angles of 30° and 45° on stalks with 1.5-3 cm diameter were conducted.

RESULTS AND DISCUSSION

Harvester design and development results

After appointment of designing factors, cutting system and harvesting frame were developed. Harvester frame has changeable cutting height from mound surface till 22 cm. The machine has four tires with 38 cm diameter that those can move in the mound by two sides. This harvester has simple bar-mechanism for guiding of cut stalks to one side to stop being crushed under tires. In the future, we will design stalk guiding mechanism of cut stalks to the harvester accumulator.

Cutting quality of harvester

The tests were conducted on three rows of Sweet Sorghum: A (with 0.5-1.3 cm average diameter), B (with 1.5-2.2 cm average diameter) and C (with 2.2-3 cm average diameter). Meanwhile, two kinds of blades with sharp angles of 30° and 45° were selected.

Cutting of stalks in row A, caused to throw stalks and to fracture of vascular tissues and filaments in cutting locality, and cutting surface that wasn't clean and smooth.

According to theoretical rules, the results were expected with two kinds of blades, because narrow stalks needed high rotating velocity of 2000-3000 rpm and linear velocity of 50-75 m/s [3]. But harvester blades in this test had linear velocity of 27 m/s for thick and heavy stalks.

Cutting of stalks in row B caused to smooth surface, relatively, and stalk filament and vascular tissues fracture was less (cutting quality with 30° blade sharp angle was better than 45°. Cutting of stalks in row C with blade sharp angle of 30° accomplished very fine cutting on stalks, and caused a very smooth and clean cutting surface on stalk filaments and vascular tissues. Blade with 45° sharp angle accomplished a fine cutting on stalks relatively.

Farm test of harvester

The farm test of harvester was conducted on one hectare farm district (100×100 m). It had 12 rows with 100m length. Advance velocity was 5 km/h and total harvesting time with considering of gathering time of harvested stalks was approximately 45 minute. Harvester operator pushed harvesting machine on the rows with about 5 km/h advance velocity.

Figure 1 The figure of sweet sorghum harvester

CONCLUSIONS

According to the test results, cutting quality for stalks will 2.5-3 cm thickness with 30° blade angle was satisfactory (smooth and clean cutting surface with no fracture on stalk filaments and vascular tissues).

Cutting quality with 45° blade angle was quite good, but in second priority. With due attention to blade resistance against the hard materials in the farm soils, the blades with sharp angle of 45° is recommended for using in manufacturing of this harvester, by reason of low height of cutting section (because gathering of sugar is the lowest points of stalks).

Electrical force of Electromotor in harvester was available with a Generator that was moved parallel with a harvester, and stalks were falling on the beside row that was harvested before with guide-bar mechanism.

It is foresaw with completing of stalk guiding system to accumulator and be able to connect to tractor, a one row completed harvester can harvest one hectare with advance velocity of 5 km/h and with calculation of accumulator evacuation.

Finally, the efficiency of this harvester for small farms or research farms of Sweet Sorghum has been evaluated well and inexpensively.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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NEW GENERATION HARVESTERS IN CORN HARVESTING

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GORAN TOPISIROVIC

ABSTRACT

Introduction of new generation harvesters is analyzed through efficiency, losses and quality of harvested crop. Purpose of the investigation is analysis of new generation harvesters working parameters in corn harvesting. On this base will be defined possibilities of improvement of efficiency and productivity, as well as decrement of fuel consumption.

Results of investigation have shown the following parameters:

- at harvester A – fuel consumption was 22.50 l/ha, or 45.82 l/h, with the efficiency of 2.07 ha/h and average working speed of 6.4 km/h.

- at harvester B – fuel consumption was 14.04 l/ha, or 58.97 l/h, with the efficiency of 4.2 ha/h and average working speed of 8.0 km/h.

Efficiency coefficient of the harvester is 0.7, but it can be significantly increased with better harmonizing of working regime and working conditions.

***Key words**: corn combine harvesters, speed, energy, losses, performance.*

INTRODUCTION

Duration of harvesting is a very important factor of harvesting efficiency. The period during which the crop is in optimal harvesting conditions takes 5 – 15 days. Considering this facts, it can be concluded that the harvesting period should be as shorter as possible [5]. This is particularly important in wheat harvesting, where the losses, caused by dispersal, hectoliter mass decrement (because of morning moisture and rain) or weeds, increase exponentially on 5^{th} to 10^{th} day after the full technological crop maturity.

Wheat harvesters, as the other agricultural machines, have the potential capacity which should be fully obtained in exploitation, to achieve minimal working costs [6]. This can be achieved by improvement of harvesters efficiency and minimizing of fuel consumption.

The purpose of this investigation is analysis of working parameters of wheat harvesters in corn harvesting [3,4]. On this base should be defined possibilities of optimization of harvesters work, in harvesting itself, as well as organization of machinery maintenance and operators education. Final goals are harvesters productivity improvement and decreasing of fuel consumption.

MATERIAL AND METHODS

Investigation was carried out with two combine harvesters whose basic technical characteristics are as follows (Tab. 1):

Tab. 1 Technical characteristics of maize harvesters A and B

Harvester A	Harvester B
Header: 6-rows, MF 1216 • Working width 4,2 m with cutter • Chains - length 1216 mm - ankles number 38 - pitch 32 mm • linear speed - 3,81 km/h • stripping rolls - 285 min^{-1} • stalk cutter -1800 min^{-1} • Engine SISU 198 kW	**Header**: 6-rows, Conspeed 6 -70 FC • Working width 4,3 m with cutter • Working width 4,1 m no cutter • Chains - length 1216 mm - ankles number 38 - pitch 32 mm • linear speed - 3,81 km/h • stripping rolls - 285 min^{-1} • stalk cutter - 1800 min^{-1} • Engine Cummins 220 kW

Investigation of harvester A was performed on October 27th 2004 at the agricultural enterprise "Mitrosrem", village Divoš, located 20 km eastern of Sremska Mitrovica.

Investigation of harvester B was performed in the period Oct. 7th to Oct. 17th 2004. at the Corporation PKB - Padinska Skela, village Lepušnica.

All the tests were performed according to the testing method of the Institute of Agricultural Engineering – Faculty of Agriculture in Belgrade.

During the investigations were registered factors that directly influence the working process. They were manifested in the fallowing intensity:

The air temperature ranged from 5 °C (morning) to 20°C (day), air humidity 50 %. Crop characteristics are shown in the table 2.

Harvesters were followed during the whole day, from the first morning activities on maintenance and basic preparations, to the end of work and storing harvesters at the parking place in the evening.

Tab. 2 Crop characteristics

Harvester A	Harvester B
• Corn variety - R-57 (hybrid – Pioneer)	• Corn variety - SK 677
• Stalk height – 200 cm	• Stalk height - 200 cm
• Ear height – 75 cm	• Ear height - 75 cm
• Plants density – 57.000 ha^{-1}	• Plants density - 57.000 ha^{-1}
• Rows distance – 70 cm	• Rows distance - 70 cm
• Inter row distance - 25 cm	• Inter row distance - 20-25 cm
• Yield – 10,83 t/ha	• Yield - 8,3 t/ha
• Grain moisture – 26%	• Grain moisture - 17%
• 1000 kernel weight - 377,8 g	• 1000 kernel weight - 366,8 g
• Ear in husks : stem - ratio - 1 : 1,2	• Ear in husks : stem - ratio - 1 : 1,2
• Grain : cob : husks – ratio - 1 : 0,13 : 0,04	• Grain : cob : husks – ratio - 1 : 0,15 : 0,06
• Crop position – stand	• Crop position – stand

During testing procedure the following were data measured and recorded:

- Speed on distance of 30 m.
- Harvester efficiency
- Fuel consumption
- Harvester (header) working width
- Cutting height
- Grain mass collected on distance of 30 m (flow).
- Stalk and grain mass on the sample sheet (losses)

For the measurements were used: stop-watch, measuring stripe, sticks, sample sheet, cloth hose, basket, balance, etc.

The harvesters were prepared before the investigations. On the back side was fixed sample sheet for collecting of stems, husks and lost grain. On the unloading auger was fixed cloth hose for directing the grain into the basket, which enables mass flow measurement [2].

RESULTS AND DISCUSSION

Exploitation investigation of harvester A was performed from Oct. 20th to Oct. 27th 2004. at the agricultural combinate Mitrosrem in Sremska Mitrovica. Exploitation investigation of harvester B was performed in the period Oct. 7th to Oct. 17th 2004. at the Corporation PKB - Padinska Skela, working unit ″Lepušnica″.

Tab. 3 Technological parameters – harvester A (corn R-57)

Num.	Hybrid markwould	Yield (t/ha)	Working speed (km/h)	Grain throughput (kg/s)	MOG throughput (kg/s)	Machine settings				Header losses %			Threshing section losses - Free grain %	Total losses %
						Drum (rpm)	Drum clearance (mm)	Ventilator (o/min)	Sieve openings 0-20	Free grain	Fold of ears	Total		
1.	R-57	10,83	6.4	8,2	10,14	500	26	1020	12/8	-	-	0.00	0.01	0.01
2.	"	"	7,0	8,85	11,05	500	"	"	"	-	-	0.00	0.08	0.08
3.	"	"	7,50	9,5	11.83	500	"	1050	14/10	-	2	0.40	0.32	0.72

Tab. 4 Technological parameters – harvester B (corn SK-677)

Num.	Hybrid markwould	Yield (t/ha)	Working speed (km/h)	Grain throughput (kg/s)	MOG throughput (kg/s)	Regulation				Adapter losses %			Threshing section losses - Free grain %	Total losses %
						Drum (rpm)	Drum clearance (mm)	Ventilator (o/min)	Sieve openings 0-20	Free grain	Fold of ears	Total		
1.	SK 677	8.30	6.62	5.98	7.91	500	26	1100	12/8	-	-	0.00	0.01	0.01
2.	"	"	6.55	6.00	8.00	500	"	"	"	-	-	0.00	0.01	0.01
3.	"	"	9.25	8.74	11.57	500	"	1100	14/10	-	2	0.70	0.02	0.72
4.	"	"	8.72	10.00	12.41	500	"	"	"	-	1	0.29	0.01	0.30
5.	"	"	10.96	10.35	11.75	450	"	1000	12/8	-	1	0.35	0.02	0.37
6.	"	"	10.36	10.79	12.20	450	"	1100	13/8	-	1	0.32	0.02	0.34
7.	"	"	10.11	8.43	10.56	450	"	"	"	-	1	0.40	0.01	0.41
8.	"	"	11.60	-	18.25	450	"	1100	13/8	-	6	2.13	-	2.13
9.	"	"	11.80	-	18.10	450	"	"	"	-	7	2.49	-	2.49

Threshing section losses are directly dependant on the working speed and are presented in tables 3 and 4. Regulation that is recommended from the manufacturer was the most optimal, but the losses do not correlate with the working speed and applied 6 row headers. No harmonized function of the adapter and the basic unit directly influence the losses increment, as well as no possibility of full capacity achievement, so the optimal harvester function is affected. This means that the basic machine is loaded with 69.44% of the nominal capacity. The declaration on capacity we gave remains valuable for the total losses of 1% also.

Registered losses were non significant, because of non optimal load of harvesters.

Adapter function in laid crop is not known, because we didn't have such a conditions, so it is not possible to estimate this parameter.

First class from the bunker was analyzed and very good cleanness was found. Ingredients were not found. With the applied regulation, the content of broken grain was 6,3 %. This is the consequent of the high grain moisture (26%) and small clearances at the beginning and the end of the threshing section, which were applied to achieve better thrashing with the high moisture content. Results of working quality are presented in tables 5 and 6.

Tab. 5 Working quality of harvester A

Line	Drum	Speed	Working quality (%)			Ear breakage (%)			
	(rpm)	(km/h)	Whole grain	Broken grain	Ingredients	Whole	1/2	1/3	< 1/3
1	500	6.40	93.84	5.8	0.36	71	20	9	0
2	500	7.00	92.25	6.3	0.45	68	22	10	0
3	500	7.55	92.65	6.8	0.55	65	30	5	0

Tab. 6 Working quality of harvester B

Line	Drum	Speed	Working quality (%)			Ear breakage (%)			
	(rpm)	(km/h)	Whole grain	Broken grain	Ingredients	Whole	1/2	1/3	< 1/3
1	500	6.62	86.17	13.47	0.36	91	6	3	0
2	500	6.55				91	5	4	0
3	500	9.25	85.82	12.95	1.23	86	8	6	0
4	500	8.72				88	7	5	0
5	450	10.96	91.76	6.83	1.41	97	3	0	0
6	450	10.36	93.41	6.30	0.29	96	4	0	0
7	450	10.11				95	5	0	0

At higher working speeds was noticed higher content of ingredients in the bunker, which means that harvester receives larger amount of stems from the 6 row header. Threshing quality, expressed as a percent of broken ears, is very high and the harvester is very well adjusted. This is approved by the fact that there was no any fraction smaller than 1/3, which is shown in tables 5 and 6.

According to the performed testing, 6 row adapters which were attached to the harvesters A and B have shown some insufficiencies. Increment of working speed over 8 km/h causes significantly raised losses of fold off ears, especially on lateral fractions 1 and 6, which is a limitation factor for successful work of the whole machine, its capacity and total losses.

Results of harvesters A and B efficiency and working regimes are presented in the following table (table 7).

Tab. 7 Working records of harvester A

	Harvester A		Harvester B		
Date of testing	27.Oct.	27.Oct.	13.Oct.	15.Oct	16.Oct.
Total working time (h)	6.97	6.97	6.97	5.02	5.58
Harvested area (ha)	12.75	16.03	30.283	18.011	23.02
Harvested grain (Mg)	138.13	173.61	180.71	131.68	153.96
Grain moisture (%)	26.00	26.00	20.3	16.9	16.6
Total fuel consumption (L)	318.75	320.06	389	281	315
Average work rate (ha h^{-1})	1.83	2.30	4.35	3.59	4.12
Average work rate (Mg h^{-1})	19.80	24.09	25.94	26.25	27.57
Average work rate (Mg ha^{-1})	10.83	10.83	5.97	7.31	6.69
Average fuel consumption (L ha^{-1})	25.00	20.00	12.85	15.6	13.68

CONCLUSIONS

According to the presented data on working of harvesters A and B in corn harvesting in 2004., fallowing results can be derived:

1. **Optimal capacity of harvester A** with tolerant loss of **1%,** can be declared on **8,2 kg/sec**, with working speed of **6,4 km/h**.

   Optimal capacity of harvester B with tolerant loss of **1%,** can be declared on **12.5 kg/sec**, with working speed of **8 km/h**.

2. **Maximal capacity of harvester A** with tolerant loss of **1%,** can be declared on **9.5 kg/sec**, with working speed of **7.5 km/h**.

   Maximal capacity of harvester B with tolerant loss of **1%,** can be declared on **14 kg/sec**, with working speed of **10 km/h**.

3. **Limitation parameters for the harvesters capacity regarding losses**:
    - adapter mass flow capacity
    - yield
    - grain moisture
4. **Header losses** are minor,
5. **Working quality** is on upper threshold (6% broken grain), with possible decrement of broken grain content by increment of threshing concave clearance to 28-30 mm, depending on crop moisture.
6. **Threshing quality** is good, which is result of functional separation.
7. **Bunker unloading** is efficient, mass flow is full and constant.
8. **Efficiency of harvester A** of 2,065 ha/h is relatively low, but can be increased, by better organization of work (transport is the main problem), to about 2,3 ha/h with tolerant loss of 0,5-1 %.

    Efficiency of harvester B of 4,02 ha/h is relatively low, which is determined by limited movement and limited loss amount of 1 %.
9. **Fuel consumption of harvester A** of 22,50 l/h is satisfactory, which correlates with work load of the working parts and the efficiency. With the correction of the working efficiency can be decreased to 20 l/ha.

    Fuel consumption of harvester B of 14,04 l/h is extremely low, which correlates with work load of the working parts and the efficiency.
10. **Computer function** is correct, differences of the data from the computer and the measured data were not noticed.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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A MULTIPLE LOGISTIC REGRESSION STATISTICAL MODEL TO ESTIMATE GRAIN LOSSES ON SIEVE CLEANING SYSTEM FROM COMBINE

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SUMMARY

Because of the seed separation process complexity in the combine cleaning system and of the multitude factors influencing it, the paper approaches the possibility to describe the separation process along the sieve using a statistic mathematical model described by the multiple logistic regression model consisting from the two parameters logistic function $P_x = \dfrac{\exp(\alpha + \beta x)}{1 + \exp(\alpha + \beta x)}$, *where* P_x *– percentage of separated seeds along sieve length x;* α *and* β *- logistic constants, expressed through multiple logistic regression functions. The values of the* α *and* β *constants are significantly influenced by the sieve oscillation frequency (f), the specific alimentation flow with material of the sieves (q) and the straw parts content (pp/s) of the processed material.*

For the logistic coefficients α *and* β *was proposed the multiple linear regression function of* $Y = A + Bx_1 + Cx_2 + Dx_3$ *were* $x_1 = n$, $x_2 = q$ *and* $x_3 = pp/s$. *By testing the multiple logistic regression model with experimental data, obtained from 7 experimentations done in laboratory conditions, was found* $\alpha = -10.381 - 0.012\,f - 0.661\,q + 36.917\,pp/s$, $\beta = 52.943 - 0.050\,f + 6.084\,q - 121.206\,pp/s$, *for a correlation coefficient* $R^2 = 0.803$, *respectively* $R^2 = 0.904$. *The conformity between estimated seed loses and those determined in experimental measurements is illustrated by a correlation coefficient* $R^2 = 0.911$.

Using the proposed model it can be anticipated the seed lose probability in the cleaning system (=1–P_1*) if we impose the working conditions through the values of f, q, pp/s and sieve length L, in experimental values range used at experimentations. These data are useful both in design activity, as well in efficient use of the cleaning system from the classic combines, which can be added to the field data library.*

***Key words**: harvesting combine, cleaning system, sizing sieve, losses, logistic regression*

INTRODUCTION

In the cleaning system from straw cereal harvesting combines is done the seeds separation from pile obtained in threshing and straw shakers, due to the combined action of the air flow and sieves oscillating movement.

Description of the material separation process, on cleaning sieves system of the cereal combines, through mathematical models, is difficult to do because of the process complexity and the large number of influence factors, which imposed the use of the simplifying hypotheses and, so, reducing theirs utilization [1-5,13,14].

In authors interest range regarding separation process research of the combines separation system, were done a series of papers [6-8,10-13], in which were proposed several mathematical models for separation process description. From the studied models, two of them are the most adequate for separation process description, having a high correlation degree with the obtained experimental data, those are: Rosin – Rammler model and the logistic mathematical model with two parameters for which $R^2 \geq 0.970$ [11,12].

The paper presents the statistical analysis, done through multiple regressions on computer, using data from the seven most significant experimental determinations, highlighting the influence of three working parameters on separation process, with the help from the mathematical model of the two parameters logistic equation expressed through multiple linear regressions.

THEORETICAL ELEMENTS

For theoretical description of the total (cumulative) separation curve of the seed pile from the superior sieve of the cereal harvester separation system were proposed in papers [5,7,8,10-12] several mathematical relations tested with experimental data and who's conformity with those was permanently improved, appreciation obtained based on the correlation coefficient R^2 values closer to unit.

Was found [10,11] that the most adequate description of the separation process on cleaning sieves system from the cereal harvester can be expressed by logistic cumulative distribution function with two parameters, like:

$$P_x(\%) = 100 \cdot \frac{\exp(\alpha + \beta \cdot x)}{1 + \exp(\alpha + \beta \cdot x)} \tag{1}$$

or by the Rosin – Rammler function:

$$P_x(\%) = 100 \cdot \exp\left(-b \cdot x^n\right) \tag{1a}$$

where: P_x (%) is weight percentage of the separated material on sieve length x (m); α, β – logistic constants, and b, n – coefficients depending on separation process parameters.

Between both models, the best correlation with experimental data is presented by logistic function (1) for which $R^2 \geq 0.996$ [12].

The multitudes of factors influencing the separation process and its random character, as well as their natural variability as part of the pile reaching the separation system, are contained in coefficients values α and β.

For expressing mathematically the influence of working process parameters on seeds separation process from the combines' cleaning system sieves, it is appreciated that logistic coefficients α and β can be estimated through multiple parameters linear functions. From experimental data in table 1, it is estimated that between five parameters had in view, three working parameters (*f* – oscillations frequency; *q* – alimentation specific flow; *pp/s* – straw content) have a significant influence over separation process, while the other two parameters (v_a – air flow velocity; D_j – sieve's shutters span) are kept relatively constants during experimental determinations. In this case, in a first approximation, we will consider α and β logistic parameters variation as a multiple linear regression $Y = A + B \cdot x_1 + C \cdot x_2 + D \cdot x_3$, in which x_1, x_2 and x_3 are working parameters modified during experimental determinations.

Thus, proposed equations for α and β logistic parameters variation, have the expression:

$$\alpha = a_o + a_1 \cdot x_1 + a_2 \cdot x_2 + a_3 \cdot x_3 \tag{2}$$

$$\beta = b_o + b_1 \cdot x_1 + b_2 \cdot x_2 + b_3 \cdot x_3 \tag{3}$$

in which $x_1 \equiv f$ (osc/min); $x_2 \equiv q$ (kg/dm·s) and $x_3 \equiv pp/s$.

The two equations coefficients a_o, a_1, a_2, a_3 and respectively, b_o, b_1, b_2, b_3, will be determined by computer multiple linear regression analysis using the MicroCal Origin vers.6.0 software with the α and β logistic coefficients values determined in each experiment and the values corresponding for x_1, x_2, x_3.

The seeds losses, represented by unselected seeds percentage at the sieve evacuation end (respectively at the $x = L$ distance from alimentation end), $R_L(\%)$ can be estimated using the relation:

$$R_L(\%) = 100 - P_L(\%) \tag{4}$$

in which $P_L(\%)$ represents percentage of separated seeds at sieve evacuation end.

Correlation degree of the obtained results by calculation regarding losses is appreciated through correlation coefficient R^2, calculated, in this case, with the relation:

$$R^2 = 1 - \frac{\sum_{i=1}^{n} \left(R_m^i - R_c^i\right)^2}{\sum_{i=1}^{n} \left(R_m^i - \overline{R_m}\right)^2} \tag{5}$$

in which: R_m^i, R_c^i represents the measured, respectively calculated losses (expressed in %), for sample *i*, at the $x = L$ distance from sieve alimentation end, *L* is sieve length; $\overline{R_m}$ (%) – arithmetic mean of seeds losses measured for those *n* experimental tests done.

MATERIALS, APPARATUS AND METHODS

Experimental determinations were done in Biotechnical Systems Department laboratories from Biotechnical Systems Engineering Faculty, “Politehnica” University of Bucharest, on a stand designed and created for this purpose, where could be done different controlled working conditions [5].

The stand is similar with traditional cleaning systems from cereal combines and is schematically presented in figure 1, in which can be followed its components. Other details are described in papers [5,9].

The parameters had in view and modified during experimental tests, for the determination of their influence on separation process, were: oscillations frequency *f*; specific feed flow *q*; weight ratio straw/seeds *pp/s*; air flow velocity at the fan exit v_a; sieve’s shutters span D_j. In experimentations were done 60 tests, from which were selected seven most representative of them.

In its normal functioning position, main characteristics of the driving mechanism from the utilized cleaning system (fig.1) were those from the C-12 Romanian combine.

Was used a sieve with adjusted vents (with Petersen shutters) having the length L_s = 1200 mm, the width of 220 mm, assembled at a 7^o angle from the horizontal.

The material used in experimentations was piled autumn wheat from the Romanian variety Fundulea 4, obtained from a C-12 combine during harvesting time, with the following main characteristics: seeds bulk density 775 – 800 kg/m^3; mass of a 1000 seeds 38.6 – 43.5 g; seeds humidity content 11.3 – 12.5%; straw bulk density 62.3 – 65.9 kg/m^3; ratio straw/seeds *pp/s* 0.2 – 0.3.

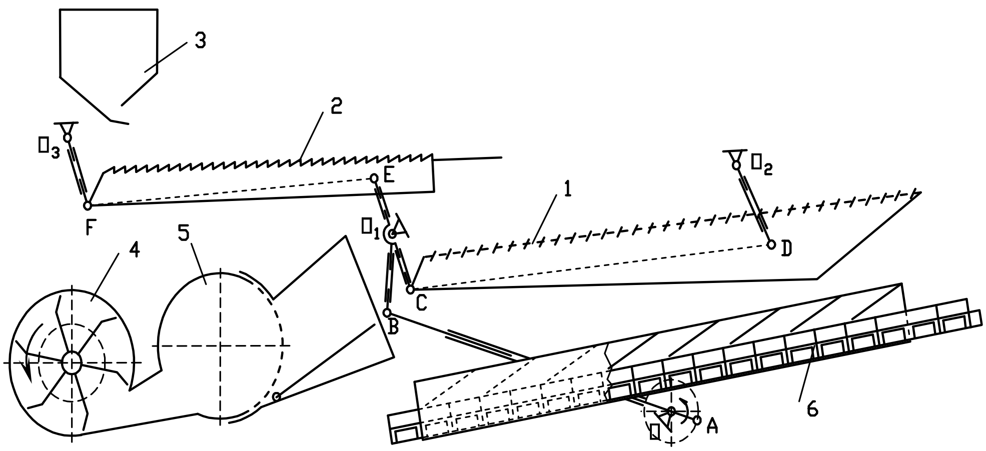

Figure 1 Schematic diagram of the experimental stand; 1.sieve with adjusted vents (Petersen); 2.osccilating conveyer; 3.feed bin with pile; 4.centifugal fan with coil case; 5.outlet air unifier; 6.slide-in chassis for separated material gathering equipped with two sets of compartments

During experimental tests were alternative modified different parameters, among which: oscillations frequency f (190 – 335 osc/min); specific feed flow q (0.05 – 0.20 kg/dm·s); ratio straw/seeds *pp/s* (0.2 – 0.4); air flow velocity v_a (6 – 10 m/s); shutters span D_j (9 – 12.5 mm).

The stand was feed with material from feed basket 3 on oscillating conveyor 2 similar to the combine conveyor and then on sieve 1, used in experimentations (fig. 1).

The material passed through vents of the sieve with shutters was collected in a slide-in chassis 6 with two sets of compartments along sieve length, because of its shifting during experiment it can be collected only the material corresponding to the sieve normal load, for a working time of 6 seconds.

Based on material quantities collected in every compartment of the slide-in chassis under the sieve was calculated the total mass percentage of the material from the compartment M_t, reported to the entire material mass of the probe $M_p = \sum M_t$.

Afterwards, seeds were separated from each compartment and reported in percentages to the entire seeds quantity of the probe.

Based on collected seeds quantities from under the sieve, during an experiment, at different distances from the alimentation end, was graphically drawn the curve that indicates the total quantity of separated seeds through vents on a specific sieve length x (total separation curve – cumulated values).

RESULTS AND DISCUSSIONS

The results obtain for the seven significant experimentations, together with corresponding values of those five modified experimental parameters are presented in table 1.

Table 1 Separated seeds percentage on sieve length

No. sample	Sieve length from which seeds are collected x (m)								Over sieve
	0.15	0.30	0.45	0.60	0.75	0.90	1.05	1.20	
1	f = 280 osc/min; q = 0.15 kg/dm·s; v_a = 8 m/s; D_j = 12.5 mm; *pp/s* = 0.24								
	2.7	12.3	45.8	82.0	95.2	98.8	99.6	99.8	0.2
2	f = 280 osc/min; q = 0.10 kg/ dm·s; v_a = 8 m/s; D_j = 11 mm; *pp/s* = 0.25								
	2.5	10.8	36.1	62.4	83.2	94.0	98.2	98.6	1.4
3	f = 280 osc/min; q = 0.15 kg/ dm·s; v_a = 8 m/s; D_j = 11 mm; *pp/s* = 0.27								
	1.7	7.9	30.9	58.0	80.0	92.6	98.2	99.2	0.8
4	f = 280 osc/min; q = 0.20 kg/ dm·s; v_a = 10 m/s; D_j = 11 mm; *pp/s* = 0.27								
	4.2	16.2	37.8	57.7	77.2	91.7	99.1	99.8	0.2
5	f = 190 osc/min; q = 0.10 kg/ dm·s; v_a = 8 m/s; D_j = 11 mm; *pp/s* = 0.25								
	17.0	59.8	90.3	97.4	99.1	99.6	99.8	99.9	0.1
6	f = 240 osc/min; q = 0.10 kg/ dm·s; v_a = 8 m/s; D_j = 11 mm; *pp/s* = 0.25								
	8.3	31.8	73.6	94.5	98.7	99.5	99.8	99.9	0.1
7	f = 335 osc/min; q = 0.20 kg/ dm·s; v_a = 10 m/s; D_j = 11 mm; *pp/s* = 0.252								
	0.2	1	4.1	18	40.6	61.4	78.2	94	6.0

Based on values of separated seeds quantities (%) along sieve length of the cleaning system was done a non-linear regression analysis on a PC computer using the MicroCal Origin vers.6.0 software of the logistic function (relation 1) and the values of the logistic regression coefficients and of the corresponding correlation coefficient R^2 are presented in table 2.

Table 2 Values of the α, β, R^2 coefficients obtained through non-linear regression of the experimental data with two parameters logistic function (rel.1)

No. sample	α	β	R^2
1	- 5.316	11.392	0.999
2	- 4.274	7.967	0.998
3	- 4.510	7.998	0.998
4	- 3.632	6.647	0.997
5	- 3.577	13.168	0.999
6	- 4.296	11.820	0.999
7	- 5.507	6.653	0.996

In figure 2 are presented the regression curves diagrams of the cumulative separation compared with experimental points for the seven considered probes.

Analyzing the diagrams from figure 2 and data from table 2, it results a very good correlation of the two parameters logistic function (eq. 1) with experimental data, correlation coefficient $R^2 \geq 0.996$.

Both working parameters modified during experimentations and natural variability of pile parameters are included in logistic coefficients values of regression equation, α and β, which changes in large limits, $\alpha = -\ 3.577 \div -5.507$, $\beta = 6.647 \div 13.168$.

Using the coefficients α and β values (table 2) and values of the working parameters used in experimental tests (table 1), the multiple linear regression coefficients for equations (2) and (3) were determined with the MicroCal Origin vers.6.0 software, where it has been considered $x_1 \equiv f$ (osc/min); $x_2 \equiv q$ (kg/dm·s) and $x_3 \equiv pp/s$, the other parameters (v_a and D_j) were considered constants or with an insignificant influence over seeds separation process.

Working regime parameters used in the analysis of the multiple linear regressions have the values presented in table 1, synthesized in table 3, and the values of the equation (2) and (3) coefficients obtained after regression are presented in table 4.

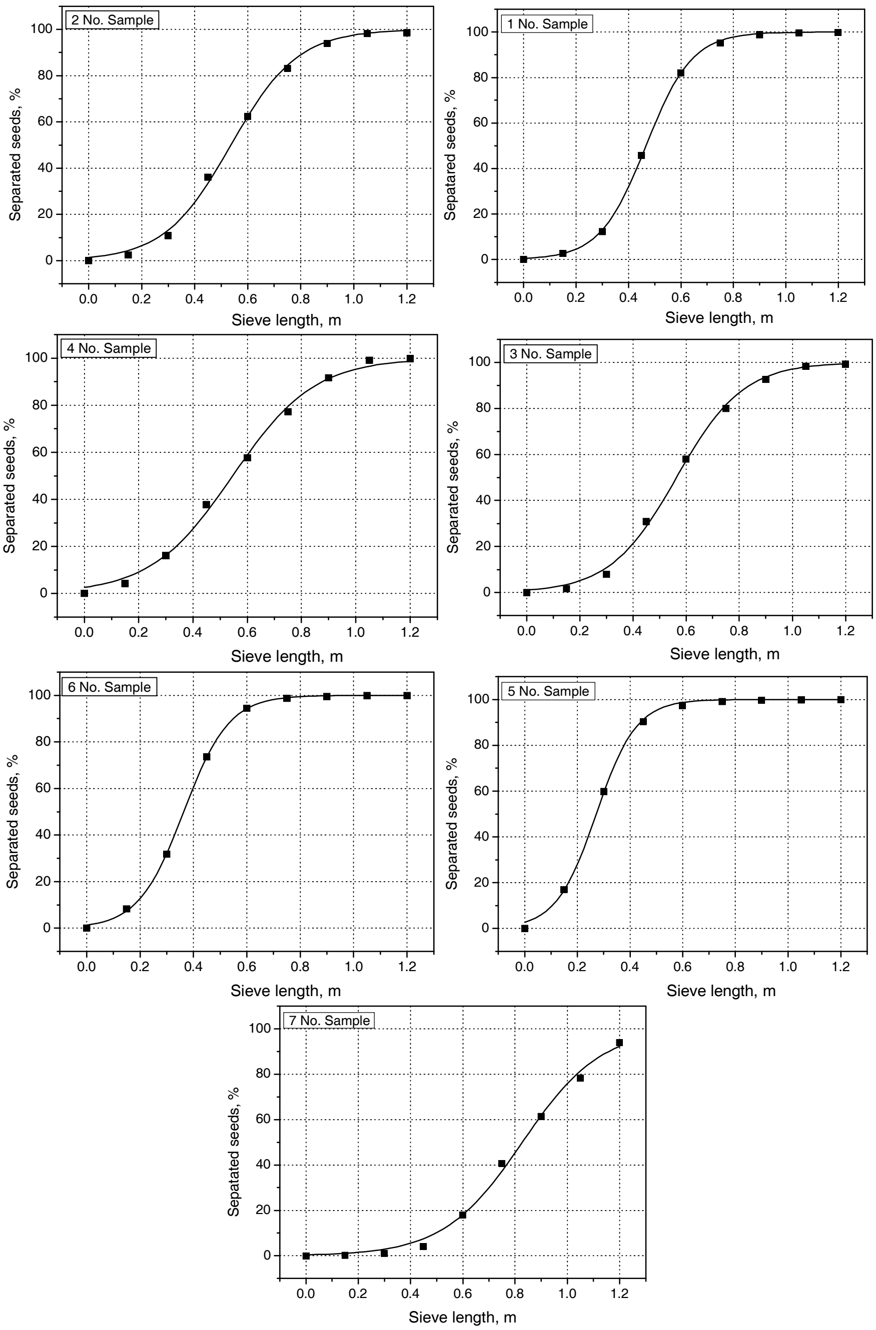

Figure 2 Non-linear regression curves based on logistic function (rel.1), the seeds cumulative separation along sieve length compared with experimental points;
■ – experimental points; — non-linear regression curve with logistic function (eq.1)

Table 3 Working regime parameters x_i used in the analysis of the multiple linear regressions, together the coefficients α and β values, considered as an independent variable Y

No. sample	$x_1 \equiv f$ (osc/min)	$x_2 \equiv q$ (kg/dm·s)	$x_3 \equiv pp/s$	$Y \equiv \alpha$	$Y \equiv \beta$
1	280	0.15	0.24	- 5.31604	11.39214
2	280	0.10	0.25	- 4.27411	7.96696
3	280	0.15	0.27	- 4.5097	7.99806
4	280	0.20	0.27	- 3.63155	6.64664
5	190	0.10	0.25	- 3.57681	13.16772
6	240	0.10	0.25	- 4.29613	11.8203
7	335	0.20	0.25	- 5.50707	6.65337

Table 4 The coefficients a_o, a_1, a_2, a_3 and b_o, b_1, b_2, b_3 values for the equations (2), respectively (3), obtained in the analysis of the multiple linear regressions based on data from table 3

For $Y \equiv \alpha$	a_o	a_1	a_2	a_3	R^2
	- 10.38141	- 0.01246	- 0.66104	36.91666	0.803

For $Y \equiv \beta$	b_o	b_1	b_2	b_3	R^2
	52.94336	- 0.05055	6.08372	- 121.20567	0.904

Analyzing the data from table 4, it results that the correlation degree of the multiple linear regression function (eq. 2 and 3) with the coefficients α and β values obtained in the analysis of the multiple non-linear regression with the logistic function (eq. 1) is relatively high for both coefficients, having a smaller value for the coefficient α (R^2 = 0.803) and higher for coefficient β (R^2 = 0.904).

Thus, using coefficients a_o, a_1, a_2, a_3 and b_o, b_1, b_2, b_3 values from table 4, the logistic parameters α and β have the expressions:

$$\alpha = -10.381 - 0.012 f - 0.661 q + 36.917\, pp/s \tag{2a}$$

$$\beta = 52.943 - 0.050 f + 6.084 q - 121.206\, pp/s \tag{3a}$$

where the working regime parameters, corresponding for each experimental determination, *f, q* and *pp/s*, are those presented in table 1 (table 3).

With the equations (2a) and (3a) was recalculated, afterwards, for each experimental determination, the coefficients α and β values (α_c and, respectively, β_c) and then the values of the seeds losses at the sieve end, with relation (4):

$$R_c^i(L) = 100 - P_c^i(L) \tag{6}$$

where L = 1.2 m – sieve length and $P_c^i(L)$ was calculated based on relation (1) with coefficients α_c and β_c in accordance with relations (2a) and (3a), i represented the sample number.

In table 5 are presented the calculated values of the coefficients α_c and β_c, based on equations (2a) and (3a), together with percentages of the seeds collected under the sieve and of the seeds losses at the sieve end, calculated with relations (1) and (6) and with the seeds losses measured after each test.

Table 5 Calculated values of the coefficients α and β (rel. 2a and 3a) and calculated (rel.6) and measured R_m seeds losses

No. Sample	$x_1 \equiv f$ (osc/min)	$x_2 \equiv q$ (kg/dm·s)	$x_3 \equiv pp/s$	Calculated values		$P_c(L)$	Seeds losses	
				α_c	β_c		$R_c(L)(\%)$	$R_m(\%)$
1	280	0.15	0.24	- 5.10937	10.61256	99.95	0.05	0.20
2	280	0.10	0.25	- 4.70715	9.096315	99.80	0.20	1.40
3	280	0.15	0.27	- 4.00187	6.976387	98.75	1.25	0.80
4	280	0.20	0.27	- 4.03492	7.280573	99.10	0.90	0.20
5	190	0.10	0.25	- 3.58575	13.64581	100.0	0.00	0.10
6	240	0.10	0.25	- 4.20875	11.11831	99.99	0.01	0.10
7	335	0.20	0.25	- 5.45855	6.924437	94.54	5.46	6.00
								$\overline{R_m} = 1.257$

Based on relation (5) and on values of the seeds losses at the sieve end, calculated and effectively measured (table 5), was determinate the correlation coefficient R^2 of the seeds losses measured in experimental tests with the seeds losses calculated based on theoretical elements from paper. This correlation coefficient had the value $R^2 = 0.911$, which shows a good correlation degree.

We conclude that the probability level of the seeds losses at the cleaning system of a traditional combine can be satisfactory predicted using a statistic model of multiple regression expressed by relations (1), (2a), (3a) and (6) for imposed values of parameters *f*, *q* and *pp/s* (in the domain of values used in experiments).

CONCLUSIONS

Based on non-linear regression analysis of the separation process in the combine cleaning system, due to the complexity and multitude of influencing factors, in paper is proposed the process description with a mathematical model expressed by multiple logistic regression model with two logistic parameters like relation (1). For logistic parameters was proposed the multiple linear regression function like relations (2) and (3), by testing the multiple logistic regression model with experimental data from seven significant experimentations done in laboratory conditions was found relations (2a) and (3a) for logistic parameters α and β.

With the proposed model can be satisfactory predicted the probability level of the seeds losses at the cleaning system for imposed working conditions through the parameters *f*, *q* and *pp/s* values and a sieve length in the domain of values used in experiments.

This data are useful both in design activity and efficient utilisation of the cleaning system from classic combines, which can be added to the field data base.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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SOME ASPECTS REGARDING THE CLEANING PROCESS EFFICIENCY FOR HARVESTING MACHINES

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ABSTRACT

In the paper are presented the experimental results obtained in laboratory conditions regarding the efficiency of the cleaning processes for plate sieves. Using a laboratory stand, designed for this purpose, different kinematical functioning conditions for the sieves working process were tested in order to evaluate the separation process quality. The tests confirm some theoretical assumptions and give us more details to evaluate the cleaning process in accordance with appropriate mathematical distribution functions assumed. Using statistic methods some aspects regarding the cleaning efficiency of the sieve surface were determined too.

Key words: *cleaning, efficiency, test, acquisition system, distribution law*

INTRODUCTION

The cleaning sieve efficiency evaluation for harvesting combines was a research subject that has been going on in the latest years in the Harvesting Machines laboratory. The steps of this research were published in the previous years, starting with 1996. Each time the author proposed new approach techniques and new research ways in this field [1, 2, 3, 4].

A final concluded step consisted in the cleaning process simulation. The simulation results show significant particular aspects of the kernel separation probability, in accordance with different sieve functioning conditions. The simulation offered more confidence to promote the theory assumed regarding the possibility to increase the cleaning process efficiency by inducing secondary oscillations of the cleaning sieves. In this way, the kernels cross the sieves following an imposed direction. The alternations of different displacements (up and down the sieves) will be selected by an imposed vibration programmer [1].

THE STAND DESIGNED

In order to evaluate the efficiency of the grain separation process, a laboratory stand was designed and a complete test was started.

For a cleaning efficiency evaluation in accordance with the assumed theory, the designed stand had to respond to the following demands:

- the grain quantity distributed on the sieves must by the same with the quantity delivered by the trashing system of the harvesting combine;
- the motion system of the sieves must have the same low and high ratio speed as the original system from the combines;
- the measured parameters must be collected automatically using an interface connected to the computer;
- in order to evaluate the sieve surface efficiency in different kinematical conditions a collecting box must by added to the cleaning system.

Considering these demands, the experimental stand was designed and built in the Harvesting laboratory (fig. 1 and fig. no. 2).

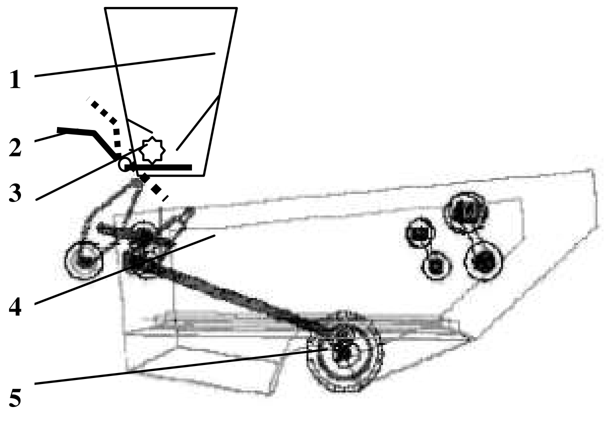

Fig. 1 The cleaning system experimental stand: 1 – grain tank; 2– grain gate; 3– discharge weel; 4– cleaning equipment; 5 – motion system; 6 – colected box

The power is supplied by an electric engine which actions a gear box. The speed ratio delivered by the gear box is: 340 rpm and 540 rpm in clock wise direction and 475 rpm in the opposite direction.

The same engine actions the grain distribution from the tank using a wheel transmission system (see fig. 2).

The measured parameters are:

- absorbed power;

- sieve oscillation frequency in min^{-1};
- the grain distributor rotation speed in rpm;
- the grain flow in cmc/min.

In order to measure these parameters, some transducers were used.

Fig. 2 The stand iamge: 1 – grain tank; 2 – action wheel; 3 – cleaning equipment from harvest combine; 4 - transmission

To measure the frequency and the rotation speed magnetic transducers were fixed on specific pieces of the stand (fig. 3 and 4).

The power absorbed by the equipment was measured using an electric converter attached to the electric engine (fig. 5).

The measured values were transmitted to a serial acquisition system RS 232 which communicates with a computer (fig. 6). A special soft was designed for a complete automatic data collection. The soft assures the complete acquisition of the following values with the characteristics mentioned in table 1.

An important part of the stand preparation for testing consists in the calibration process. Some special problems appeared with the grain flow evaluation. In this respect, the flowing equipment was tested in different conditions in order to determine the grain quantity distributed at each complete rotation. Consequently 35 probes were collected for one open gate of the distributor and the results were evaluated using statistical methods (fig. 7).

The results show a normal distribution of the tests and in these conditions we obtain the quantity of material distributed on the sieve in two different units of measurements: gram/minute and cmc/minute.

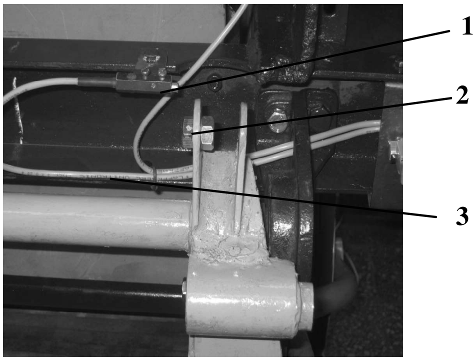

Fig. 3 The frequency of sives oscilations transducer: 1 – transducer; 2 - height flux magnet; 3 – vire for connected to the RS

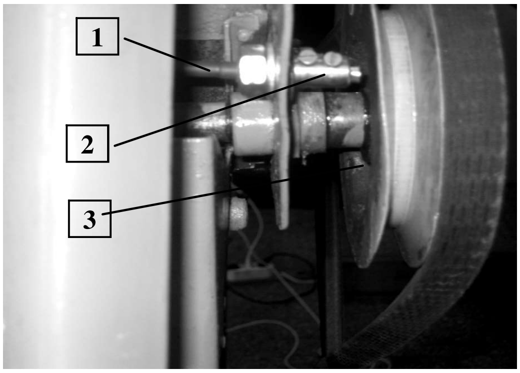

Fig. 4 The speed of the alimentation: 1 – wire for colect data on RS; 2- speed transducer; 3 – heigh fux magnet incorporeted in the weel

Fig. 5 The absorbed power transducer measured equipment: 1 – power convertor; 2 – transducer conection to the electric engine

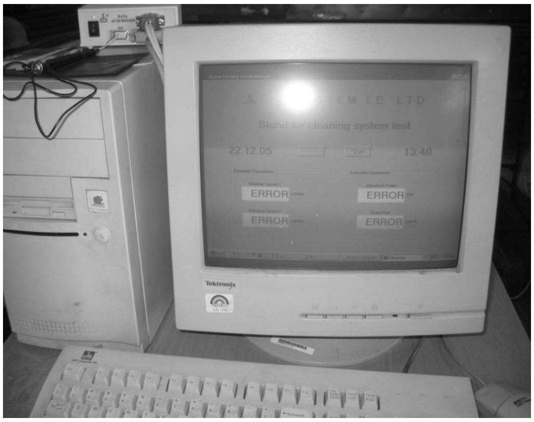

Fig. 6 The acquisition RS 232 and PC connected to the transducers

Table 1 The measured parameters and the characteristics of the collected data:

Parameters	Transducers type	Frequency of input values [Hz]	Obs
Sieve oscillations	Magnetic	10	
Distributor rotation speed	Magnetic	10	
Absorbed power	Electric converter	20	
Grain flow		10	Calculated parameter

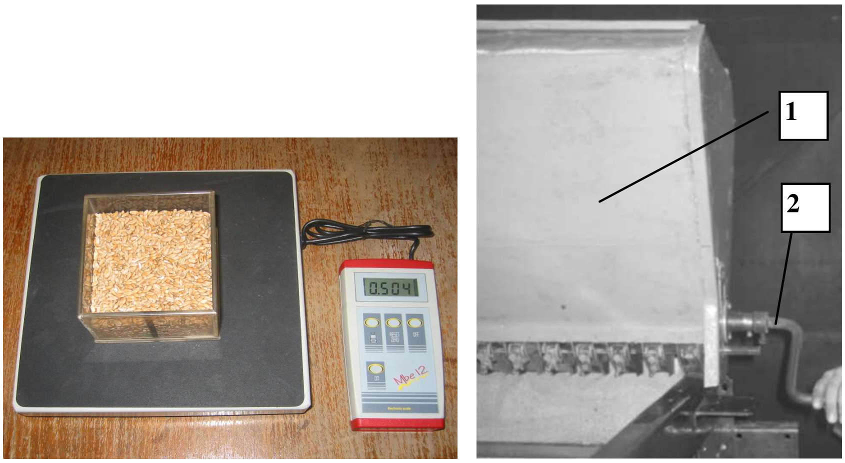

Fig. 7 The grain quantity and volume evaluation (left) . The calibration process (right)
1 – the grain thank; 2 – manual action of the distributor

TEST RESULTS AND MATHEMATICAL EVALUATIONS

The purpose of this stage of the research carried out consists in establishing the evaluation method of the cleaning system efficiency. As we know, the efficiency of the separation process is not evenly distributed on the sieve surface.

To evaluate the quantity of the grains sorted in each part of the sieve the collecting box was divided in equal squares.

After each test, the quantity of material accumulated in each square was measured.

The distribution of the quantity of material by length and width of the sieve was mentioned in the test observation paper.

The statistical evaluation of the grain flow from the tank shows a capability to correct it within limits: 0 to 3357 kg/h which corresponds to a volume flow in limits: 422,9 cmc/h.

The correction of the kernel flow is possible due to the tank gate which is adjustable in steps shown in table 2.

Table 2 The gate steps of the grain tank

Step no	Grain flow	
	gr/sec	cmc/sec
1	116.527	14.718
2	233.055	29.436
3	349.582	44.155
4	466.110	58.873
5	582.637	73.591
6	699.164	88.309
7	815.692	103.028
8	932.219	117.746

The measured quantity of grain sorted for two different rotation ratio of the equipment, show significant differences regarding the results of the grain separation from the straw. For two different speed rotations (in fact frequency of oscillations), the separation capacity on the plate sieves is changed. This is caused due to the different displacement conditions of the kernels in the sieve surface.

If we analyze the quantity of material sorted for both conditions mentioned we observe a different distribution of the sorted efficiency. If the frequency of oscillations is near to the indicated frequency for this cleaning system (540 rpm), the distribution of the sorted efficiency is covered by an exponential law (fig. 8).

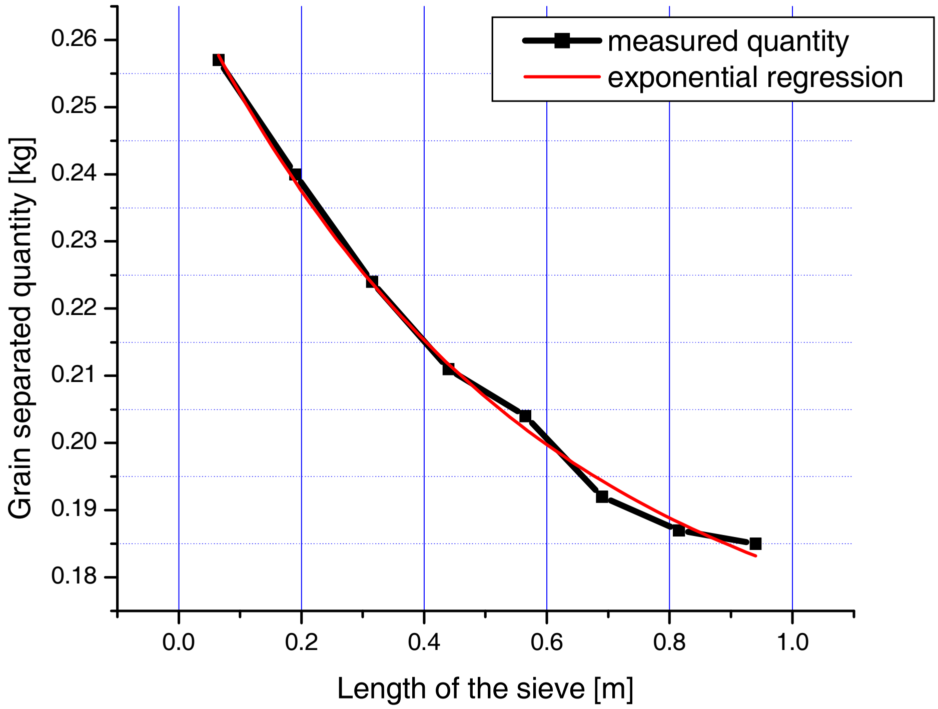

Fig. 8 The distribution of the cleaning process efficiency, for oscillation frequency 540 min^{-1}

The characteristic equation which describes that distribution of the cleaning process is:

$$f(x) = y_0 + A \cdot e^{-\frac{x}{t}} \tag{1}$$

where:

f(x) represent the density of grain separation the distribution function;

y_0 is the position parameter, in this case with the value 0,16336;

A is the function coefficient, evaluate at 0,10592;

t is the characteristic coefficient of the exponential law, depending by the length of the sieve, equal with 0,56;

x the variable of the equation.

The distribution of the cleaning efficiency on the width of the sieve is presented in figure 9.

If we increase the rotation speed with 100 rot/min on the length of the sieve the separation efficiency is covered by a polynomial second degree distribution law (fig. 10).

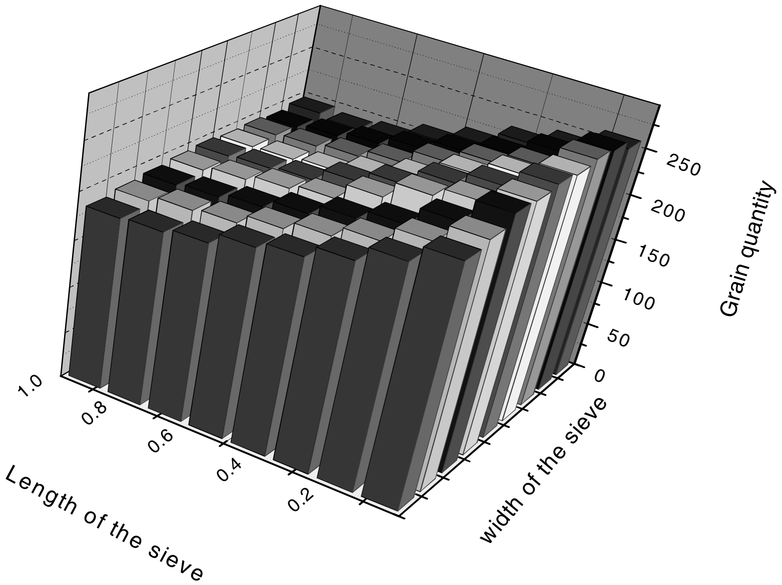

Fig. 9 The cleaning efficiency dsitribution on the width and length of the sieve

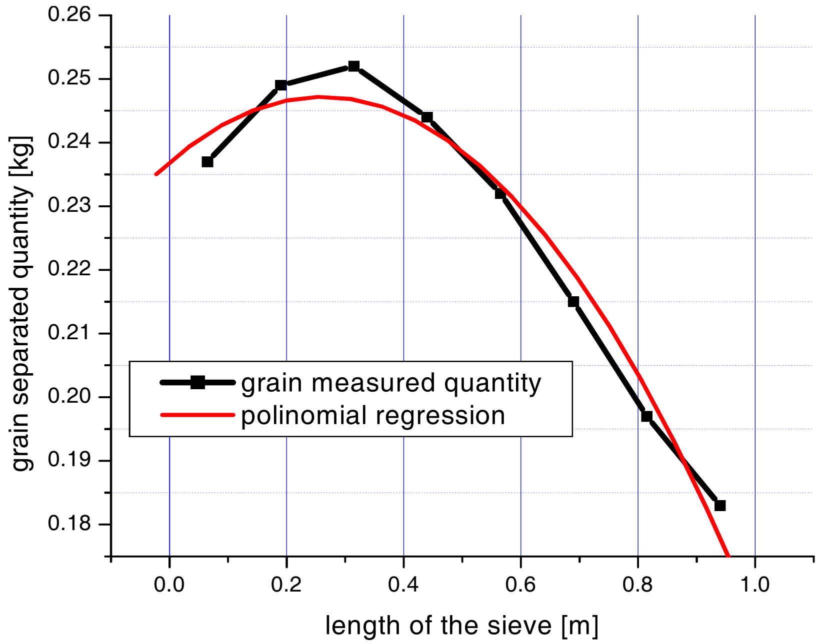

Fig. 10 The quantity of grain sorted in height speed conditions and it polynomial distribution on the length of the sieve

The characteristic equation in this case is:

$$f(x) = A + B_1 x + B_2 x^2 \qquad (2)$$

where:

f(x) represent the distribution function of the polynomial second order regression ;

A free coefficient, equal with 0,23689;

B_1 first degree coefficient: 0,7875;

B_2 second degree coefficient: - 0,15048.

In this case however the total quantity of grain collected in the box under the sieve increases with 4 %.

Some kernels were also collected behind the sieve but this quantity represents only less then 1,5 % of the overall quantity.

CONCLUSIONS

The stand designed and built in the laboratory assures a complete cleaning process evaluation. The results obtained so far offer some information regarding the energetic cleaning process consumption and the kinematical parameters controlled during the tests. The first tests also confirm some determinations obtained in the simulation stage. On the other hand, the information is completed with experimental values obtained in the tests.

The challenge for the future consists in developing the research by taking into consideration a secondary induced vibration. In this case the efficiency evaluation will be made using the same procedure detailed in this paper.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

ISKUSTVO U ŽETVI ULJANE REPICE

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SAŽETAK

U žetvi uljane repice na obiteljskom gospodarstvu u Baranji kombajni sa žitnim hederom, A i B imali su podjednake gubitke kose 2,7, odnosno 2,2%, dok su na razdjeljivaču gubici bili 4,8-5,2, odnosno 7,1%, a na vršalici 1,8%, odnosno >2%. Kombajn C, s hederom za repicu imao je 16,1% gubitaka na hederu i >2% na vršalici. Na IPK Osijek RJ Bara u žetvi usjeva tretiranog s Agrovital-om (ljepilom) ukupni gubici kombajna A bili su 7,0%, kombajna B 12,85%, te kombajna C s hederom za žito 10,35%. U žetvi netretiranog, poleglog i isprepletenog usjeva kombajn s hederom za repicu D imao je gubitak od 26,0%, a kombajn E, s hederom za žito 24,4% na hederu, te 22,8% na razdjeljivaču i >2% na vršalici.

Ključne riječi: *kombajn, gubici, uljana repica, žetva*

UVOD

Uzgoj uljane repice u EU intenziviran je posljednjih 15 godina, a u Hrvatskoj je ona još uvijek zastupljena na 13 do 16 tisuća ha, ovisno o godini. Uzgaja se radi ulja, sačme, pogače i sjemenki koje sadrže 40-48% ulja i 18-25% bjelančevina. Urodi uljane repice u zapadnoj Europi u prosjeku su od 3,5 do 4 t ha^{-1}, dok je hrvatski prosjek oko 2,2 tone ha^{-1}. Žetva uljane repice u Hrvatskoj obavlja se uglavnom kombajnima s hederom za strne žitarice, pa su gubici u pravilu neprihvatljivo visoki, 10-30% uroda. Žetvu treba obaviti kada je usjev žućkasto smeđe boje, stabljika žućkasto žuta, lišće pretežno osušeno, a ono koje nije osušeno žuto-smeđe je boje. Komuške na postranim granama većim djelom su žuto-smeđe boje, a samo manjim djelom žuto-zelenkaste boje. Komuške na centralnim granama sivo-smeđe su boje. Pri laganom udaru rukom po stabljici komuške na centralnoj grani pucaju. Gubici zrna uljane repice u žetvi kod nas vrlo su malo kvantificirani na znanstvenoj osnovi. Agronomski fakultet Zagreb – Zavod za mehanizaciju je gotovo prije 3 desetljeća istraživao gubitke zrna u žetvi uljane repice i nakon dobivenih rezultata predložio rješenje, ugradnjom produžetka stola žitnog hedera na ukupnu duljinu 6o cm. Ulaskom u

EU, Hrvatska će u godini pridruživanja biti obvezna imati udjel potrošnje biodizel goriva na razini 2% ukupne potrošnje goriva mineralnog podrijetla. U sljedećim godinama treba se udjel biodizela povećavati godišnje za 0,75% sve do 2010. godine, a u 2020. Hrvatska bi trebala tržištu ponuditi 20% biodizela.

MATERIJAL I METODE

Istraživanje je obavljeno tijekom žetve uljane repice u 2005. godini na jednom obiteljskom gospodarstvu u Baranji i na IPK Osijek RJ Bara. Žetva uljane repice u Baranji obavljena je s kombajnima A i B, sa žitnim hederima, te kombajnom C, s posebnim hederom za repicu (duljina stola hedera l = 80 cm + kosa). U RJ Bara žetvu su obavljali kombajn A s hederom za repicu (duljina stola hedera l = 100 cm + kosa) i kombajn B (vertikalna kosa razdjeljivač), te kombajn C,sa žitnim hederom. U Baranji je žetva sorte Express obavljena 29. lipnja, a 1. i 5. srpnja 2005. god. na IPK Osijek RJ Bara požnjevene su sorte Navajo i Bristol. Gubici su skupljani na sredini hedera i na razdjeljivaču limenim posudama površine A = 0,1 m^2, postavljanim na tlo prije prolaska kombajna. Gubici vršalice utvrđeni su s pet (5) PVC posuda (proizvod Instituta za agrotehniku i Poljoprivrednog fakulteta za bilinogojstvo, Halle Njemačka), koje su ubacivane u padajuću masu biljnih ostataka iz kombajna. Visine biljaka izmjerene su metrom, a sklop je utvrđivan na $1m^2$. Stanje usjeva utvrđivano je slobodnom procjenom ispitivača. Urod i vlaga zrna uljane repice izmjereni su u IPK Tvornica ulja Čepin d.d..

REZULTATI I DISKUSIJA

Tablica 1 Oborine (mm) tijekom vegetacije repice u 2004/05 i 10-godišnji prosjek 1995-2004.

Naziv	IX	X	XI	XII	I	II	III	IV	V	VI	Ukupno
	2004				2005						
2004/05	44,7	80,1	120,7	39,9	33,3	65,9	45,3	56,0	60,2	92,1	638,2
1995-2004.	83,5	58,5	69.8	55,0	48,3	34,8	32,4	57,9	69,7	57,6	567,5

Tablica 2 Srednje mjesečne temperature zraka (ºC) tijekom vegetacije repice u 2004/05 i 10-godišnji prosjek 1995-2004.

Naziv	IX	X	XI	XII	I	II	III	IV	V	VI	Srednja
2004/05	15,8	13,0	6,0	2,1	0,0	-3,6	3,9	11,6	17,4	20,1	11,24
1961-90.	16,6	11,2	5,4	0,9	-1,2	1,6	6,1	11,3	16,5	19,5	9,9

Na pokusno polje u vegetacijskom razdoblju uljane repice od rujna 2004. do lipnja 2005. god. palo je ukupno 638,2 mm ili 12,5 % više u odnosu na višegodišnji prosjeke. Uočava se manjak oborina u rujnu mjesecu sjetve, te izraziti višak u studenom 2004. i lipnju 2005.

god. Olujno nevrijeme s 44 mm oborina 1. srpnja, te još 42,6 mm oborina 4. srpnja znatno su utjecali na polegnuća biljaka i produženje žetve.

Srednja mjesečna temperatura zraka u zadnja četiri mjeseca 2004. i prvih šest mjeseci 2005. god. veća je za 14% u odnosu na višegodišnji prosjek. Topliji su bili listopad i prosinac, a hladniji veljača i ožujak.

Usjev sorte Express na obiteljskom gospodarstvu u Baranji bio je uspravan, vrlo malo nalegnut sa sklopom od utvrđenih 24 biljke m^{-2}. Tablica 3. pokazuje gubitke repice u žetvi. Pri žetvi kombajnom A na vršalici je utvrđen gubitak 1,8 % ha^{-1}, dok su nedovoljno podešeni kombajni B i C stvarali gubitke >2%. Naime, kod kombajna B evidentirano je prosječno 38 zrna/PVC posudi, a kod kombajna C prosječno 30 zrna. Kalibracijski grafikon PVC posude ne predviđa više od prosječno 10 zrna/ posudi, jer je već to gubitak od 2%. Dakle, veći broj zrna u posudi jasan je pokazatelj ne podešenosti vršalice kombajna. Kod kombajna C, opremljenog s posebnim hederom za repicu, gubitak na hederu od 9,2% ha^{-1} i 6,9% posljedica je nestručnog rada rukovatelja kombajna s vitlom.

Tablica 3 Gubici (% ha^{-1}) u žetvi uljane repice na obiteljskom gospodarstvu, naturalni urod 3060 kg ha^{-1}, vlaga zrna 11,0 -11,5%

Naziv	Kombajni s hederom za žito		Kombajn s hederom za repicu
	A	B	C
Heder	2,7	2,2	9,2
Razdjeljivač	4,8-5,2	7,1	6,9
Sita	1,8	> 2	> 2
Ukupno:	9,3 – 9,7		

Na RJ Bara požnjevena je uljana repicu Navaho, tretirana 24. lipnja s Agrovital-om u dozi 0,7 l + 80 l vode ha^{-1} i pretežito polegao i nezaštićeni usjev uljane repice sorte Bristol. Utvrđeni sklop na toj tabli bio je 26 biljaka/m^2. Tablica 4. pokazuje gubitke u žetvi za ovu lokaciju.

Tablica 4 Gubici (% ha^{-1}) pri žetvi uljane repice na RJ «Bara», naturalni prinos 2602 kg ha^{-1}, vlaga zrna 11,36 %, 2 % primjesa

Naziv	Kombajn s hederom za repicu (stol+v.kosa)	Kombajn s vertikalnom kosom	Kombajn s hederom za žito	Kombajn s hederom za repicu (stol+kosa)	Kombajn s hederom za žito
	A[1]	B[1]	C[1]	D*	E*
Heder	2,7	10,8	7,5	14,7	24,4
Razdjeljivač	4,0	1,7	2,2	10,3	22,8
Sita	0,3	0,35	0,65	1,0	>2
Ukupno:	7,0	12,85	10,35	26,0	-

[1] Usjev tretiran Agrovitalom

* Usjev nije tretiran s Agrovital-om (ljepilo)

Najmanje gubitke je imao kombajn A, opremljen s produženim stolom od 100 cm i vertikalnom kosom. Kod ovog kombajna utvrđen su najmanji ukupni gubici od 7,0 % ha-1 ili 182 kg ha-1. Kod kombajna B opremljenog samo vertikalnom kosom utvrđeni gubitak na hederu od 10,8 % četiri puta je veći nego kod kombajna A. Kod kombajna C utvrđen je gubitak na hederu od 7,5 % ha-1, na razdjeljivaču hedera 2,2 % ha-1 i na vršalici 0,65 % ha-1, ukupno 10,35 % ha-1 ili 269 kg ha-1. Vrlo veliki gubici utvrđeni su kod kombajna E, i to u žetvi netretiranog i pretežito poleglog usjeva (rubni dijelovi table 70-80%, unutar table 30-40%). Na istoj tabli je dobro opremljeni kombajn D imao velike gubitke na hederu (14,7 % ha-1) i na razdjeljivaču (10,3 % ha-1), 1,0 % ha-1na vršalici, odnosno neprihvatljivo ukupno 26 % ha-1 ili 677 kg ha-1. Međutim i tako veliki gubici znatno su manji u odnosu na gubitke kombajna E koji je pri žetvi gotovo pola uroda ostavljao na tlu.

ZAKLJUČAK

Na temelju jednogodišnjeg ispitivanja gubitaka zrna pri žetvi uljane repice na području Baranje i IPK Osijek u 2005. godini mogući je zaključiti slijedeće:

- žetvu s minimalnim gubicima moguće je obaviti samo s dobro opremljenim i podešenim kombajnom, odnosno s hederom za uljanu repicu (produženi stol hedera + desna vertikalna kosa);
- u žetvi valja posebnu pažnju pridati "režimu" rada vitla (položaj i obodna brzina vitla);
- izbjegavati, ukoliko je moguće, žetvu poleglog i isprepletenog usjeva neopremljenim i poluopremljenim kombajnom;
- utvrđivanje gubitaka treba obaviti stručna osoba s odgovarajućim priborom (metalne posude odgovarajuće površine i PVC posude).
- istraživanje treba svakako nastaviti kako bi se potvrdila dosadašnja saznanja i stekla nova iskustva pri žetvi uljane repice.

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EXPERIENCE IN OIL SEED RAPE HARVESTING

SUMMARY

In harvesting oil seed rape on familly farm in Baranja unequipped foreign combine «A» and «B» were making equal losses on header (2,7 i 2,2%), bigger on divider (4,8-5,2 i 7,1%), but also on sieves 1,8%, apropos >2% which is determined for combine «B». Fully equipped inland combine «C» was making losses 16,1% on adapter and >2% on sieves. On IPK Osijek RJ Bara under harvesting treated crops of oil seed rape with Agrovital (adhesive) total losses at «A» combine are 7,0%, at «B» 12,85%, as well as inland unequipped combine 10,35%. In harvesting untreated, layed and convoluted crop with fully equipped foreign combine «D» was making loss by 26,0%, but inland unequipped combine 24,4% on adapter, 22,8% on divider and >2% on sieves.

Key words: *combine, losses, oil seed rape, harvesting*

34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.354
Stručni rad
Expert paper

FAKTORI POUZDANOSTI ŽITNIH KOMBAJNA U RADU

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SAŽETAK

Eksploatacijska sigurnost u radu značajan je pokazatelj radne sposobnosti stroja što je posebno značajno kod složenih strojeva koji rade unutar kratkog agrotehničkog roka. Pouzdan rad složenog stroja-kombajna utječe na povećanje proizvodnosti i kvalitetu rada kao i na smanjenje ukupnih troškova proizvodnje.

U radu su navedene metode dijagnosticiranja i mjere održavanja kombajna. U svrhu istraživanja stanja izvansezonske pripreme i smještaja kombajna obavljeno je anketiranje i analiza stanja kombajna na području Slavonije i Baranje. Pored navedenog, analiziran je utjecaj pripremljenosti kombajna na frekvenciju kvarova tijekom žetve.

Istraživanjem je obuhvaćeno 382 kombajna. U radu je, između ostalog, ukazano na povećavanje troškova rada pri nekvalitetnoj organizaciji sustava pripreme kombajna za rad i nepravilnog tehničkog održavanja.

Ključne riječi: *kombajn, pouzdanost u radu, metode dijagnosticiranja, mjere održavanja kombajna*

UVOD

Suvremeni žitni kombajni visoko su proizvodni strojevi velike nabavne cijene i ograničenog broja sati rada tijekom sezone zbog čega se za njih može reći da su izloženi tzv. vršnim opterećenjima. Radi toga se vrijeme potrebno za popravak, uvjetovan neadekvatnom pripremom i održavanjem kombajna, teško može nadoknaditi tijekom žetve. Izvansezonsko održavanje kombajna također ima značajan utjecaj na njegovu pouzdanost u radu.

Pouzdan rad kombajna može se osigurati na više načina i to uglavnom kupovinom kvalitetnog stroja, ali i organiziranjem što optimalnijeg sustava tehničkog održavanja, popravka, pripreme za rad, izvansezonskog održavanja i stalnog praćenja tijekom rada. Do smanjenja pouzdanosti u radu dolazi i kod novijih strojeva veće nabavne cijene ako navedeni sustav održavanja nije dobro organiziran i izveden.

Na eksploatacijsku pouzdanost i siguran rad kombajna utječe veći broj čimbenika čije nam poznavanje omogućava poduzimanje mjera radi smanjenja ili isključivanja njihovog utjecaja. Navedeni čimbenici mogu se podijeliti na opće, tehničke i čimbenike održavanja i upravljanja strojem.

PREGLED LITERATURE

Zadnjih tridesetak godina naglo se razvio interes za izučavanje pouzdanosti rada strojeva, opreme, objekata i dr. Djelomično se to može objasniti razvojem vojne i kozmičke tehnike gdje pouzdanost strojeva treba biti besprijekorna. Navedeno uvjetuje brži razvoj znanosti o pouzdanosti strojeva tijekom rada.

Pouzdanost strojeva je svojstvo održavanja zadane funkcije tijekom vremena rada, utvrđenih eksploatacijskih pokazatelja u zadanim granicama, režima rada, uvjetima pripreme, popravka i izvansezonskog smještaja. Prema tome, znanost o pouzdanosti izučava zakonomjernost promjena pokazatelja radne sposobnosti stroja tijekom vremena i prirodu nastalih kvarova.

Utvrđivanje tehničkog stanja, o čemu ovisi radna sposobnost stroja, obavlja se dijagnosticiranjem na temelju čega se dobiju podaci o potrebnim zahvatima na svakom ispitivanom stroju. U novije vrijeme intenzivno se razrađuju metode i oprema za dijagnosticiranje. Ovisno o opremljenosti dijagnostički pregledi obavljaju se subjektivnim, objektivnim ili kombiniranim metodama. Subjektivna metoda odnosi se na iskustvo i sposobnost zaključivanja osobe koja obavlja dijagnosticiranje. Objektivna dijagnoza obavlja se pomoću specijaliziranih instrumenata i aparata. U našoj praksi uglavnom se koristi subjektivna metoda dijagnosticiranja.

Na temelju dijagnosticiranja dobiju se podaci o potrebnim zahvatima na ispitivanom stroju koji se mogu odnositi na preventivnu izmjenu ili podešavanje pojedinog dijela, zamjenu dotrajalih dijelova ili na generalni popravak ako se radi o većem oštećenju ili dotrajalom stroju. Navedeni postupci odnose se na razdoblje od završetka sezone rada do završetka priprema za novu sezonu. Takav postupak osigurava bolju pouzdanost rada stroja tijekom sezone.

Održavanje strojeva može se obaviti na tri načina:

- očekivanjem zastoja, a zatim intervencijom
- provođenjem zahvata održavanja temeljem unaprijed utvrđenog roka bez obzira na stanje (dijela) stroja
- provođenje održavanja praćenjem slijeda trošenja i prognoziranja vremena intervencije na osnovu utvrđenog stanja.

U literaturi se, prema složenosti popravka, predlaže sljedeća klasifikacija otklanjanja kvarova modificirana za kombajne:

- prva grupa složenosti su zastoji koji se otklanjaju jednostavnim zahvatima, a odnose se uglavnom na podešavanja tijekom rada (zategnutost remena, zategnutost lanaca i slično)

- druga grupa složenosti su kvarovi koji se otklanjaju zamjenom lako dostupnih dijelova, sklopova i agregata u trajanju 1,5-2 sata
- treća grupa složenosti su kvarovi kod kojih treba obaviti rasklapanje i obrađivanje sklopova i njihovih dijelova ili obaviti zamjenu u trajanju većem od dva sata.

Istraživanja ukazuju na povećavanje troškova rada za 30-50%, pri nekvalitetnoj organizaciji sustava pripreme stroja za rad i nedostatnog tehničkog održavanja, u odnosu na troškove dobro pripremljenih kombajna kod kojih se pravovremeno primjenjuju pravila tehničkog održavanja (koja se nalaze u uputstvima za rad kombajna). Značajnu ulogu u održavanju tehničkog stanja zauzima pripremljenost za izvansezonski smještaj i sam smještaj kombajna. Utvrđeno je da trajanje zastoja zbog kvara u žetvi nije u izrazitoj korelaciji s kvalitetom pripreme i popravka. To se tumači i utjecajem drugih čimbenika na pojavu kvarova. Analiza zastoja zbog kvarova pokazuje povećanje učestalosti kvarova u prvim danima žetve koji kasnije postepeno opadaju. Obavljena istraživanja ukazuju da se najveći gubici vremena radi popravka kombajna u žetvi, javljaju kod kombajna na kojima uočeni nedostaci u pripremi nisu otklonjeni.

CILJ I METODE RADA

U žetvi dolazi do zastoja kombajna radi kvarova, a time i do smanjenja proizvodnosti i produljenja trajanja žetve. Istraživanje je podijeljeno na:

- utvrđivanje izvansezonske pripreme i smještaja kombajna
- utvrđivanje utjecaja pripremljenosti kombajna na frekvenciju kvarova tijekom žetve

Istraživanja nisu obavljena na istim kombajnima niti u istom vremenskom razdoblju, ali utvrđene činjenice upućuju na razinu cjelokupnog održavanja žitnog kombajna.

Utvrđivanje izvansezonske pripreme i smještaja kombajna

Pri utvrđivanju stanja izvansezonske pripreme i smještaja kombajna obavljeno je anketiranje i analiza stanja kombajna na području Slavonije i Baranje. Ispitivani uzorak je sačinjavalo 382 kombajna. Anketiranjem je utvrđeno da su svi kombajni bili očišćeni prije garažiranja i izvana oprani vodom, a manji broj je bio detaljno očišćen.

Utvrđivanje utjecaja pripremljenosti kombajna na frekvenciju kvarova tijekom žetve

Istraživanje je obavljeno u dva vremenska razdoblja, a svako je bilo u trajanju od dvije godine. U prvoj grupi istraživanja analizirano je osam kombajna u pripremi i za vrijeme rada. U drugoj grupi analizirano je 25 novih kombajna temeljem nalaza servisne službe tvornice. U tijeku dvogodišnjeg istraživanja praćene su intervencije rada servisne službe proizvođača kombajna u servisnom roku u trajanju od godinu dana. U prvoj godini istraživanja obuhvaćeno je 25, a u drugoj 15 kombajna (gdje je intervenirala servisna služba). Kombajni se nalaze u privatnom vlasništvu. Većina vlasnika kombajna koristi servisnu službu tvornice za nabavu rezervnih dijelova i otklanjanje onih kvarova koje ne može samostalno otkloniti. Servisna služba svaki nedostatak i popravak uvodi u zapisnik s napomenom zašto je došlo do kvara i broj utrošenih dijelova.

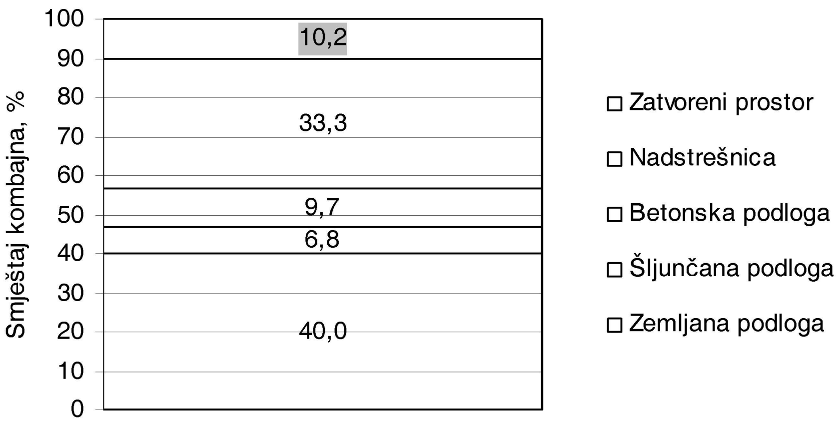
Zadatak istraživanja je bio:

- utvrditi frekvenciju kvarova glavnih sklopova kombajna u pripremi i žetvi
- utvrditi utjecaj starosti kombajna na frekvenciju kvarova
- utvrditi vrijeme otklanjanja kvarova tijekom žetve
- analizirati nalaze servisne službe proizvođača kombajna.

REZULTATI ISTRAŽIVANJA

Analiziranjem izvansezonske pripreme i smještaja kombajna može se zaključiti da su na oko 50% kombajna unutarnje površine oprane vodom što se smatra pogrešnim postupkom, a na preostalom broju kombajna očišćene su zrakom pod tlakom (bez detaljnijeg čišćenja). Pregledom kombajna utvrđeno je da znatan broj kombajna koji su bili u berbi kukuruza nisu iznutra očišćeni nakon završetka radova. Mjere konzerviranja kombajna kao i motora, uglavnom se ne provode. Na 90% kombajna remenje nije bilo skinuto, a od toga je na samo 20% bilo olabavljeno. Lančanim prijenosnicima snage na kombajnu pridaje se nešto više pažnje. Na 75% kombajna lanci nisu skinuti niti konzervirani, a olabavljeni su na 85% prethodnog broja, dok su skinuti lanci u skladištu uglavnom premazani rabljenim motornim uljem, a samo na jednom mjestu su smješteni u kupku mješavine ulja i nafte. Postupak s pneumaticima se svodi na pranje vodom, a konzerviranje se ne provodi. Na podmetače su uglavnom smješteni kombajni koji se nalaze u hangarima ili pod nadstrešnicama. Kombajni se izvan toga nalaze na pneumaticima, često sa smanjenim tlakom zraka. Zaštiti elektroinstalacije ne pridaje se izrazitija pažnja, posebno kod kombajna smještenim na otvorenom prostoru. Akumulatorima se pridaje malo više pažnje tako što se većina pohranjuje u akumulatorsku stanicu, povremeno nadopunjuje i po potrebi koristi na traktorima.

Uvjeti smještaja anketiranih kombajna su različiti što je prikazano na histogramu 1.



Histogram 1 Prikaz smještaja kombajna

Analiziranjem histograma 1. može se zaključiti da je najmanji postotak ispitivanih kombajna smješten na šljunčanoj (6,8%) i betonskoj podlozi (9,7%), a najveći na zemljanoj podlozi (40,0%) i pod nadstrešnicama (33,3%).

U tablici 1. navedeni su, na temelju kronometriranja izračunati, koeficijenti zastoja kombajna prve grupe istraživanja razvrstanih u četiri starosne grupe.

Tablica 1 Pregled koeficijenata zastoja kombajna k_z u žetvi

Starost kombajna, god.	Broj kombajna navedene starosti	Godina istraživanja	
		I.	II.
		k_z, %	
11	3	20,3	11,2
8-9	3	8,0	15,6
6	1	8,3	-
4	1	8,0	9,5
$\overline{k}_{z \text{ ponderirano}}$		12,65	11,23

Nakon završene žetve izvršen je popis mogućih nedostataka i gruba detekcija stanja kombajna što je utvrđeno zapisnikom. Vrijeme utrošeno za popravak nije registrirano jer se uz popravak u međuvremenu obavljaju i drugi radovi u radionici.

S obzirom na učestalost zastoja utvrđeno je da je broj zastoja najveći u prva dva do tri dana žetve, dok zastoji u daljnjem tijeku rada imaju trend opadanja. To se objašnjava postepenim intenziviranjem i naknadnim podešavanjem. Prema rezultatima istraživanja trend opadanja je više izražen u prvoj godini.

U tablici 2. prikazan je pregled nedostataka kombajna druge grupe istraživanja razvrstanih po radnim sklopovima u dvije godine istraživanja.

Tablica 2 Pregled nedostataka razvrstanih po radnim sklopovima u dvije godine istraživanja

Mjesto kvara	I. godina		II. godina	
	Broj nedostataka	%	Broj nedostataka	%
Žetelica	18	25,0	6	14,6
Vršalica	25	34,7	15	36,6
Vozni postroj	7	9,7	2	4,9
Hidraulički uređaji	1	1,4	-	-
Mjenjač i spojka	18	25,0	17	41,5
Mjenjač	3	4,2	1	2,4
Σ	72	100,0	41	100,0

Podaci navedeni u tablici 2. ukazuju na trend opadanja nedostataka kombajna u drugoj godini u odnosu na prvu godinu istraživanja. Prethodno ukazuje na pravovremenu intervenciju servisne službe. Neki nedostaci ukazuju na nedovoljnu završnu kontrolu u tvornici, dok neki drugi zahtijevaju poboljšanje izvedbe. Treća grupa nedostataka može se odnositi na uobičajene nedostatke takvih sklopova, teže uvjete rada u žetvi kao i nestručno rukovanje kombajnom.

ZAKLJUČAK

Anketiranjem je utvrđen veliki broj nedostataka i/ili neadekvatnih zahvata izvansezonskog održavanja i smještaja kombajna što pokazuje podatak da je svega 10,2% kombajna smješteno u zatvorenom prostoru. Najveći broj uočenih nedostataka u obje godine istraživanja utvrđen je na vršalici kombajna (I. godina: 25, II. godina: 15), žetelici (I. godina: 18, II. godina: 6), te na mjenjaču i spojci (I. godina: 18, II. godina: 17). Prema tome, treba raditi na stvaranju boljih uvjeta izvansezonskog održavanja i smještaja kombajna.

Dobra pripremljenost značajno utječe na povećanje proizvodnosti kombajna, bolje korištenje vremena i na smanjenje troškova kombajniranja. Utjecaj pripremljenosti kombajna na frekvenciju kvarova je očigledan. Broj utvrđenih nedostataka u drugoj godini (41) je znatno manji u odnosu na prvu godinu istraživanja (72). Broj utrošenih dijelova tijekom pripreme je znatno veći od broja dijelova tijekom žetve. Povećanje starosti znatno utječe na povećanu pojavu kvarova kombajna.

Vrijeme utrošeno na otklanjanje kvarova kombajna tijekom žetve ima trend opadanja približavajući se završetku žetve. Pri servisnom pregledu novih kombajna utvrđeno je da se dio nedostataka odnosi na konstrukcijsko-proizvodne uzroke, a dio na nedovoljnu završnu kontrolu novog kombajna.

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RELIABILITY FACTORS OF UNIVERSAL GRAIN COMBINE HARVESTERS AFFECTING THE PERFORMANCE

SUMMARY

Working reliability is an important indicator of the operational capability of a machine, which is especially important for complex machines operating within a short agrotechnical period of time. The reliability of a harvester as a complex machine brings about an increase of the productional and qualitative level and on the other side a decrease of the overall productional cost.

This paper presents diagnosis methods and measures for combine harvester maintenance. The research surveyed and analyzed the conditions of the off-seasonal preparing and storing of combine harvesters in the region of Slavonija and Baranja. It also analysed the influence of the combine harvester preparation on the occurance of failures during harvesting.

The research was done on 382 combine harvester and among other it points out to a cost increase in the case of a low-quality organization of the system of combine harvester preparation and its technical maintenance.

***Key words**: combine harvester, working reliability, diagnosis methodology, combine harvester maintenance measures*

34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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UTJECAJ DODAVANJA VEZIVNIH MATERIJA - PINOTANA NA PRODUKTIVNOST PELETIRKE WALTER U TSH KLINAPREMIX U KLINI

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SUMMARY

Vrednovanje utjecaja tretiranja peleta parom na učinak, kao i kvalitetu smjese s vezivom tvari (smjesa s 1%, 2% i 3%) i bez veziva omogućuje slijedeći zaključak: povećanje količine veziva pinotan, kapacitet smjese se povećava sa 9,0 t /h za smjesu bez veziva na 10,5 t/h za smjesu s 3% veziva Pinotan. Utrošak snage za proizvodnju peleta se dodatkom veziva pinotan smanjuje i to sa 16,5 kW/h za smjesu bez pinotana na 14,1 kW/h za smjesu s 3% pinotana. Tretiranje peleta vrućom parom nije smanjilo sirove proteine i masti u smjesi budući temperatura pare tijekom peletiranaja nije bila odveć visoka, a vrijeme peletiranja je bilo vrlo kratko. Ukoliko je količina pinotana veća, izlazna temperatura peleta je niža, jer vezivo očito smanjuje trenje mase kroz matricu. Dodatak pinotana povećava postojanost peleta. Tretiranje vrućom parom i peletiranje smanjuje broj bakterija, a potpuno uništava plijesni u stočnoj hrani.

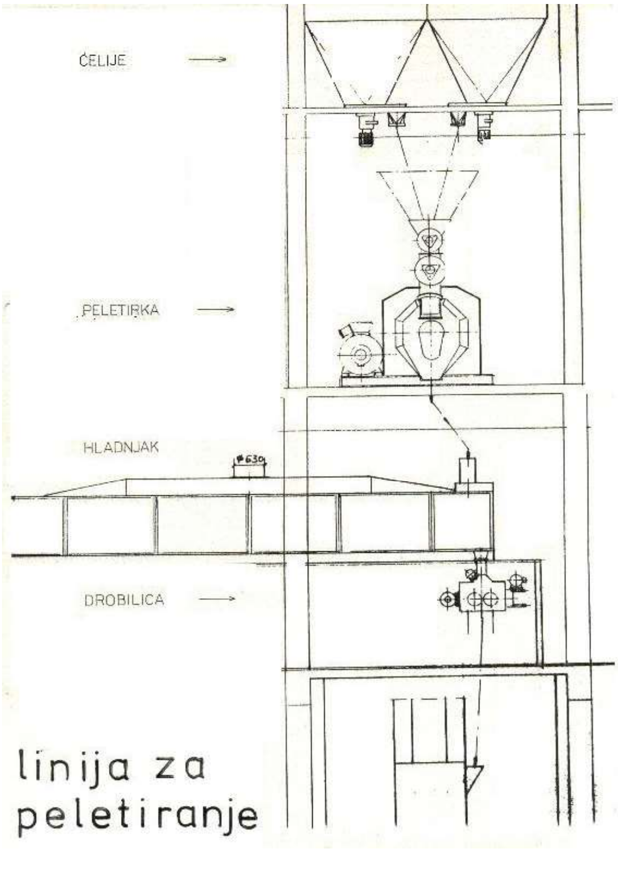
Ključne riječi: *Tretiranje parom, peletiranje, vezivo-pinotan, krmna smjesa*

UVOD

U proizvodnji stočne hrane peletiranje je već dugo jedna od uobičajenih faza i gotovo da nema pogona većeg kapaciteta bez uređaja za peletiranje. U Kosovu peletiranje nije našlo širu primjenu, ali sudeći prema intenzitetu razvoja ove tehnologije u drugim zemljama, možemo reći da će i naša industrija stočne hrane brzo preći na peletiranje većeg dijela svoje proizvodnje a osobito za proizvodnju peleta za perad.

Peletirani proizvod ima mnoge prednosti a neke od njih su: kombinacija vlage, topline i tlaka na prirodna visokoenergetska krmiva vrši određeni stupanj geliranja, što omogućava stoci i peradi da efikasnije iskoriste sastojke, pa prema tome poboljšava konverziju hrane, peletirana hrana onemogućava selektivnu ishranu, tj. odabiranje pojedinih sastojaka iz sastava hrane, pelete sprečavaju segregaciju sastojaka prilikom manipulacije i transporta, peletiranje povećava gustoću mase, prednosti skladištenja i opreme su očite, pošto omogućavaju povećan utovar i smanjenje potrebe za skladišnim prostorima, pri hranidbi peletama gubici rasipanjem su minimalni, dok kod hranidbe brašnastim smjesama gubici rasipanjem hrane sežu i do 15 %. Cijena peletirane hrane općenito je veća za 1.5 do 3 %, ali je taj trošak daleko ispod ušteda koje osigurava njezina upotreba.

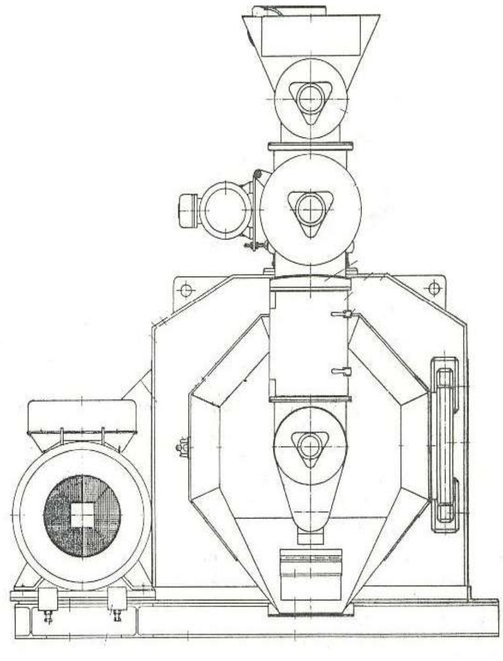
Da bismo mogli koristiti navedene prednosti peleta, potrebno je da one ostanu u svom prvobitnom obliku, kakve izlaze iz hladnjaka do životinje. Na trajnost peleta djeluju karakteristična svojstva komponenata, kondicioniranje smjese, veličina čestica smjese, oblik i kvaliteta matrica, hlađenje peleta i druge. Za proizvodnju čvrstih peleta smjesi se dodaje vodotopivo vezivo, a upravo tijekom kondicioniranja dolaze do izražaja njegove adhezivne sposobnosti, tako što vezivo čvrsto veže čestice smjese. Smjesa lakše prolazi kroz rupe matrice i trenje je slabije, postiže se niža temperatura, troši se manje energije, a i kapacitet je veći. U proizvodnji peleta upotrijebili smo vezivo Pinotan koji se sastoji od 90 % organskih tvari, sadrži i 22 % reduciranih šećera visoke hranjive vrijednosti.



Slika 1 Linija za peletiranje Walter tipa Jumbo

METODE RADA

Tehnološki pokusi peletiranja izvršeni su na liniji za peletiranje Walter tipa Jumbo u tvornici stočne hrane "Klinapremix" u Klini. Linija je slijedećih karakteristika: Blok od 2 metalne ćelije, svaka zapremine 14 m^3. Iz ćelije izmiješanu smjesu okrugli izuzimač dostavlja u kondicioner. U kondicioner se dodaju tekući aditivi suhoj smjesi i on se sastoji od komore s miješalicom, koja stapa aditive u stočnu hranu. Peletiramo pomoću pare koju dobijemo iz kotla kapaciteta 1000 kg/h. Kondicioner je povezan sa sistemima za dodavanje melase i masti.

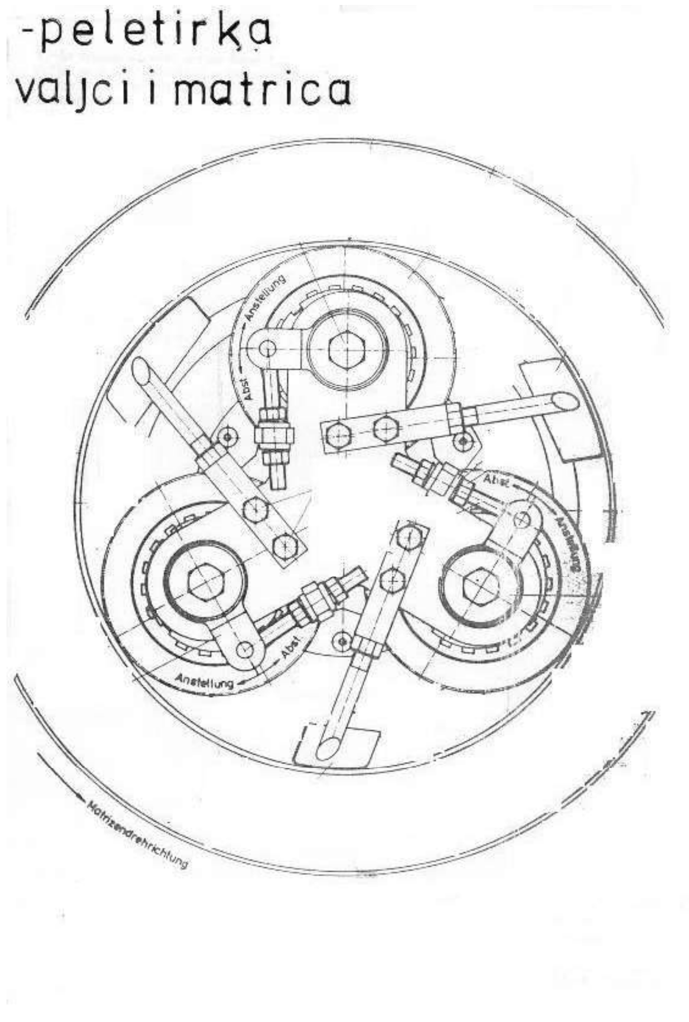


Slika 2 Peletirka sa elektromotorom

Peletirka je kapaciteta 20 t/h s jednim preciznim rotorom. Na prednjoj strani rotora nalazi se nosač matrice i matrica. Tokom peletiranja smo upotrebljavali matricu promjera rupa 4 mm i debljina stjenke 40 mm. Stražnja ploča je opremljena s tri tlačna valjka. Dužina peleta se određuje pomoću podesivih noževa. Peletirku pokreće glavni pogonski motor od 160 kW/1000 okr/min.

Proizvedene pelete iz peletirke padaju u horizontalni trakasti hladnjak s protustrujnim hlađenjem tipa Hurrikan. Vrijeme zadržavanja peleta u hladnjaku je bilo šest minuta. Hladnjak ima kapacitet 20 t/h peleta. Sušenje i hlađenje peleta obavlja ventilator sa 468 m^3

/min zraka i elektromotor snage 30 kW. Ohlađene pelete vođene su kasnije ili izravno na vibracijsko sito ili preko drobilice tipa HBKRU 3, za drobljenje peleta promjera 4-5 mm, kapaciteta 10-15 t/h.



Slika 3 Peletirka sa tri valjcima i matricom

Karakteristike ispitivane smjese

Tretirana brašnasta smjesa sadrži 60.8 % mljevenog kukuruza, 18 % sojine sačme, 2 % ribljeg brašna, 2 % mesnog brašna, 12.5 % pšenice i 1 % masti. Pored kontrolne smjese bez pinotana , pripremljena je smjesa s 1, 2 i 3% veziva – pinotan (Tablica 1).

Tablica 1 Sastav ispitivane smjese u %

Hranjiva	I	I I	I I I	I V
Kukuruz	60.8	60.8	60.8	60.8
Sojina sačma	18.0	18.0	18.0	18.0
Riblje brašno	2.0	2.0	2.0	2.0
Mesno brašno	2.0	2.0	2.0	2.0
Pšenica	12.5	11.5	10.5	9.5
Mast	1.0	1.0	1.0	1.0
Dikalcij fosfat	1.5	1.5	1.5	1.5
Stočna kreda	0.8	0.8	0.8	0.8
Sol	0.3	0.3	0.3	0.3
Premiks	1.0	1.0	1.0	1.0
Metionin	0.1	0.1	0.1	0.1
Pinotan	0.0	1.0	2.0	3.0
Ukupno	100.0	100.0	100.0	100.0

Tablica 2 Granulacija čestica smjese u %

Pinotan	0 %	1 %	2 %	3 %
Čestice > 2,5 mm	3.5	4.0	4.3	3.6
1.6 – 2.5 mm	9.4	8.3	8.1	7.0
1.25 – 1.6 mm	10.6	12.1	8.8	7.7
1.0 – 1.25	5.4	6.5	6.1	4.2
0.5 – 1.0	39.3	38.6	35.3	38.0
Čestice < 0.5 mm	33.8	30.5	37.4	39.5
Ukupno	100.0	100.0	100.0	100.0

Smjesa iz Tablice 2 ima finu granulaciju, što znači da ima veću površinu za apsorpciju vlage iz pare. Ovo rezultira boljim kondicioniranjem što omogućava brže kemijske promjene i poboljšava kvalitetu peleta.

Uzorke bez pinotana, sa 1, 2 i 3% pinotana uzeli smo na slijedećim mjestima: Izmiješanu i homogeniziranu smjesu ispod miješalice; kondicioniranu smjesu s parom ispod kondicionera; pelete ispod peletirke i pelete nakon hlađenja.

Tablica 3 Uvjeti peletiranja

Procesni parametri peletiranja	
Temperatura osnovne pare (°C)	145
Temperatura reducirane pare (°C)	105
Promjer provrta matrice (mm)	4,0
Debljina matrice (mm)	40,0
Omjer između debljine i provrta matrice	10 : 1
Vrijeme hlađenja peleta (min)	16,0
Zazor između valjaka i matrice (mm)	0,5

REZULTATI I DISKUSIJA

U ispitivanju je praćeno nekoliko pokazatelja koji omogućuju sagledavanje bitnih tehnoloških i biokemijskih efekata peletiranja kao : kapacitet peletirke, utrošak električne energije i pare, kemijske promjene sirovih proteina, masti i celuloze tokom kondicioniranja parom i peletiranja, čvrstoću peleta, te broj bakterija i plijesni u smjesi za peletiranje i peletama.

Kapacitet peletirke povećavao se porastom količine dodanog pinotana. Kod smjese bez pinotana kapacitet peletirke je bio 9,0 t/h, dok je pri dodavanju 1 % pinotana kapacitet bio 9,6 t/h, što je 6,7 % više od grupe bez pinotana. U primjeru dodavanja 2 % pinotana, kapacitet peletirke je povećan na 9,9 t/h, odnosno 10 % više od grupe bez pinotana. Uz dodavanje 3 % pinotana, kapacitet je povećan na 10,5 t/h, odnosno 16,7 % više od grupe bez pinotana.

Utrošak električne energije se smanjio porastom količine dodanog pinotana i to sa 16.5 kW/h za tonu peleta kod smjese bez pinotana na 15,7 kw/h kod 1% pinotana, 15,0 kW/h kod 2% pinotana i 14.1 kW/h za tonu peleta kod smjese sa 3% dodanog pinotana.

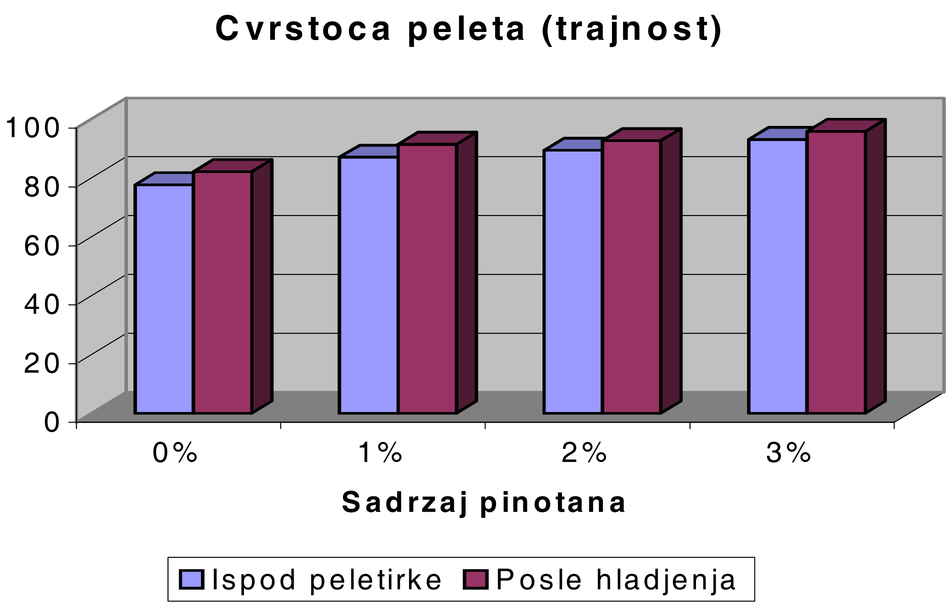
Čvrstoća peleta

Ispitivanje trajnosti peleta obavljeno je pomoću laboratorijskog uređaja – kutije za ispitivanje dimenzija 300mm x 127mm, koja dobiva pogon od elektromotora. Okretanje kutije traje 10 minuta pri 50 min^{-1}. Ispitivanje trajnosti je obavljeno 24 sata nakon peletiranja.

Iz podataka iz Tablice 4. vidljivo je se su da veću trajnost imale pelete prošle kroz hladnjak, a manju pelete uzete odmah ispod peletirke, što znači da prolaskom kroz hladnjak pelete dobijaju na čvrstoći. Ove razlike kod svih grupa bile su statistički značajne na razini vjerojatnosti ($P<0.01$). Dodatkom pinotana povećana je čvrstoća peleta, a razlike u čvrstoći između grupe bez pinotana i svih grupa s dodatkom pinotana, kao i između grupa sa 1 , 2 i 3 % pinotana, bile su statistički visoko signifikantne.

Tablica 4 Čvrstoća peleta u %, za dva uzorka (n=6) : (A) - ispod peletirke i (B) - poslije hlađenja

Uzorak	x	S	Sx	Cv	Raspon
			Bez pinotana		
A	77.71	0.93	0.31	1.20	76.43-79.30
B	83.12	1.32	0.44	1.59	81.03-84.60
			1 % pinotana		
A	87.05	1.68	0.48	1.93	85.40-88.90
B	91.44	0.66	0.22	0.72	90.67-92.13
			2 % pinotana		
A	89.44	0.57	0.19	0.64	88.48-90.41
B	92.67	0.59	0.20	0.64	91.98-93.63
			3 % pinotana		
A	93.06	0.51	0.18	0.55	92.70-94.42
B	95.86	0.58	0.20	0.61	94.30-96.43



Grafikon 1 Čvrstoća peleta u %

Ujednačenost kemijskog sastava smjese i peleta

Kod svih ispitivanih grupa u peletama je smanjen nivo surovih proteina, ali navedeno smanjenje nije bilo statistički signifikantno, osim kod grupe sa 3% pinotana. Ovo praktično znači da kondicioniranje parom i peletiranje nisu u značajnijoj mjeri utjecali na smanjenje količine proteina.

Tablica 5 Sadržaj proteina u smjesi: (A)-prije kondicioniranja, (B)-kondicionirane smjese, (C)-pelete ispod peletirke, (D)- pelete nakon hlađenja

Tretman	x	S	Sx	Cv	Raspon
			Bez pinotana		
A	16.56	0.43	0.14	2.60	15.81-17.08
B	16.40	0.47	0.16	2.87	15.68-17.10
C	16.39	0.32	0.11	1.95	15.72-16.80
D	16.36	0.25	0.08	1.53	15.71-16.50
			1 % pinotana		
A	16.35	0.28	0.09	1.71	15.84-17.22
B	16.18	0.19	0.06	1.17	15.94-16.86
C	16.24	0.48	0.16	2.96	15.40-17.10
D	16.22	0.46	0.15	2.84	15.42-16.70
			2 % pinotana		
A	16.31	0.46	0.15	2.82	15.78-17.21
B	16.30	0.31	0.10	1.90	16.24-17.20
C	16.22	0.43	0.14	2.65	15.94-17.14
D	16.20	0.44	0.14	2.72	15.87-17.24
			3 % pinotana		
A	15.18	0.41	0.14	2.58	15.24-16.27
B	15.95	0.36	0.12	2.26	15.40-16.52
C	15.86	0.33	0.11	2.08	15.48-16.80
D	15.90	0.46	0.15	2.90	15.28-16.61

I kod sadržaja masti nije bilo statistički značajnih razlika osim grupe bez pinotana i grupe s 3 % pinotana. Ovo znači da doziranje većih vrijednosti veziva moramo obavljati pažljivo zbog mogućeg smanjenja masti u hrani.

Peletiranje je reduciralo broj saprofitnih bakterija u tretiranoj smjesi i gotovo potpuno uništilo plijesni, odnosno gljivice.

Tablica 6 Broj saprofitnih bakterija i plijesni: (A)-smjese prije kondicioniranja, (B)-kondicionirane smjese, (C)-peleta ispod peletirke, (D)-pelete nakon hlađenja.

Tretman	Broj saprofitnih bakterije / g
A	506.000
B	173.000
C	50.500
D	67.300
	Broj plijesni / g
A	52.000
B	17.500
C	170
D	5.700

ZAKLJUČAK

Na temelju rezultata ispitivanja i provedene analize utjecaja dodavanja vezivne materije-pinotana na produktivnost peletirke Walter, može se zaključiti slijedeće:

- Povećanjem količine dodanog pinotana kapacitet se povećao s 9.0 t/h kod smjese bez pinotana na 10.5 t/h kod smjese s 3 % pinotana,
- Povećanjem količine pinotana, potrošnja električne energije se smanjila i to od 16,5 kWh/t peleta za smjesu bez pinotana na 14.1 kWh/t za smjesu s 3 % pinotana,
- Kondicioniranje parom i peletiranje nije bitno utjecalo na smanjenje sirovih proteina i masti zbog toga što temperatura kondicioniranja i peletiranja nije bila visoka, a vrijeme kondicioniranje je bilo kratko,
- Što je veći dodatak pinotana, niža je temperatura peleta izašlih iz peletirke, što znači da vezivo olakšava prolaz smjese kroz matricu, odnosno smanjuje trenje,
- Čvrstoća peleta se povećala povećanjem količine pinotana, i to od 83,12 % kod peleta bez pinotana do 95,86 % kod pelete s 3 % dodatog pinotana,
- Kondicioniranje parom i peletiranje je značajnije reduciralo bakterije i gotovo potpuno uništavalo plijesni u peletama.

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THE INFLUENCE OF BINDING MATERIAL – PINOTAN ON THE WALTER PELLET MILL PRODUCTIVITY AT THE AFF KLINAPREMIX IN KLINA

SUMMARY

Evaluating the impact of steam pelleting on the production rate, as well as the pellet quality on the mixture with binding substances (mixture with 1%, 2%, and 3%) and without binding substances, we may conclude as follows: By increasing pinotan quantity, the mixture capacity is increased from 9,0 mt per hour in the mixture without pinotan, to 10,5 mt per hour in the mixture with 3% of pinotan. Power expenditures for pelleting with increased amount of pinotan are lower, from 16,5 kW/h pelleted mixture without pinotan to 14,1 kW mixture with 3% of pinotan. Steam conditioning and pelleting did not affect the decrease of raw proteins and fat, due to the fact that the temperature through conditioning and pelleting was not high and the time of pelleting was very short. If the amount of pinotan is high, pellets are extracted from pellet mill with low temperature, which means that binding material helps mixture to pass through matrix easier and friction is lower. Durability of pellets is increased with added pinotan. Pellet without pinotan is 83,12%, with 1% of added pinotan is 91,44%, with 2% of added pinotan is 92,67%, and with 3% added pinotan the durability is 95,86%. Steam conditioning and pelleting reduced the number of bacteria and totally destroyed molds in feeds due to the high temperature and pressure.

Key words: *steam conditioning and pelleting, binding material – pinotan, feed mixture*

34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.353:631.22:636.083.1
Izvorni znanstveni rad
Original scientific paper

SYNTHESIS A LOCAL DRIVER DRIVEN MANIPULATOR FOR THE SCRAPER OF A PRESS MANURE REMOVAL

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SUMMARY

This paper analyses different types of scrapers for the press manure removals and offers to use a local driver for the manipulator, connected to the frame of the scraper of a Press Manure Removal. The authors of the present paper refer to their previous papers, where the dimensions of the manipulator were specified by the synthesis and discuss the advantage of using two separate drivers for moving manipulator and whole scraper relative to the case, when the scraper's manipulator is driven only by global driver. The motion of the scraper's manipulator is simulated in one working cycle. Several frames of composed video clips are illustrating the working process of a scraper's manipulator driven by local driver. The results of this paper are useful for the designers of manipulators for press manure removals, for the specialists of computer graphics and for the users of computer package Mathcad.

***Keywords**: agriculture, machinery, manure, technology, simulation, computer graphics, Mathcad, synthesis, manipulator, scraper.*

INTRODUCTION

Schauer Maschinenfabrik Ges.m.b.H. & CoKG (2001), Merivirta OY (1998), Paskervilleri (1997, 1999) produces different manure press removals, which are intend to remove manure from a cowshed and store it into a dung pit. Fig. 1 shows a principal scheme of a manure press removal.

The principle of work of the press manure removal in Fig. 1 is the following. The manure scraper, driven by a hydraulic cylinder 2, transports the portions of manure to the manure pipe and presses these by the first manipulator of the manure scraper through the pipe 6 into a heap of muck 7. After the working stroke the valve 4 changes the direction of flow of oil in the oil pipes 3 and the scraper moves back to the initial position. By repeating this working cycle a large heap of muck will be structured. Press manure removal is safe in winter, economical and environmentally sound. A press manure removal might be in use in a small farm with 20 – 50 cows.

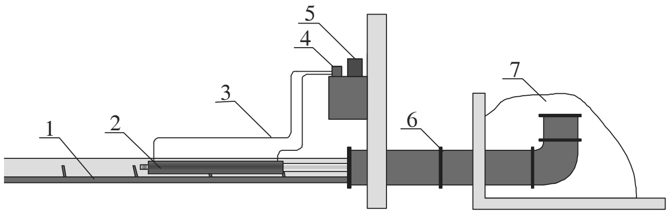


Figure 1 A principal scheme of the press manure removal, 1 – one-sided scraper; 2 – hydraulic cylinder; 3 – oil pipe; 4 – valve; 5 – electric engine; 6 – manure pipe; 7 – heap of muck

Fig. 2 shows a principal scheme of a one-sided manure scraper in the working stroke (a) and in the return stroke (b), which have been used by Schauer Maschinenfabrik Ges.m.b.H. & CoKG (2001), Merivirta OY (1998) and Paskervilleri (1997, 1999) as the working tool of the manure press removal.

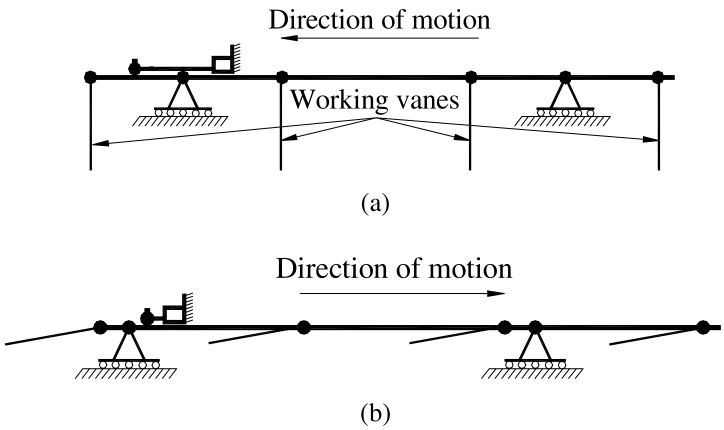


Figure 2 A principal scheme of a one-sided manure scraper in the working stroke (a) and in the return stroke (b)

The working vanes of the manure scraper in Fig. 2 are foursquare and can rotate freely around its vertical (or horizontal) axis under the resistance forces, applied to vane in the manure ply.

A review of possible scrapers for press manure removal is given by Heinloo, Leola (2005a).

The team, headed by Professor Emeritus Vambola Veinla, in Estonian Agricultural University have created novel manure scraper for press manure removal in which the first working vane was clamped to the forced driven manipulator (Fig. 3).

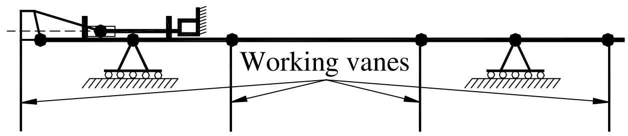


Figure 3 Novel manure scraper for manure press removal

The structure of Scraper's manipulator in Fig. 3 is shown in Fig. 4.

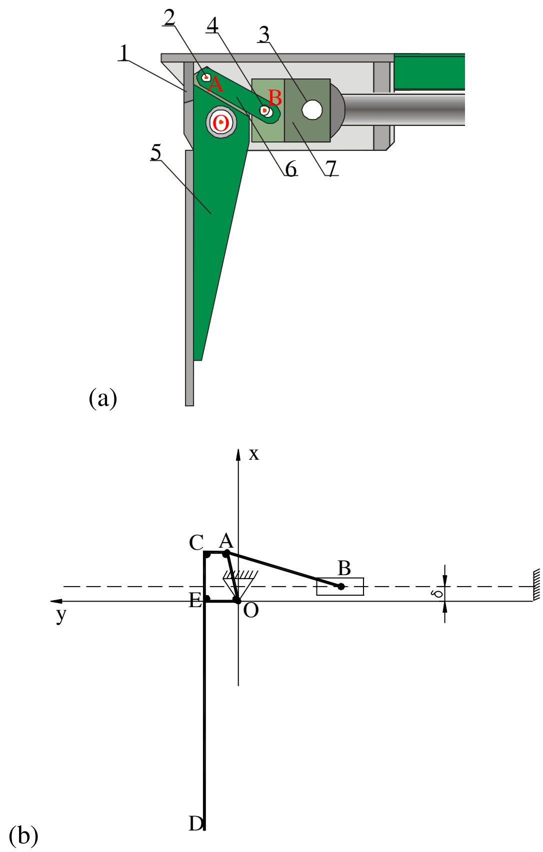


Figure 4 Manipulator (a), 1 – case; 2, 3 – pivots; 4 – pivot with large tolerance; 5 – rib with a vane, 6 – connecting plate; 7 – slider and its model (b) O, A – pivots; B – pivot with a large tolerance; OACED – rigid link

The using of the scraper in Fig. 3 in the press manure removal may be complicated in the case of dry manure, when the turning of the vane needs to apply very high valued force.

To withdraw this problem the authors of this paper offer for press manure removal the scraper, with manipulator and scraper are driven by separate drivers. Fig. 5 shows the idea of creation of such scraper.

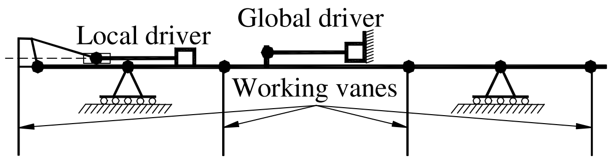
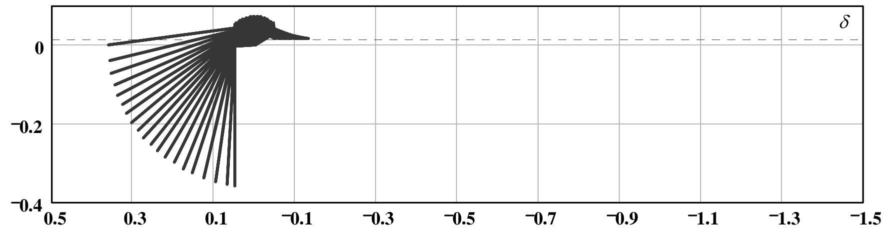


Figure 5 A Manure scraper with Local Driver Driven Manipulator

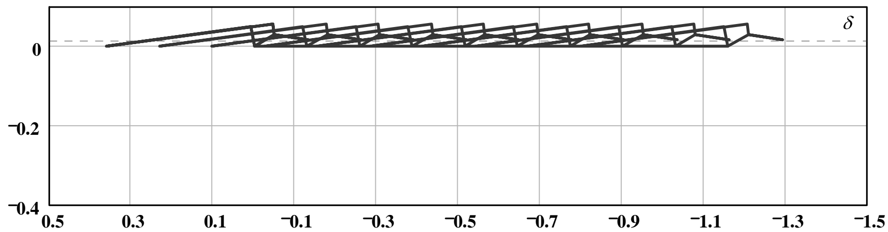
Heinloo, Leola, Veinla (2005b, c) have synthesised the manipulator in Fig. 4 for the scraper in Fig. 3 of the press manure removal in Fig. 1, with the following dimensions:

$$\rho_{AB} = 0.0837 \text{ m}, \rho_{OE} = 0.0490 \text{ m}, \rho_{CA} = 0.0270 \text{ m},$$
$$\rho_{EC} = 0.0560 \text{ m}, \rho_{DC} = 0.4110 \text{ m}, \rho_{AE} = 0.0622 \text{ m}, \quad (1)$$
$$\rho_{OC} = 0.0718 \text{ m}, \delta = 0.0177 \text{ m}, \rho_{AO} = 0.0564 \text{ m},$$

where the symbol "ρ" indicates the distances between points, marked in the subscript. Figs. 6, 7 show the working process of the manipulator in Fig. 4.



(a)



(b)

Figure 6 Second (a) and third (3) stages of return stokes of the link OACED

One cycle of the working process of the manipulator in Fig. 3 consists of working and return strokes. The return stroke of the slider B (7) consists of three stages. First stage: ($0 \le t \le t_0$) the pin 4 moves in the oval hole of the connecting plate 6 and the slider 7 (B) doesn't move the rib with a vane (link OACED). Second stage: ($t_0 < t \le t_1$) the slider 7 (B) turns the rib with a vane (link OACED) clockwise from the working position to the position of return stroke (Fig. 6a). Third stage: ($t_1 < t \le t_2$) the slider 7 (B) moves the rib with a vane (link OACED) to the beginning of the working stroke (Fig. 6b).

Analogical stages have the working stroke that returns the vane with the rib back to the initial position. First stage: ($0 < t' \le t'_0$) the pin 4 moves in the oval hole of the connecting plate 6 and the slider 7 (B) doesn't move the rib with a vane (link OACED). Second stage: ($t'_0 < t' \le t'_1$) the slider 7 (B) turns the rib with a vane (link OACED) anticlockwise from the position of return stroke to the working position (Fig. 4a). Third stage: ($t'_1 < t' \le t'_2$) the slider 7 (B) moves the rib with a vane (link OACED) to the initial position (Fig. 4b), Here t', t'_0, t'_1, t'_2 are the local times, counted from the beginning of the working stroke.

(a)

(b)

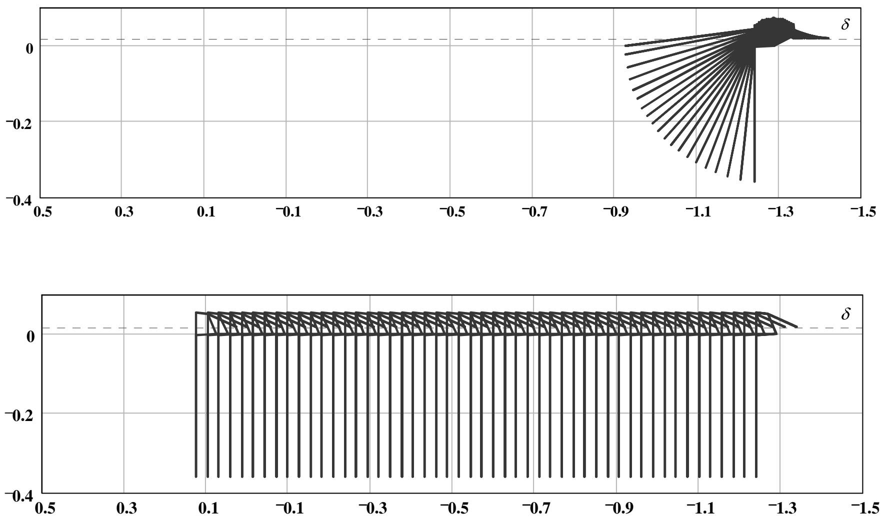


Figure 7 Second (a) and third (3) stages of working stokes of the link OACED

The purpose of this paper is to synthesis a local driver driven manipulator for the scraper of the press manure removal

MOTION OF THE VIRTUAL MANIPULATOR ON THE RETURN STROKE

Let us assume that the slider of the local driver is moving at the return stroke with the velocity $v_t = 0.0400$ m/s relative to the scraper and the global driver drives the scraper with the velocity $v'_t = 0.2285$ m/s (Fig. 5)

The local law of motion at the return is

$$x_B = \delta\,,\ y_B(t) = y_{BO} - v_t(t - t_0),\ (t \ge t_0 > 0) \tag{1}$$

where δ is the distance between the pivot O and the track of the slider B (Fig. 6), v_t – the local velocity of the slider relative to the scraper at its return stroke, y_{BO} – the y-coordinate of the slider's pivot at the moment of time $t_0 = \dfrac{L}{v_t}$, here L – the distance, covered by the slider's at the beginning of the return stroke without moving the manipulator because of large tolerance in the pivot B (Fig. 4). The positions of the manipulator were determined analogically as Heinloo, Leola, Veinla (2005a, b).

Fig. 8 shows the images of virtual manipulator (Fig. 6) on the optimal positions at the beginning (dot line) and end (solid line) on the second stage of the return stroke.

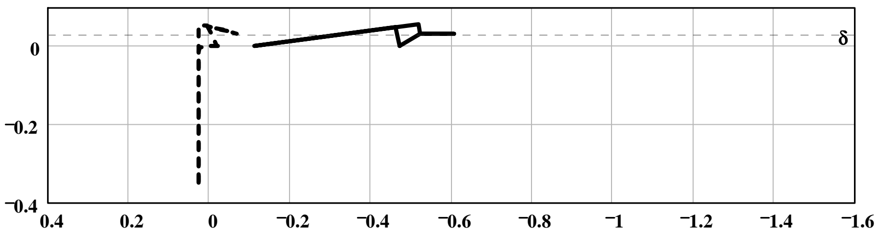


Figure 8 The images of virtual manipulator at the beginning (dot line) and end (solid line) on the second stage of the return stroke

MOTION OF THE VIRTUAL MANIPULATOR ON THE WORKING STROKE

Let us assume that the slider of the local driver is moving at the working stroke with the velocity $v_w =$ 0.0800 m/s relative to the scraper and the global driver drives the scraper with the velocity $v'_w = 0.1393$ m/s (Fig. 5). The local law of motion at the working stroke is

$$x_B = \delta\,, \quad y'_B(t') = y'_{BO} - v_w(t' - t'_0), \tag{22}$$

where $y'_{BO} = y_B(t'_1) + L$ the y-co-ordinate of the pivot B at the moment of the local time $t'_0 = L/v_w$, when the second stage on the return stroke is begins and t' – current time counted from the beginning of the working stroke.

Fig. 9 shows the optimal positions of virtual manipulator at the beginning (dot line) and at the end (solid line) of the second stage on the working stroke

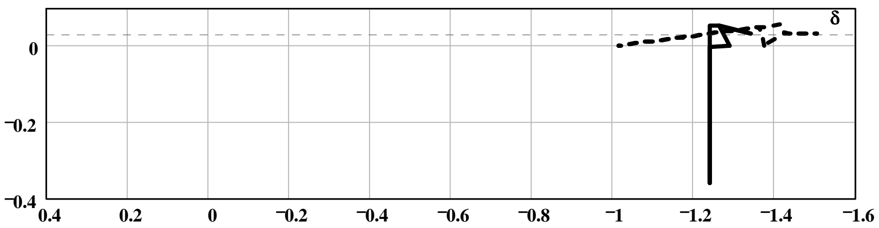


Figure 9 Positions of virtual manipulator at the beginning (dot line) and at the end (solid line) of the second stage on the working stroke, when the local time t'1 is determined from the equality t'1 = h/vw (a), or by the optimum position condition (24) (b)

Fig. 10 shows several video frames in the global co-ordinate system from the composed video clip that simulates the working process of the link OACED in one cycle.

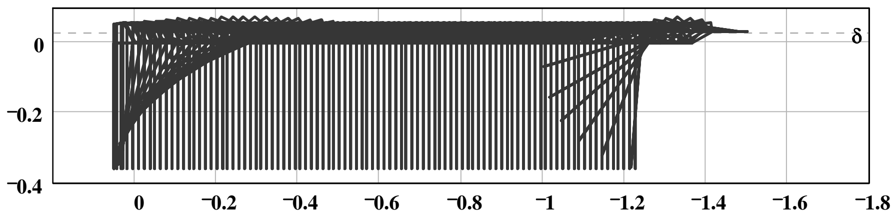


Figure 10 Video frames in the global co-ordinate system from the composed video clip that simulates the working process of the link OACED in one cycle.

CONCLUSION

One can conclude that it is possible to prevent the turning manipulator in the compressed manure (Fig. 6a) by using local driven manipulator (Fig. 10) with different local and global velocities of the manipulator. We conclude also that there is exists different manure scrapers with cinematically possible manipulators for manure press removal. A designer has the possibility of choose a suitable manipulator for press manure removal to be designed.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.153.46:636.2.034:65.011.4
Tehnička bilješka
Technical note

IZBOR STROJNIH AGREGATA PRI PROIZVODNJI HRANE ZA 1000 KRAVA

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SAŽETAK

Za racionalnu primjenu visokoučinkovitih strojnih agregata neophodno je prethodno pravilno uređenje površina za buduće usjeve. To je učinjeno kod izgradnje farme «Holstein – Orlovnjak» uz multidisciplinaran pristup stručnjaka različitih specijalnosti. Na promišljeni način izabrana je široko zahvatna, visoko učinkovita i polivalentna oprema, koja kvalitativno i kvantitativno zadovoljava potrebe farme za 1000 grla (muzne krave i ostale kategorije stoke) po svim vidovima. Izgrađena i tehnikom dobro opremljena spremišta za hranu (silaža i sijeno) u neposrednoj su blizini štala, pa je uz spremanje i distribuciju hrane i transport bitno racionaliziran.

Ključne riječi*: hrana, muzne krave, racionalizacija, strojni agregati*

UVOD

Osnova visoke i kvalitetne proizvodnje mlijeka uvelike ovisi o kvalitetnoj hrani. Ovome se mora pridati izuzetna pažnja prilikom izbora strojnih agregata pri zasnivanju usjeva i pripreme zemljišta za buduću proizvodnju što se posebno odnosi za lucerišta i djetelinsko travne smjese. Tlo mora biti ocjedito i maksimalno ravno kako bi budući usjev mogao primiti brze i široko zahvatne strojne agregate u različitim vremenskim uvjetima.

Pored ovoga kod izbora strojnih agregata mora se voditi promišljeni način izbora strojnih agregata koji zadovoljavaju potrebe farme po kvalitetu i kvantitetu učinaka i racionalnost svakog radnog procesa. Znači ovo moraju raditi stručne osobe različitih specijalnosti, znači multidisciplinarno. Strojevi moraju biti višenamjenskog karaktera kako bi mogli raditi više poslova radi njihove racionalizacije i smanjenih troškova održavanja. Kolika je godišnja potreba hrane za farmu 1000 grla vidljivo je iz tablice 1.

Tehnološko-tehnički pokazatelji proizvodnje hrane

Tablica 1 Potrebe hrane za 1000 grla

Hrana - krma	Dnevna potreba (kg)	Ukupno dnevno (kg)	Ukupno godišnje (t)
Sijeno	4,5	4.500	1.642
Silaža	36,20	36.200	13.213
Koncentrat	6,30	6.300	2.299
Ukupno hrane:	47,0	47.000	17.154

Navedene količine su uvećane za 10% radi rastura i 30% za ishranu ostalih pratećih kategorija uz mliječne krave. Za tu proizvodnju hrane potrebne su površine pod usjevima što je vidljivo iz tablice 2.

Tablica 2 Površine usjeva potrebne za proizvodnju hrane i stelje za 1000 grla

Kultura	Površina (ha)
Lucerna ili DTS	228
Silažni kukuruz	444
Merkantilni kukuruz	140
Pšenice, ječam (radi slame)	780

Hrana za krave u laktaciji, steone i zasušene krave sastoji se od 80% voluminoznog obroka, koji se osigurava iz silirane kukuruzne stabljike i klipa, prvog otkosa lucerne i sjenaže od lucerne i pšenice. Važno je napomenuti da je sva hrana spremljena u odgovarajućim uvjetnim trenč silosima, a sijeno u natkrivenim sušarama.

Kako bi se hrana spremila kvalitetno i na vrijeme nužno je posjedovati opremu koja zadovoljava tehničko-tehnološke zahtjeve u kvaliteti i količini. Linija strojeva za spremanje kukuruzne silaže sastoji se od samokretnog kombajna John Deere 7300 (273 kW) s pripadajućim adapterom Kemper Champion M 4500 (zahvat 4,5 m, učinak 100-110 t/h), transportnih samoistovarnih prikolica Pecon tip 131 volumena sanduka 13 m^3 u agregatu s traktorom John Deere 6410 (77 kW) , te traktora John Deere 8200 (167 kW) i gusjeničara BNT-110 (78 kW) za ravnanje i gaženje mase u silosu.

Spremanje silaže obavlja se u vremenu kada biljka kukuruza ima najveću koncentraciju energije, a to je mliječno-voštana zrioba i kada odnos klipa i stabljike iznosi 1/2 do 2/3 silirane mase. Zelena biljka kukuruza u toj fazi sadrži oko 35% suhe tvari što je idealno za siliranje, a posebno pri gaženju mase silaže. Stvarna dužina sječene mase bila je 3-4-5 cm kako bi se pri prolasku isjeckane mase kroz valjke (procesor) moglo zgnječiti gotovo svako zrno radi buduće bolje iskoristivosti te silirane mase. Visina rezanja bila je 20 do 30 cm od tla kako bi se smanjila nepotrebna celuloza donjeg dijela stabljike te kišom i vjetrom nanesena zemlja i herbicidi tijekom vegetacije.

Vrijeme punjenja jednog horizontalnog silosa obavljeno je za 5 dana, a šesti je dan utrošen za dodatno gaženje i pokrivanje. Pri tome je bilo usko grlo planiranje, ravnanje i gaženje mase, pa je bilo neophodno puniti dva silosa radi racionalnosti u postupku spremanja hrane. Radi homogenosti masa je ravnomjerno raspoređivana iz svake prikolice po cijelom silosu. Prikolice su imale pokretno dno (samoistovarne), a silosi uzlazno-silazni otvoreni.

Koliko je važan sadržaj vlage u siliranoj masi i stupanj zbijanja u horizontalnom (trenč) silosu vidljivo je iz tablice 3.

Tablica 3. Odnos suhe tvari i zbijenost silaže

Vrsta silaže	Suha tvar (%)	Zbijenost (kg m^3)
Lucerna i djetelinsko travne smjese (DTS)	20 – 25	160
	35 - 45	230
Silažni kukuruz	<28	230
	>30	270

Linija strojeva za spremanje sjenaže od lucerne, DTS i pšenice jednaka je strojnim agregatima pri spremanju kukuruzne silaže, s tim da se pridodaju strojevi za košnju zelene krme rotacijska kosilica + gnječilica/lomilica tip SA-FC 353 RGC Kuhn zahvata 3,5 m (učinak 3,2 ha h^{-1}) i strojevi za rastresanje i sakupljanje prosušene mase grablje Kuhn tip SA-GA 7822 (zahvat 8,5 m, učinak oko 10 ha h^{-1}) i Kuhn tip SA-GF 8501 T (zahvat 7,8 m, učinak oko 8 ha h^{-1}. Kombajn John Deere 7300 s pick-up adapterom tipa 630 B podiže, sjecka i ubacuje tu masu u prikolicu. Kosilica mora ravnomjerno odsijecati usjev lucerne na visinu 5 – 7 cm (ni više, ni niže) kako bi se brzo mogli formirati novi izbojci za sljedeći otkos, što se vrlo često ne poštuje. Agregat mora raditi brzinom 10 i više km/h, pa radi toga i pravilne visine rezanja zahtjeva se maksimalno ravno lucerište za sve otkose i godine trajanja eksploatacije. Gnječilica mora lomiti i gnječiti stabljike kako bi ista ravnomjerno prosušila prije stavljanja u zboj. Grablje za rastresanje i skupljanje mase u zboj moraju biti velikog učinka i ravnomjerno podešene radi kopiranja terena. Zbojevi prosušene mase trebaju biti što veći kako bi kombajn imao što veći učinak bez praznih hodova. Sve ove agregate farma «Holstein – Orlovnjak» posjeduje jer je kod izgradnje opremana prema prijedlogu agronoma – specijalista (multidisciplinaran pristup). Nakon završenog gaženja silaže i sjenaže neophodno je dobro pokrivanje silosa koje treba osigurati anaerobne uvjete siliranja. U tu svrhu silos treba brzo pokriti posebnim folijama i pravilno zaštiti od vjetra i oborinskih voda. Folije su njemačke proizvodnje firme «Beck», debljine 150 µm i otporne na UV zračenja i razgradnju.

Linija za spremanje sijena i slame jednaka je prethodno opisanim agregatima s nadopunom preša za valjkaste i kvadar bale. Kod spremanja sijena važno je sačuvati lisnu masu i postići skladišnu vlagu na polju, kako ne bi došlo do kvarenja u sjeniku. Također je potrebno posjedovati odgovarajuća transportna sredstva za prijevoz ovih bala radi što bolje racionalnosti u transportu. Skladištenje se obavlja u sušarama ili otvorenim depoima pri čemu se složene bale moraju prekriti folijama i zaštiti od oborinskih voda.

U neposrednoj blizini objekata s životinjama locirano je 6 silosa dužine 60 m, širine 15 m i visine 3 m po svakom silosu, ukupnog kapaciteta 16. 200 m^3 što u potpunosti zadovoljava uskladištenje cjelokupne potrebe hrane za 1000 muznih krava i ostalih kategorija stoke. Dvije sušare dimenzija 60 m x 20 m x 8 m također zadovoljavaju potrebe uskladištenja sijena za cijelu godinu. Slama se slaže u kamare koje su pokrivene folijama što sprečava propadanje, a omogućava izuzimanja po svim vremenskim uvjetima.

Izuzimanje hrane iz horizontalnog silosa, priprema obroka, miješanje komponenti, transport i postavljanje na krmni stol obavlja se mikser prikolicama Pecon zapremine 13 m^3 . Prikolice posjeduju dva vertikalna mješača za sjeckanje i miješanje hrane, te uređaj za distribuciju krme.

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SELECTION MACHINERY AGREGATE AT PRODUCTION OF FOOD FOR 1000 COWS

SUMMARY

For rational implementation high effective machinery agregates it's necessary previously properly organize area for future sowing. That was done at the construction of farm „Holstein – Orlovnjak“ with multi – disciplined approach of experts from different specializations. On prudential methods was selected wide range, high-effective and multi-purpose equipment, which qualitatively and quantitatively to serve the needs of farm for 1000 head (milk cows and other categories of cattle) in all aspects. Builted and technology good equipped storages for food (silage and hay) are next to stables, therefore is storage and distribution of food significantly rationalized.

Key words: *food, milk cows, rationalization, machinery agregates*

34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Izvorni znanstveni rad
Original scientific paper

MATHEMATICAL MODELING OF TEMPERATURE REGIME OF MILKING PARLOR

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SUMMARY

Dynamic thermal processes take place in the milking parlor. During the milking time cows separate a lot of heat. Milking parlors have often installed constant or periodical operating heat sources. The optimum temperature of the air during milking time is approximately 18 ^{o}C, and during the winter period the temperature should be not less than 10 ^{o}C. When there are no people working in the milking parlor the temperature can be still less, but it should be positive for the water to stay in liquid state and for the proper operation of electronic apparatus. The fluctuations of the heat flows in the premises have been influenced by the temperature changes of the partition surfaces and the thermal energy accumulated in partitions and the one returned to the premises.

Mathematical model of the dynamic resemblance of the inside air temperature that could be solved by simple method has been made. The heat accumulation of the partitions, periodical heaters and the flow of animal heat have been estimated with the help of this model. The model parameters have been chosen after the analysis of the technological and technical data of the typical milking parlors. When the outside temperature is 20 ^{o}C below zero and the inside air temperature during milking time should be 15 ^{o}C, then the heater has to be used twice day for 3 hours and its power should be 1.5 kW/for every milking place. This has been calculated with use of this mathematical model. The inside temperature fell down to 6 ^{o}C between the milking periods.

Key words: *accumulation, ventilation, heating, animal heat, temperature, dynamics, model*

INTRODUCTION

Dynamic thermal processes take place in the milking parlor. During the milking time (most often twice a day for two-three hours) cows separate a lot of heat. Milking parlors have often installed constant or periodical operating heat sources. The optimum temperature of the air during milking time is approximately 18 ^{o}C, and during the winter period the temperature should be not less than 10 ^{o}C. When there are no people working in the milking parlor the temperature can be still less, but it should be positive for the water to stay in liquid state and for the proper operation of electronic apparatus. The fluctuations of the heat flows in the premises have been influenced by the temperature changes of the partition surfaces and the thermal energy accumulated in partitions and the one returned to the premises.

There are methods to anticipate the microclimate indices of the premises and to substantiate the factors governing these indices during the stationary exchange of heat and moisture. The methods have been also created to analyse the stationary and dynamic heat exchange in the outside partitions of the buildings (Iljinskij 1974). Recently the sound mathematical models of the balance similarity of the pigsty temperature, water vapour, dust, ammonia in unstationary situation (Zhang et al 2001), the dynamic and stationary processes of heat and water vapour in the pigsty (Daskalov 1997) have been investigated. But the methods prepared have not estimated the dynamics of the heat accumulation of the building partitions and the equipment, and the heat flows. The calculation of the heat accumulation would allow to more fully estimate the required output of the heaters and to foresee the dynamics of the air temperature of the premise. Besides the models used are differential equations that have been solved with special Simulink program (Zhang et al 2001).

The work aim is to make and solve the mathematical model of the dynamic similarity of the air temperature inside the building. This model enables to estimate the heat accumulation in partitions and equipment, and the periodical flow of the heating and animal heat.

The principles of the thermal physics of construction have been used in this model. The initial values of the model have been determined during the analysis of the peculiar technological and technical data of milking parlors, published in recommended and scientific literature.

METHODS

The thermal balance of the premise estimating the heat accumulation by the partitions and equipment and periodical heating can be expressed by the following differential equation:

$$\sum Q_{ac}\frac{dt}{d\tau} = \sum Q_a + \sum Q_w - \sum Q_d\left(t_i - t_0\right) \tag{1}$$

here:

$\sum Q_{ac}$ – is the heat amount accumulated and released by the partitions and equipment, when the surface temperature changes by one degree, kWh/K;

$\sum Q_a$ – is the sensible heat flow of the animals, kW;

$\sum Q_w$ – is the heating intensity, kW;

$\sum Q_d$ – is the flow of the heat losses via the external partitions together with the ventilation air, when the temperature difference between the inside and ambient air is one degree, kW/K;

t_i, t_0 – is the temperature of inside and ambient air, ^{o}C;

t – is the temperature of partitions and equipment surface, ^{o}C;

τ – is the time, h.

We chose the particular peculiar technical and thermal indices of the milking parlors, such as, the area of partitions, the mass of equipment, ventilation intensity, falling to one milking place, that in its turn heat one kW of the total heat flow from the cows. All the terms of equation (1) divided by the total heat flow of the animals will give:

$$Q_{ac}\frac{dt}{d\tau} = \varepsilon + Q_w - Q_d\left(t_i - t_0\right), \qquad (2)$$

where:

Q_{ac} – is the specific amount of accumulated and released heat, i.e. the heat amount accumulated and released by the partitions and equipment, falling to the unit of the total heat flow from the cows, when the surface temperature changes by one degree, kWh/(kW·K);

ε – is the ratio of the sensible heat of cows with the total heat;

Q_w – is the specific heating intensity, i.e. the heat flow of the heaters falling to the unit of the total heat flow from the cows, kW/kW;

Q_d – is the specific flow of the heat losses, i. e. the flow of the heat losses via the external partitions and that with the ventilation air falling to the unit of the total heat from the cows, when the difference between the inside and ambient air temperatures is one degree kW/(kW·K).

To solve this differential equation (2) both variables should be placed in different sides of the equation. Besides we will chose that the surface temperature of the partitions and equipment has been equal to air temperature, and when the time changes from 0 to τ, then the inside temperature will change from t_{i1} to $t_{i\tau}$. Then

$$-\int_0^{\tau}\frac{d\tau}{Q_{ac}} = \int_{t_{i1}}^{t_{i\tau}}\frac{dt}{Q_d\left(t_i - t_0\right) - \varepsilon - Q_w}. \qquad (3)$$

After the rearrangement of equation (3), we get such equation for calculation the dynamic relationship of the inside air temperature and the specific thermal and technical indices of the premises and time

$$t_{i\tau} = t_{i1}\exp\left(-\frac{Q_d}{Q_{ac}}\tau\right) + \left[1-\exp\left(-\frac{Q_d}{Q_{ac}}\tau\right)\right]\left(t_0 + \frac{\varepsilon + Q_w}{Q_d}\right). \tag{4}$$

When there are no cows and the heater has not been used then equation (4) becomes as follows:

$$t_{i\tau} = t_{i1}\exp\left(-\frac{Q_d}{Q_{ac}}\tau\right) + t_0\left[1-\exp\left(-\frac{Q_d}{Q_{ac}}\tau\right)\right]. \tag{5}$$

Equation (4) should be changed so that it would be much easier to calculate the required heating intensity.

When the difference between the inside and ambient air temperature is $t_{i1} - t_0 = \Delta t$, and the permissible fall of the inside air temperature is $t_{i\tau} - t_{i1} = \Delta t_i$, then the required specific heating intensity will be

$$Q_w = Q_d\left[\Delta t + \frac{\Delta t_i}{1-\exp\left(-\frac{Q_d}{Q_{ac}}\tau\right)}\right] - \varepsilon\,. \tag{6}$$

When there are no cows in the milking parlor $\varepsilon = 0$.

The amount of the specific accumulated and released heat of the partitions and equipment when the temperature change period has been 12 hours is

$$Q_{ac} = 10^{-3}(0{,}728A_{ac}\sqrt{c_a\lambda\rho} + 0{,}278c_mM)\,, \tag{7}$$

where:

A_{ac} – is the area of the partitions that accumulate the heat, falling to the flow unit of the total heat flow from cows, m^2/kW;

c_a – is the specific thermal capacity of the partition, kJ/(kg·K);

λ – is the coefficient of the thermal conductivity of the partition, W/(m·K);

ρ – is the density of the partition, kg/m^3;

c_m – is the specific thermal capacity of the equipment, kg/(kg·K);

M – is the mass of the equipment falling to the unit of the total heat flow of the cows, kg/kW.

The flow of the specific heat losses is

$$Q_d = gc_0 + x\,, \tag{8}$$

here:

g – is the specific ventilation intensity, i. e. the amount of air calculated for the unit of the total heat of the cows, kg/kJ;

c_0 – is the specific thermal capacity of the air, kJ/(kg·K);

x – is the module of the heat losses via the external partitions, i.e. the flow of the heat losses via the external partitions falling to the unit of the total heat flow of the cows, when the difference between the inside and ambient air is one degree, 1/K.

Module

$$x = 10^{-3}\left(\sum UA + \psi P\right) / \sum Q_0 , \tag{9}$$

where:

U – is the coefficient of the heat transmission from the partition, W/(m^2·K);

A – is the partition area, m^2;

ψ – is the specific heat losses via the floor and foundations, W/(m·K);

P – is the perimeter of the foundations, m;

$\sum Q_0$ – is the flow of the total heat of the cows, kW.

Mathematical model of the differential equation (2) of the inside air temperature that could be solved by the simple method (Equation 4) has been made. The heat accumulation of the partitions, periodically switched on heaters and the flow of the animal heat have been estimated with the help of this model. Equation (6) is used to calculate the required intensity of the heating.

RESULTS AND DISCUSSION

After the analysis of the data of technological and technical parameters of the milking parlors, and the physical data of the construction structures, the data of the model parameters has been received, that are defined as follows:

- one milking place is adequate to 1 kW of the total heat flow of the cows;
- two walls of the milking parlour are external, and two are internal. The internal layers of all partitions accumulate and release the heat. The thermal losses occur via external walls, ceilings and floors (foundations);
- the coefficient of heat transmission, W/m^2·K,: of the walls is 0.5 and the ceiling is 0.25. The specific heat losses via the floors and foundations are 0.9 W/(m·K);
- the milking of cows has been twice a day from 6 to 8 a. m. and from 6 to 8 p. m.;
- during winter or cold season the heater has been used one hour before the milking time and is switched off after the milking has been finished;
- the ambient air temperature is 20 ^{o}C below zero;

• the specific ventilation intensity is 0.034 kg/kJ during the milking and 0.017 kg/kJ between the milking.

The calculation results of the analysed model have been given in Figure 1.

The calculation results of the model show that when the ambient air temperature is 20 °C below zero, the temperature in the milking parlor at the beginning of milking should be 10 °C, thus the heater should be switched on one hour in advance (the heater output should be 1.5 kW for one milking place). Then the temperature of the milking parlor would be 15 °C at the end of the milking. After the milking has been finished and the heater switched off, the temperature will fall down to 6 °C.

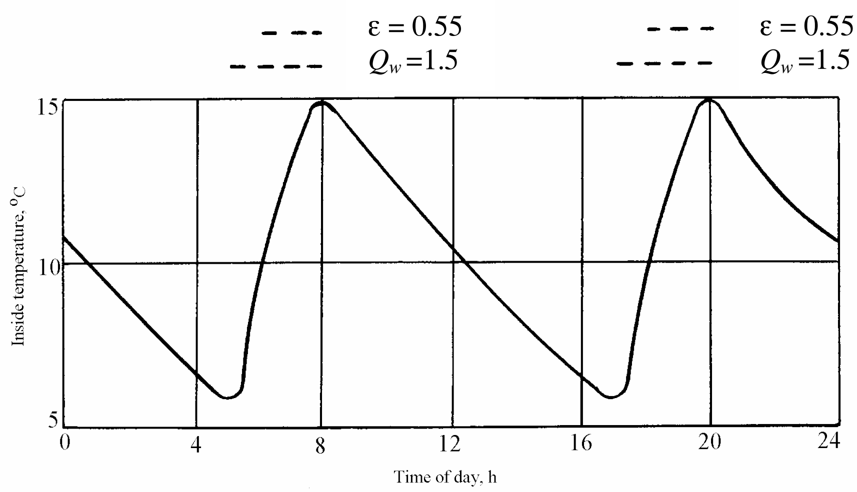

Figure 1 The dynamics of the air temperature of the milking parlor when the ambient temperature is 20 °C below zero: ε = 0.55 – during the milking; Q_w =1.5 kW/kW – from 1 hour before the milking to end of the milking

CONCLUSIONS

The model of dynamics resemblance of the air temperature has been made. This model enables to estimate the heat accumulation by the partitions and equipment, and the periodical heat flow of the heater and the cows. It has been suggested to express the model parameters via the total heat flow of the animals, when the milking place is adequate to 1 kW of the total heat flow. When the ambient air temperature is 20 °C below zero and we expect to raise the inside air temperature up to 15 °C, then the utilization of this model has enabled to define that: the heater should be switched on twice a day for the period of 3 hours. The heater output should be 1.5 kW for one place. The inside air temperature decreases to 6 °C between the milking periods.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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MILKING WORK ENVIRONMENT IN FARM WITH UNINSULATED COWSHED

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SUMMARY

The inside climate of an uninsulated shed's waiting area and milking parlour is greatly influenced by outside climate (especially during wintertime) and by different work operations performed in the rooms. Higher air relative moisture content and noxious noisome gases are caused by milking, cleaning jobs and manure disposal and by a great number of cows crowding small waiting area. The cows spend relatively short time on waiting area and milking parlour, compared to herdsman and, especially, milker, who's period of duty is much longer, in big farms even 6…7 hours per day.

The aim of the paper was to study the influence of work operations, carried out on waiting area and milking parlour of uninsulated cowsheds (352 and 730 cows, respectively) and the influence of outdoor climate on the inner climate of rooms during wintertime. Indoor temperature, relative humidity, air velocity, oxygen, carbon dioxide and ammonia content were measured for twenty four hours in succession, at the height of 1.5 m. At the same time outdoor air temperature and relative moisture were observed. In addition, all work operations performed were observed in chronological order and the workers' pulse rates were measured and taken as a basis to calculate the work load rate.

Key words*: waiting area, milking parlour, milking, air temperature, ammonia, carbon dioxide, oxygen, relative humidity, ventilation, cubicles, pulse rate, work load rate*

INTRODUCTION

In recent years increasingly more attention is paid to human work environment and the environment for keeping of animals. It is essential to study the indoor climate of premises and energetic work load rate imposed by working environment.

The indoor climate of waiting area and milking parlour of a farm with uninsulated cowshed is to great extent affected by outdoor climate, especially in winter, and works performed in these premises. Milking and cleaning works performed in these areas and high concentration of animals cause increase of relative humidity and deterioration of gas composition in these premises. Whereas a cow stays in waiting area and at milking parlour for a short time, the duration of working hours of herdsman/cattle-tender and especially milker is much longer, reaching to 6…7 hours a day in large farms.

The objective of this research was to study the impact of outdoor climate and works performed in waiting areas and at milking parlours in milking stations of uninsulated cattle-sheds with resting stalls on indoor climate of these premises in winter. For that purpose indoor air temperature, relative moisture, indoor air velocity and contents of oxygen, carbon dioxide and ammonia were measured in milking stations during 24 hours. Simultaneously outdoor air temperature and relative moisture were measured.

Works performed in the premises were monitored and chronometrically measured, and also workers' heart rate was measured, which was used as a basis for determining the level of physical effort for work.

METHODICS

The impact of outdoor climate and works related to milking cows on indoor climate of the waiting area and milking parlour was studied in milking stations of two farms with 352 and 730 milking cows respectively, hereinafter referred to as Farm 1 and Farm 2 and milking stations 1 and 2. Both farms have uninsulated cowsheds, waiting areas and milking parlours and natural ventilation (Mikson *et al.,* 2003).

The area of waiting area in the milking station of Farm 1 is 233.5 m^2 (for 155 cows) and sloped ascending towards the milking parlour. The ceiling and side walls of the waiting area were covered with plastic in order to keep the premises warm. Milking parlour has open pit at one end. Cows are milked three times a day, milking duration in the morning, in the afternoon and in the evening is 4.5, 3.5 and 4.5 hours respectively. Cows are milked at the parallel milking parlour with the milking device Strangko 2x20, two milkers work at the parlour simultaneously. Animals are driven to and released from the parlour one side at a time. Both the milking parlour and waiting area are cleaned at the end of the shift.

In Farm 2 the waiting area floor is also sloped ascending towards the milking parlour. Milking parlour has open hollow and natural ventilation, but in 300 m^2 waiting area (for 200 cows) forced ventilation can also be used. During the study of indoor climate the roller blinds on side walls were partially opened. In this farm cows are also milked three times a day, each milking period being 5.5 hours. Cows are milked with the milking device DeLaval at the milking parlour with 2x20 lots. Two milkers work at the milking parlour simultaneously. Here also the animals from one side of the parlour are released simultaneously after being milked. At the end of shift the milkers clean the milking parlour with water jet, whereas herdsman removes manure from the waiting area with small tractor.

Indoor air velocity, temperature, relative moisture, and contents of oxygen, carbon dioxide and ammonia in waiting area and at milking parlour were measured at the height of 1.5 m (http..., Karhunen, 1992) during twenty-four hours. Simultaneously outdoor air temperature and relative moisture were measured and the work of herdsmen and milkers was monitored and measured chronometrically. The study was performed in February 2004.

ALMEMO Data Logger 8990-8 equipment with computer programme AMR WinControl was used for studying the parameters of indoor climate. Indoor air temperature and relative humidity were measured with AMR company sensor FH646-1 with measurement area –20…+80 °C (measuring accuracy 0.01 °C) and 5…98% (measuring accuracy 0.1%). Oxygen and carbon dioxide content were measured with sensor ZA 9000-AK2K (measurement area 0…100%, measuring accuracy 0.01%) and FY A600 (measurement area 0…2.5%, measuring accuracy 0.01%) respectively. Sensor ZA 3601-FS2 was used for measuring ammonia content (Bacarach EIT Co), measurement area 0…100 ppm and measuring accuracy 0.01 ppm. Air velocity was measured by using thermo-anemometer FHA645TH2 with measurement area 0…2 m/s and resolution 0.001 m/s. HygroLog device with HygroClip S sensor were used for measuring the temperature and relative humidity of outdoor air (measurement area -40…+85 °C and 0…100%, measurement accuracy ±0.3 °C and ±1.5% respectively). Measurement results were analysed by using computer programmes AMR WinControl, HW3 and MS Excel (Kiviste, 1999).

The level of physical effort for work was determined according to the average and the highest heart rate of milkers, based on the Classification of Workload approved by World Health Organization (WHO) (Tuure, 1991) and according to authors (Andersen *et al.*, 1978). Hence the following workload classification was used for determining the level of physical work: heart rate less than 100 beats per minute - light (L); heart rates 100…124, 124…150 and heart rate over 150 represent moderate (M), heavy (H) and very heavy (VH) level of physical effort for work respectively.

Workers' heart rate was measure with „Polar Sport Tester" equipment consisting of sender (sensor) and receiver (tester). Sender was attached to the heart area and the receiver on the hand. Receiver recorded the information concerning heart rate every 5th second. After processing the data computer programme Polaris produced statistical series and diagrams of workers according to chronologically identified heart rate, as well as minimum, maximum and average values of heart rates. Diagram print-outs were supplemented with additional scales facilitating the observance of changes in the level of physical effort for work during the work operations performed (Figure 3).

RESULTS

Study results reveal that both outdoor climate and works performed in these premises have significant effect on the numerical values of indoor climate parameters of waiting area and milking parlour of uninsulated cowshed.

Air temperature of waiting areas 1 and 2 was between -3.86...15.45 °C, which constituted average of 5.21 °C. At the same time outdoor temperature was -8.0...0 °C (Table 1).

In case of waiting area of Farm 1 daily relative humidity was very high, 99.89% on average, which significantly exceeded allowed limits (Maatalouden…, 1990; Praks, 2001; Liiske, 1992). That was caused by the plastic applied to the ceiling and sides of waiting area, intended for insulation of the waiting area. Outdoor relative humidity was also high, 87.43% on average.

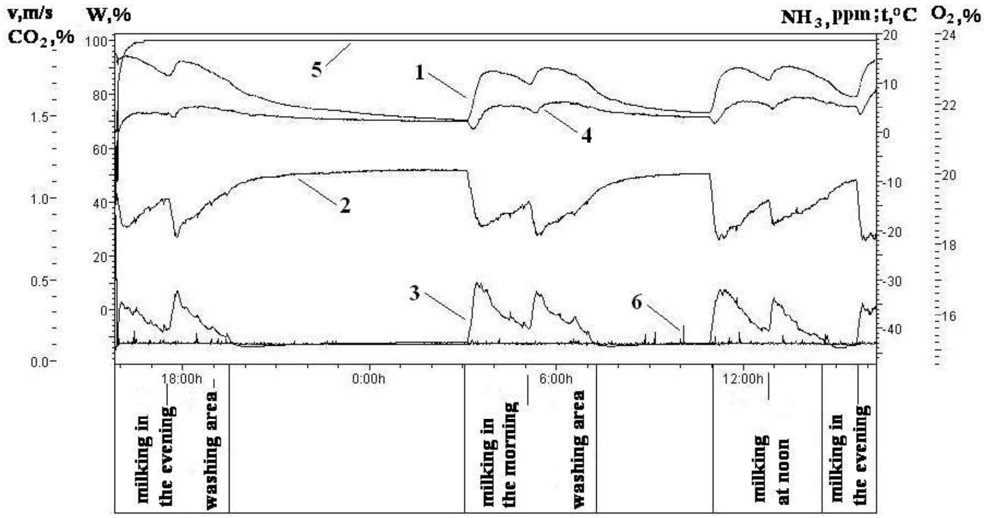
Table 1 Indoor and outdoor parameter values of the waiting area and milking parlour in the Farms 1 and 2 ($\bar{x}$ – mean value)

Measured parameters	Min	Max	$\bar{x}$	Min	Max	$\bar{x}$
1	2	3	4	5	6	7
	24 hours values					
	Waiting area			Milking parlour		
Farm 1						
Temperature,°C	2.34	15.45	8.53	2.27	10.97	8.53
Relative humidity, %	85.8	100.0	99.89	63.2	91.9	77.18
Oxygen O_2, %	18.10	20.13	19.41	18.02	19.71	19.00
Carbon dioxide CO_2, %	0.08	0.48	0.19	0.33	0.54	0.41
Ammonia NH_3, ppm	0.21	8.75	4.08	2.67	3.94	3.71
Air speed, m/s	0.10	0.22	0.11	0.09	0.38	0.12
Outdoor temperature, °C	-3.6	0	-2.21	-15.2	-0.5	-12.79
Outdoor relative humidity, %	72.5	92.9	87.43	70.7	84.7	77.94
Farm 2						
Temperature,°C	-3.86	8.50	1.89	6.78	14.57	12.97
Relative humidity, %	66.9	100.0	92.11	56.8	82.2	66.47
Oxygen O_2, %	19.45	20.85	20.19	18.73	19.63	19.24
Carbon dioxide CO_2, %	0.12	0.25	0.17	0.193	0.35	0.26
Ammonia NH_3, ppm	0.17	3.80	1.62	1.96	5.32	4.95
Air speed, m/s	0.07	1.60	0.23	0.09	0.25	0.12
Outdoor temperature, °C	-8.0	-0.6	-3.60	-1.4	0.2	-0.40
Outdoor relative humidity, %	78.0	96.0	90.37	78.9	87.5	84.17

Relative humidity of waiting area in Farm 2 increased after the milking started and cows stayed in waiting area (Figure 1). Humidity was rather high, 92.11% on average, but also the value of 100% has been measured. At the same time, outdoor relative humidity changed within the range of 78.0...96.0%, average value being 90.37% (Table 1).

Maximum values of carbon dioxide and ammonia content in waiting areas were measured when cattle stayed in waiting area, average values were up to 0.19% and 4.08 ppm respectively (Figure 1). Maximum values of carbon dioxide and ammonia content yielded to 0.48% and 8.75 ppm respectively, thus exceeding the allowed limits (Table 1).

a)



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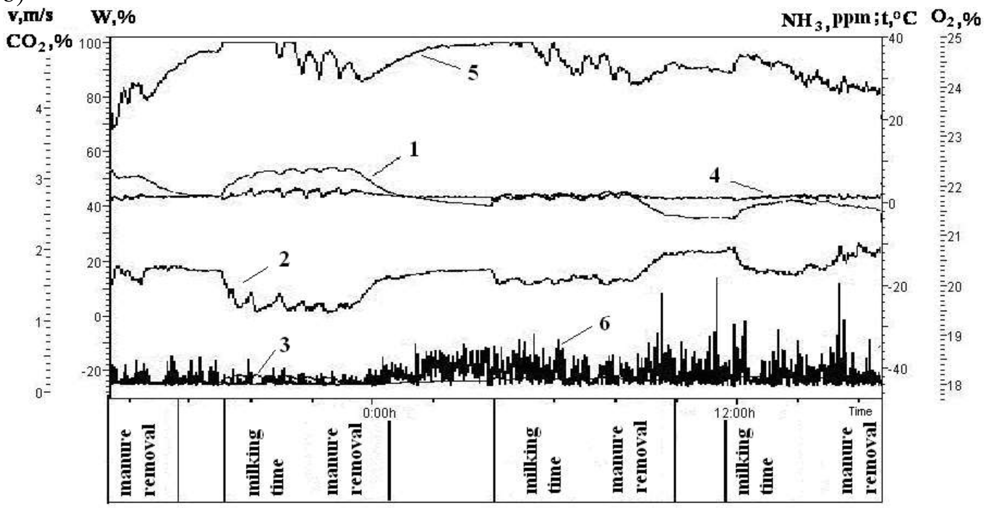
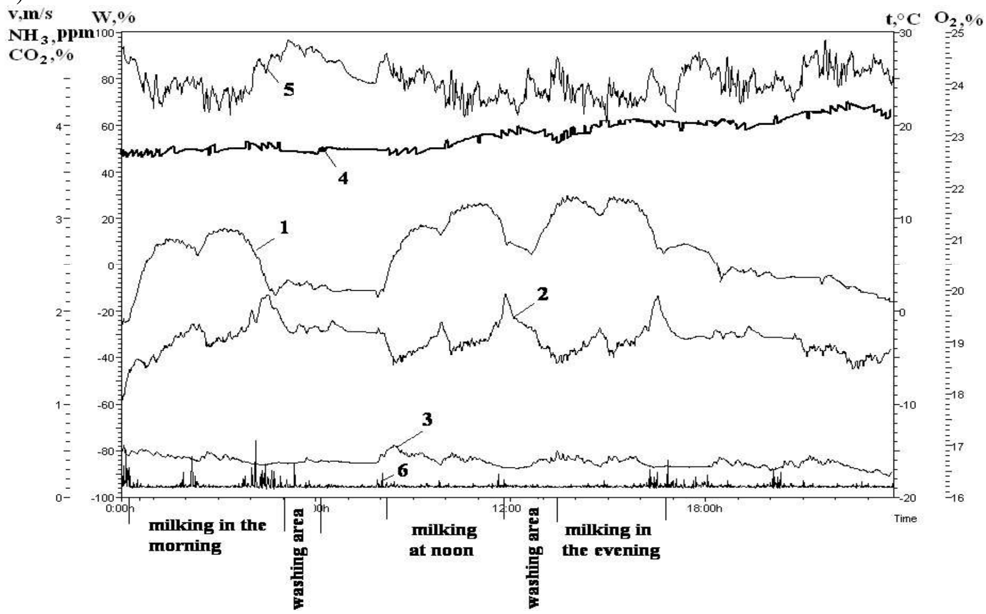


Figure 1 Diurnal change of measured air parameters values of waiting area in Farms 1 (a) and 2 (b): 1 - temperature; 2 - oxygen; 3 - carbon dioxide; 4 - ammonia; 5 - relative humidity; 6 - air speed.

a)



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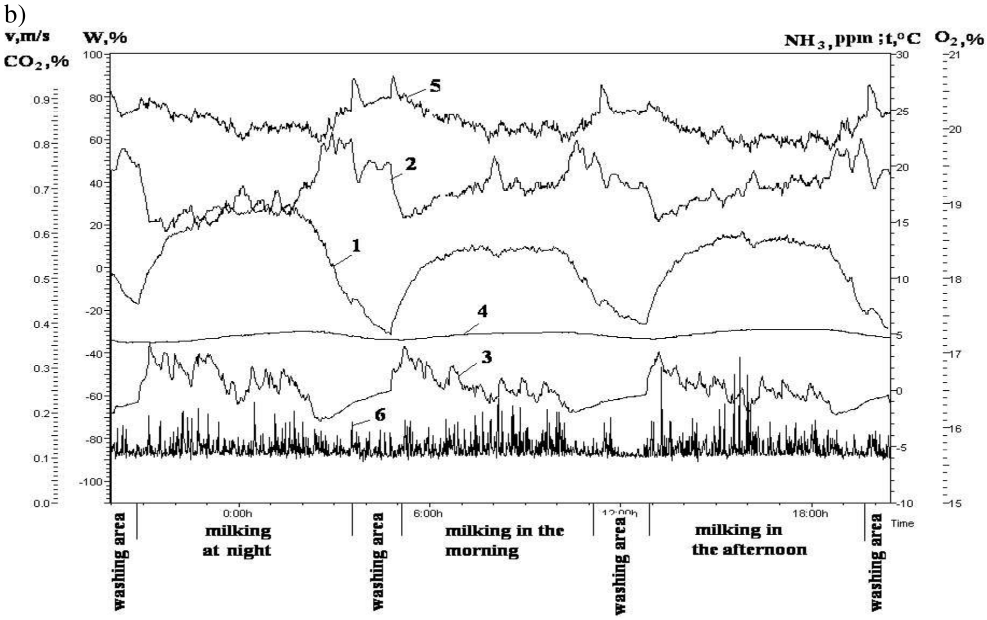

Figure 2 Diurnal change of measured air parameters values of milking parlour in Farms 1 (a) and 2 (b): 1 - temperature; 2 - oxygen; 3 - carbon dioxide; 4 - ammonia; 5 - relative humidity; 6 - air speed.

Table 2 Milker's pulse rate, physiological data and level of physical effort for work in Farms 1 and 2: L – light, M – moderate, H – heavy, VH – very heavy

Parameters	Farm 1 Morning	Farm 1 Noon	Farm 1 Evening	Farm 2 Morning	Farm 2 Noon	Farm 2 Evening
Pulse rate, Beats/minute						
- min	68	60	65	62	68	67
-average	100	100	105	100	120	105
- max	133	140	145	138	170	143
Milker						
- sex	female	female	female	female	female	female
- mass, kg	70	70	76	95	87	54
- height, cm	162	162	172	162	176	160
- age, a	36	36	51	35	24	44
Work load rate						
- average	M	M	M	M	M	M
- max	H	H	H	H	VH	H

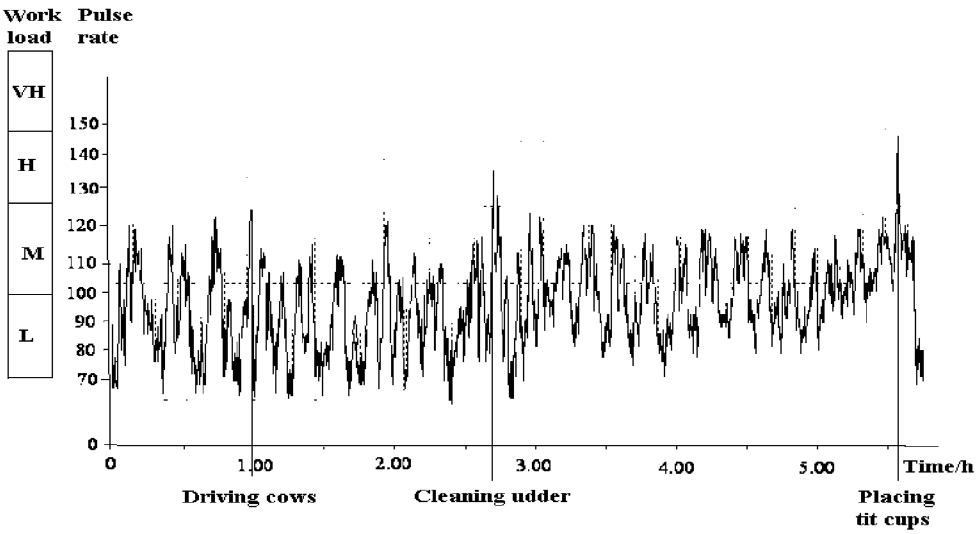

Figure 3 Milker's pulse rate and work load rate in Farm 2, in the evening

Oxygen content and air velocity in waiting areas remained within the limits of 18.10…20.85% and 0.07...1.60 m/s respectively, average values being 19.41…20.19% and 0.11…0.23 m/s. Oxygen content approached the level (17%) that has shown increase in human heart rate and breathing frequency (Maatalouden…, 1990).

In case of average outdoor temperature -12.79…-0.40 °C and relative humidity 77.94…84.17 average air temperature of milking parlours in Farm 1 and Farm 2 is 8.53…12.97 °C and relative humidity 66.47…77.18% (Table 1).

During taking measurements average oxygen and carbon dioxide contents were in range of 19.00…19.24% and 0.26…0.41% respectively, maximum carbon dioxide value reached 0.54% during milking at parlour 1 due to high concentration of cattle and insufficient ventilation (Figure 2).

Ammonia content ranged from 1.96 ppm to 5.32 ppm, average content being 4.33 ppm. Ammonia content was higher with animals staying at the milking parlour, reaching up to 5.32 (Figure 2). Air velocity was relatively low, average 0.12 m/s (Table 1).

The heart rate values of milkers were 60...176 beats per minute and average values remained within the range of 100...120 beats per minute (Table 2, Figure 3). Maximum values were recorded at the milking parlour, where the work load of milkers was higher due to greater number of cattle. Based on the level of physical effort for work it appears that work load of milkers was moderate in Farm 1 and 2, in case of one milker (Farm 2) the effort reached maximum level (very heavy) when driving cows to the parlour (Table 2).

CONCLUSIONS

The research measured indoor temperature, relative humidity, air velocity and oxygen, carbon dioxide and ammonia content in waiting area and at milking parlour of milking station in two uninsulated cowsheds of different size in winter. Simultaneously outdoor air temperature and relative moisture were measured. Works performed in the premises were monitored and chronometrically measured. Also workers' level of physical effort for work was determined.

Daily study results revealed that the daily change in numerical values of indoor climate parameters was directly dependent on the works performed in milking stations (driving cows to waiting area, milking, cleaning of waiting areas and milking parlours and removal of manure) and outdoor climate.

It was discovered that in case of outdoor temperature between -2.21...-3.60 °C in winter average daily temperature in waiting areas was 1.89...8.53 °C, which is lower than allowed for a herdsman (17…21 °C).

In case of outdoor relative humidity 87.43...90.37% average indoor relative humidity in waiting areas was 92.11...99.89%.

Average daily values of oxygen and carbon dioxide content in the air in waiting areas were 19.41...20.19% and 0.17...0.19% respectively. But in some cases the oxygen content dropped to 18.10%, which is close to the value (17%) that has shown increase in human heart rate and breathing frequency. Furthermore, maximum carbon dioxide content was 0.48% (whereas recommended limit is less than 0.25%). Excessive concentration of carbon dioxide is caused by closely packed animals in the waiting area, which indicates to the need of ventilating the waiting area.

Average air velocity at milking parlours was 0.11...0.23 m/s. If the doors were open during feeding of animals, the maximum air velocity in waiting area of milking station 2 was 1.60 m/s, which exceeded the nominal rate (0.3…0.7 m/s).

Average daily air temperature at milking parlours was 8.53…12.97 °C. Average relative humidity at milking parlours remained within 66.47…77.18%, and was increased to 100% during cleaning the parlour.

Average oxygen and carbon dioxide contents was 19.00…19.24% and 0.26…0.41% respectively.

Ammonia content did not exceed allowed limits. Air velocity measured at milking parlours was 0.09...0.38 m/s, average velocity being 0.12 m/s.

When compared to time between milking periods, air temperature, and particularly relative humidity increased at all milking parlours and waiting areas during milking process. At the same time increase in air velocity was detected in these premises.

Plastic used for insulation of waiting area deteriorates indoor climate of the premises. Additional heating should be used for elevating the air temperature and ventilation for reducing humidity in waiting areas and at milking parlours of milking stations.

The highest energetic work load was imposed on milkers, who worked during longer milking periods. In case of some milkers the heart rate increased to 176 beats per minute, which refers to very heavy level of physical effort for work, but on average the level of physical effort for work was considered heavy (H).

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

OPTIMALAN OMJER PILEĆEG GNOJA I PŠENIČNE SLAME ZA PROCES AEROBNOG KOMPOSTIRANJA

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SAŽETAK

Za razliku od pilećeg gnoja (koji je vrlo bogat izvor dušika), pšenična slama ima vrlo visok sadržaj ugljika. Aerobno kompostiranje pilećeg gnoja i slame je istraženo upotrebom četiri mala laboratorijska reaktora (volumena 1 litre) i jednog većeg laboratorijskog reaktora (volumena 32 litre) u kontroliranim laboratorijskim uvjetima. Niz eksperimenata (u trajanju od 14 dana) je izveden s ciljem određivanja optimalnog omjera pilećeg gnoja i pšenične slame. Utjecaj različitih početnih omjera na proces kompostiranja je određen praćenjem promjena temperature supstrata/komposta, ugljik dioksida, amonijaka i organske tvari.

***Ključne riječi**: aerobno kompostiranje, organski otpad, pileći gnoj, prisilna aeracija.*

UVOD

Na području Tuzlanske županije (Bosna i Hercegovina) postoji veliki broj peradarskih farmi; samo na području Gračanice oko 60; koje svakodnevno proizvode ogromne količine gnoja. Nažalost, ovaj se gnoj bez ikakvog prethodnog tretmana koristi kao gnojivo i odlaže na tlo. Na ovaj način se u atmosferu emitira znatna količina štetnih plinova (ugljik dioksid, amonijak), gubitak dušika iz gnoja i kontaminacija tla patogenim mikroorganizmima. Aerobno kompostiranje je efikasan i siguran način za tretiranje organskog otpada, koji istovremeno smanjuje negativan utjecaj na okoliš i osigurava ekonomski vrijedan konačan proizvod (kompost).

Pileći gnoj predstavlja značajan izvor dušika, ali mu je potrebno dodati izvor ugljika ukoliko se želi postići veća razgradnja organske tvari u procesu aerobnog kompostiranja. U ovom istraživanju je kao izvor ugljika korištena pšenična slama.

Ciljevi ovog rada su: 1) odrediti optimalan omjer pilećeg gnoja i slame pri kojem će se postići maksimalna razgradnja organske tvari u procesu kompostiranja s prisilnom aeracijom, 2) pokazati efikasnost reaktorskog sustava u smanjenju emisije ugljik dioksida i amonijaka u atmosferu.

MATERIJALI I METODE

Kao eksperimentalni materijal, korišteni su pileći gnoj i pšenična slama pri čemu su miješani u različitim omjerima (Tablica 1). Prije miješanja, slama je prethodno isječena na dužinu cca 2.5 cm. Gnoj i slama su izmiješani rukama u plastičnim kadama u trajanju od oko 30 minuta, kako bi se postiglo homogeniziranje smjese supstrata. Početni udio vlage u smjesama iznosio je oko 65%.

Tablica 1 Smjese pilećeg gnoja i slame sa omjerima (suha tvar)

	Pileći gnoj (%)	Pšenična slama (%)
Reaktor 1 (R1)	89	11
Reaktor 2 (R2)	84	16
Reaktor 3 (R3)	57	43
Reaktor 4 (R4)	67	33
Reaktor 5 (R5)	84	16

Slika 1 Eksperimentalni reaktorski sustav za kompostiranje

Kao laboratorijski reaktori, korištene su četiri termos boce volumena 1 L, zatvorene gumenim čepom s otvorima za dovod zraka, temperaturne senzore i odvod smjese plinova (Slika 1). Reaktori su dodatno izolirani stiroporom. Također je korišten i jedan veći posebno dizajniran laboratorijski reaktor od polietilena volumena 32 L (Slika 1), koji je izoliran slojem poliuretana.

Konstatntni protok zraka u male reaktore ostvaren je pumpom za akvarij, dok je za aeraciju velikog reaktora korišten kompresor. Mjerenje protoka zraka je vršeno preko rotametara (0.4-5 LPM, 1-10 LPM, Cole-Parmer, USA).

Prije ulaza u reaktore, zrak je uveden u otopinu natrij-hidroksida kako bi se odstranili tragovi ugljik dioksida. Nakon toga, zrak prolazi kroz ispiralicu s vodom kako bi se postigla stalna vlažnost zraka na ulazu.

Temperatura je bila najvažniji čimbenik praćenje procesa u ovom istraživanju. U svim reaktorima, temperatura je mjerena u intervalima od 15 minuta u masi supstrata preko termoparova (tip T i K, Digi-Sense, Cole-Parmer, USA) priključenih preko akvizicijskog modula (Temperature Data Acquisition Card / Thermocouple CardAcq, Nomadics, USA) na prijenosno računalo. Na ovaj način, postignuta je automatska registracija podataka tijekom cijelog eksperimenta. Osim temperatura smjesa u reaktorima, mjerena je temperatura zraka u laboratoriju.

Plinska smjesa nakon izlaza iz reaktora prolazi kroz hladilo, bocu ispiralicu sa 1 M otopinom natrij-hidroksida i bocu ispiralicu sa 0.65 M otopinom borne kiseline, s ciljem eliminiranja kondenzata, ugljik dioksida i amonijaka. Tikvice su mijenjane svakodnevno.

Za određivanje sadržaja ugljik dioksida, alikvotni volumen otopine natrij-hidroksida (u kojoj je «zarobljen» ugljik dioksid) je titriran sa standardnom otopinom 1 M kloridne kiseline i indikatorom fenolftaleinom. Razlika između slijepe probe i uzorkovane probe je korištena za izračunavanje mase «zarobljenog» ugljik dioksida.

Za određivanje sadržaja amonijaka, alikvotni volumen otopine borne kiseline (u kojoj je «zarobljen» amonijak) je titriran sa standardnom otopinom 1 M kloridne kiseline i indikatorom bromkrezol zeleno-metil crveno. Razlika između uzorkovane probe i slijepe probe je korištena za izračunavanje mase «zarobljenog» amonijaka.

Materijal je miješan svakodnevno samo u velikom reaktoru, neposredno prije uzimanja uzorka (oko 50 g). Tijekom procesa, voda nije dodavana u materijal za kompostiranje. Proces je trajao neprekidno 14 dana.

Maseni udio vlage u smjesi supstrata i kompostu izračunat je iz razlike mase prije i nakon sušenja uzoraka u sušnici pri 105°C u trajanju od 24 sata, do konstantne mase (APHA 1995). Nakon hlađenja u eksikatoru (30 minuta) uzorci su žareni u peći pri 550°C u trajanju od 6 sati do konstantne mase, a zatim ponovno slijedi hlađenje u eksikatoru. Razlika u masama između sušenog i žarenog predstavlja masu isparljivih organskih tvari (APHA 1995). To je upravo ona masa tvari koja se može biološki razgraditi.

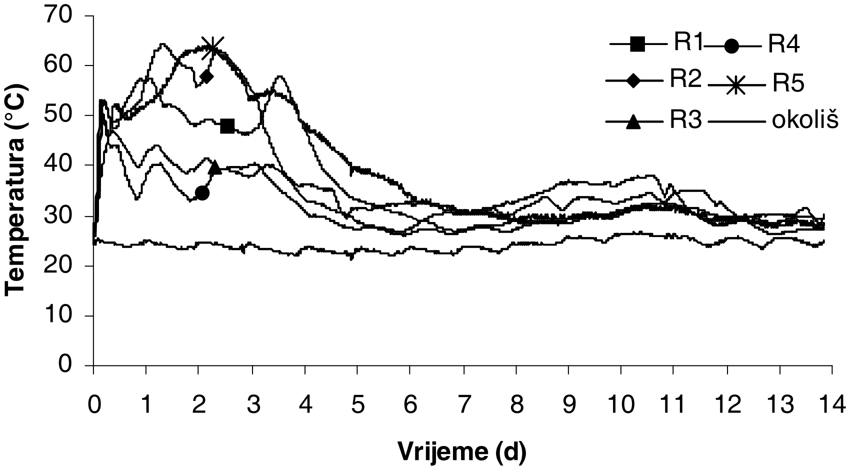
Gubitak organske tvari (OM) je izračunat iz početnog i konačnog sadržaja organske tvari, prema sljedećoj jednadžbi (Haug 1993, Diaz i sur. 2002):

$$k = \frac{\left[OM_m(\%) - OM_p(\%)\right] \cdot 100}{OM_m(\%) \cdot \left[100 - OM_p(\%)\right]}$$

gdje su OMm – sadržaj organske tvari na početku procesa (mas. %), OMp – sadržaj organske tvari na kraju procesa (mas. %).

REZULTATI I RASPRAVA

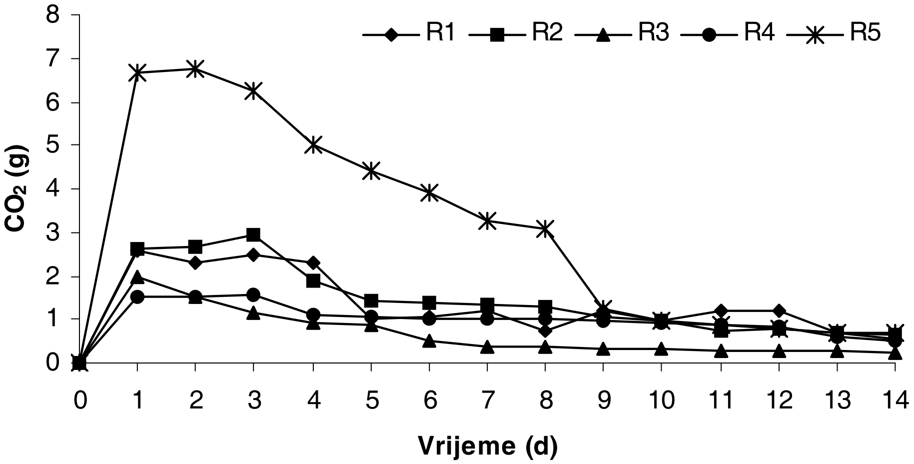
Oslobođena toplina u procesu je bila rezultat mikrobiološkog metabolizma, a akumulirana toplinska energija se zadržala u masi supstrata (Aydin i Kocasoy 2002). Temperaturni režim reaktora za kompostiranje sa različitim smjesama prikazani je na grafu 1. Proces kompostiranja dostiže temperaturu 64.6°C nakon 2.1 dana dana u reaktoru 5, 64.5°C nakon 1.3 dana u reaktoru 2, dok reaktori 1, 3 i 4 dostižu niže maksimalne temperature. Sa malim odstupanjima (reaktori 2 i 4), nakon 8 dana ne postoji značajnija razlika u temperaturnim režimima među 5 reaktora. Kroz cijelo vrijeme kompostiranja, temperature su bile najviše u reaktorima 2 i 5.



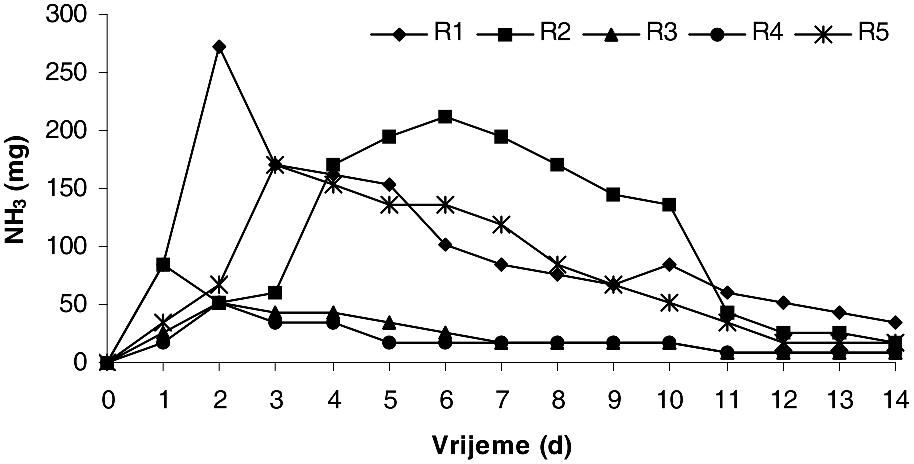
Graf 1 Promjene temperature u supstratu u svim reaktorima tijekom procesa aerobnog kompostiranja

Nastanak ugljik dioksida je uzrokovan mineralizacijom organske tvari u supstratu (Bernal *i sur.* 1998). Graf 2 prikazuje rezultate promjena ugljik dioksida unutar svih reaktora. Brzina nastajanja ugljikovog dioksida je rasla u svim reaktorima proporcionalno aktivnosti mikroorganizama tijekom procesa i bila je veća u reaktorima 2 i 5 nego u ostalim reaktorima. Brzina nastajanja ugljik dioksida je rasla nakon prvog dana, a smanjivala se nakon 3 dana u svim reaktorima.

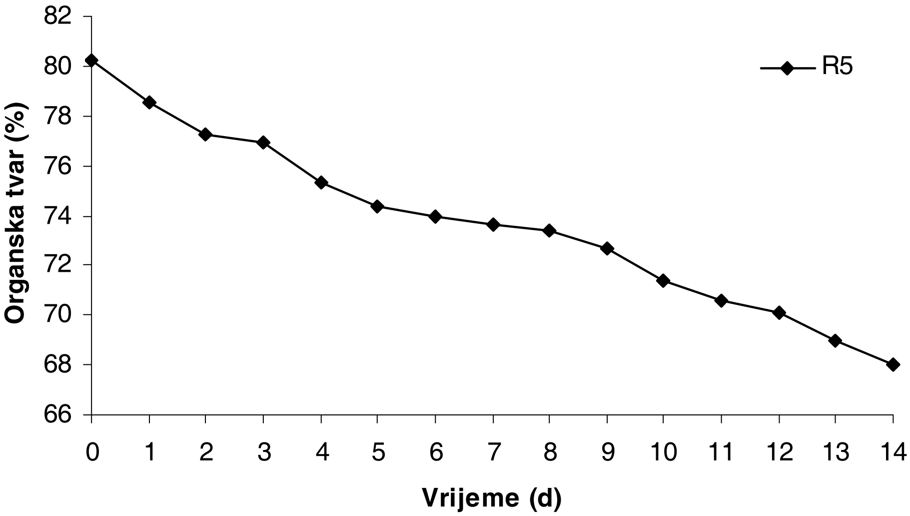
Povećana emisija amonijaka je primjećena u reaktorima 2 i 5 (Graf 3), što se može objasniti većim sadržajem dušika u početnoj smjesi nego u ostalim reaktorima. Amonijak čini čak 98% emisije dušika iz materijala za kompostiranje (Beck-Friis *i sur.* 2001). Tijekom kompostiranja peradarskog gnoja, gubici dušika često dosežu do 33% (Hansen *i sur.* 1989a). Ostali bitni čimbenici za gubitak dušika u obliku amonijaka su: temperatura i pH vrijednost materijala za kompostiranje (Martins i Dewes 1992), kao i veličina čestica (Hansen *i sur.* 1989b). Kao što je izvedeno u ovom istraživanju, u praksi bi trebalo planirati zatvoreni reaktorski sustav sa hlađenjem plinske smjese i «zarobljavanjem» amonijaka u pogodnoj otopini. Na ovaj način se postiže znatno smanjenje emisije amonijaka u atmosferu. Isto vrijedi i za ugljik dioksid.



Graf 2 Promjene sadržaja ugljik dioksida u reaktorima tijekom procesa aerobnog kompostiranja



Graf 3. Promjene sadržaja amonijaka u reaktorima tijekom procesa aerobnog kompostiranja



Graf 4 Promjena sadržaja organske tvari u smjesi u velikom reaktoru tijekom procesa aerobnog kompostiranja

Razgradnja organske tvari je bila povezana s gubitkom organske tvari, koji je direktno povezan s mikrobiološkom respiracijom (Paredes *i sur.* 2002). Sadržaj organske tvari u materijalima se smanjivao u svim reaktorima tijekom procesa, ali je smanjenje bilo najbrže u reaktorima 2 i 5 (Tablica 2). Na grafu 4 prikazan je postotak organske tvari u reaktoru 5. U odnosu na reaktor 2, u reaktoru 5 je postignut nešto veći gubitak organske tvari, što se može objasniti svakodnevnim miješanjem materijala. Do sličnih rezultata u svezi razgradnje pilećeg gnoja došli su Kulcu i Yaldiz (2005), koji su umjesto slame koristili vinogradarski otpad. U njihovom istraživanju proces je trajao 21 dan (u reaktoru volumena 64 L s aeracijom od 15 minuta u jednom satu), pri čemu je postignut gubitak organske tvari od 57.2%.

Tablica 2 Gubitak organske tvari (*k*) na kraju procesa kompostiranja

	R1	R2	R3	R4	R5
k (%)	41.4	44.5	26.6	35.7	47.6

ZAKLJUČCI

Prema eksperimentalnim rezultatima, najveće vrijednosti gubitka organske tvari, temperature, nastalog ugljik dioksida i amonijaka su dobijene u reaktorima 2 i 5, pa je omjer pilećeg gnoja i pšenične slame u ovim reaktorima pogodniji za kompostiranje nego ostali omjeri. Prema tome, smjesa sastavljena od 84% pilećeg gnoja i 16% pšenične slame trebala bi se koristiti za proces aerobnog kompostiranja uz uvjet da se kontrolom bitnih parametara procesa (početni sadržaj dušika u smjesi, miješanje, temperatura, pH, veličina čestice) smanji gubitak dušika u obliku amonijaka u atmosferu. Primjena reaktorskog sustava za aerobno kompostiranje pilećeg gnoja i slame značajno utječe na okoliš, što se prije svega odnosi na emisiju amonijaka i ugljik dioksida u atmosferu.

ZAHVALA

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OPTIMUM RATIO OF CHICKEN MANURE AND WHEAT STRAW FOR COMPOSTING PROCESS WITH FORCED AERATION

SUMMARY

Whereas chicken manure is a very rich source of nitrogen, wheat straw has a very high carbon content. The aerobic composting of chicken manure and straw was investigated using four small reactors (each with volume of 1liter) and one large reactor (with a volume of 32 litres) under controlled laboratory conditions. The series of experiments (with 14 days duration) were performed with the aim to determine an optimum mixture ratio of chicken manure and wheat straw. The effect of the different initial ratios on the composting process was evaluated by monitoring the changes of: temperature of substrate/compost, carbon dioxide, ammonia and organic matter.

Key words: *aerobic composting, organic waste, chicken manure, forced aeration.*

34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 614.31:665
Izvorni znanstveni rad
Original scientific paper

DETERMINATION OF HEAVY METALS IN EDIBLE OIL BY ELECTROCHEMICAL METHOD, DPASV

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SUMMARY

Determination of heavy metals in food has been a problem for a long time. For that reason sophisticated methods, such as differential pulse anodic stripping voltametry, can be applied in monitoring of heavy metals.

In this work DPASV method has been used in order to determine the content of heavy metals in edible oil. Samples of oil were taken from the commercial market and the content of Cu, Pb, Cd and Zn was determined.

The purpose of this work was to find the optimal conditions for application of DPASV method in the control of commercialy available oil samples. Based on the results obtained in this work, the overwiev of an average content of heavy metals in oil samples is presented.

***Key words**: heavy metals, oil, DPASV*

INTRODUCTION

The presence of heavy metals in food is not entirely unknown phenomenon and many dates in history of several nations were signed by mass tragic poisoning by these elements. Their concentration in foodstuff is at trace level, but some of them can be very dangerous for consumers health in very short period, particularly when food is contaminated with higher content(1).

The presence of heavy metals in oils is due to both endogenous factors, connected with plant metabolism, and hexogenous factors due to contamination arising from the agronomic techniques of production and harvesting of plants, from oil extraction and processing, as well as to packaging systems and materials and storage(5).

As oil is a widely consumed product, and due to the well known toxicity of lead, cadmium, and other metals, even trace levels of these metals may be significant to be harmful for consumers[13].

There are numerous sophisticated instrumental methods used in analyses of food products for determination of concentrations of heavy metals such as zinc, copper, lead, cadmium, mercury, etc. In literature several methods have been described for heavy metals determination at low concentration, although spectroscopic and electrochemical techniques have been the most frequently employed. The advantages of voltammetric methods are firstly, economic efficiency, secondly, simplicity, and thirdly that the sample is not destroyed, as it is in atomic spectroscopy[4].

The choice of the most suitable electroanalytical technique for the determination of metals at ultratrace levels must consider several parameters, such as sensitivity, selectivity, detection limit, sample preparation, analysis time and instrumental cost. Differential pulse anodic stripping voltammetry (DPASV) is one of the best, owing to its ability to simultaneously determine several elements at ultratrace level and its low cost [9]. The main limitation of the anodic stripping voltammetry, in comparison with the spectroscopic techniques, is the limited number of the elements that can be determined because they must form an amalgam [5].

Any electrochemical analysis can be divided into three sequential steps: 1) collection of the samples; 2) chemical and/or physical preparation of the sample(s) for analysis: and 3) measurement of the concentrations of the target constituents in the sample(s) [7].

Determination of trace elements in biological samples is usually difficult because of long and tedious digestion procedures and risks of interference problems. The interfering ions have to be separated by pre-concentration techniques such as solvent extraction, ion exchange procedures or hydride generation. These are all time consuming procedures, and losses of elements are also possible. It is very important to accomplish the determination with minimum interference problems (1).

With electrochemical methods, the interference problems can be solved. These methods require relatively expensive instrumentation, and are capable of determining elements accurately at trace and ultra-trace levels, and they demonstrate the ability for multi-element determination (7).

Considering the above mentioned, the aim of this work was to apply the electrochemical method; DPASV, for determination of lead, cadmium, zinc, and copper in oil.

METHODS

Oil samples were taken from commercial market and, divided into four groups and then prepared for the analysis. Preparation of oil samples was performed by conventional methods of digestion; dry burning and wet mineralization.

Cadmium, copper and lead were determined by simultaneous and individual analyses, but zinc was only determined by individual analyses, because it demands analytical media with specific pH value.

Standard solutions for heavy metals determinations used in investigations were suprapure chemicals produced by Merck. Analyses of cadmium, copper and lead were performed in nitrate supporting electrolytes, KNO_3, and zinc was determined at pH value 5 to 6, with the following instrumental parameters:

- Working Electrode (WRK): HMDE
- Referent Electrode (REF): Ag/AgCl (1 M KCl), E = 0.22 V
- Potentials:

Metal	Initial	Final
Lead	-0.7 V	0.1 V
Copper	-0.4 V	0.1 V
Zinc	-1.3 V	-0.9 V
Cadmium	-0.9 V	-0.6 V

- Deposition Time 300 s and 600 s for cadmium and zinc in some samples
- Speed of Scanning 2 mV/s
- Deareration Time 120 s
- Amplitude 0.05 V

Equipment:

- Electrochemical Cell, Princeton Applied Research (EG & G) model 303A with Working (HMDE), Referent (Ag/AgCl) and Supporting (Pt-wire) Electrode.
- Potenciostat/Galvanostat, PAR, model 263 A.
- Computer P II with software Model 270/250 Research Electrochemistry Software, version

RESULTS AND DISCUSSION

Table 1 An average content of Cd, Pb, Cu and Zn in oil samples

Metal	I	II	III	IV
mg/kg Zn	0,37	0,163	0,1	0,24
mg/kg Cu	0,15	0,035	0,06	0,04
μg/kg Pb	6,03	2,51	4,3	5,49
μg/kg Cd	5,07	3,80	8,3	3,76

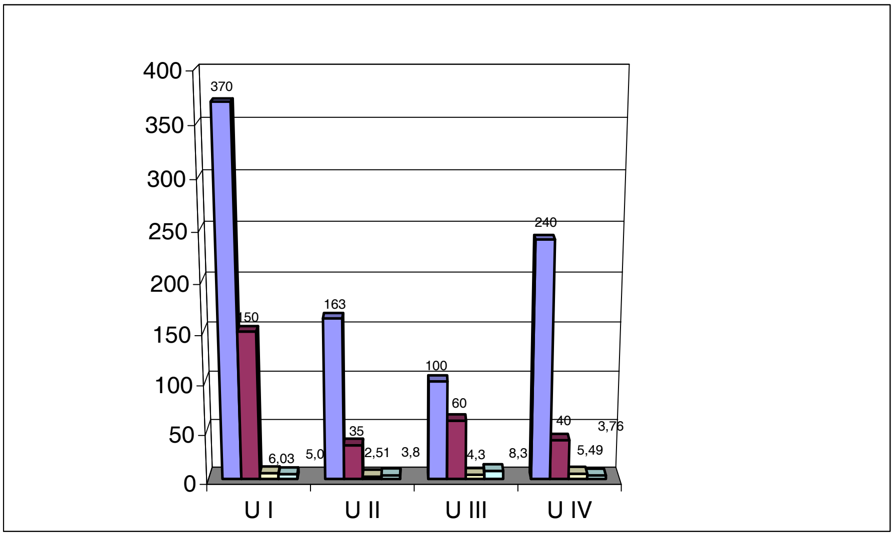

Figure 1 Relationship between an average concentrations (µg/kg) of Zn, Cu, Pb and Cd in oil I, II, III and IV.

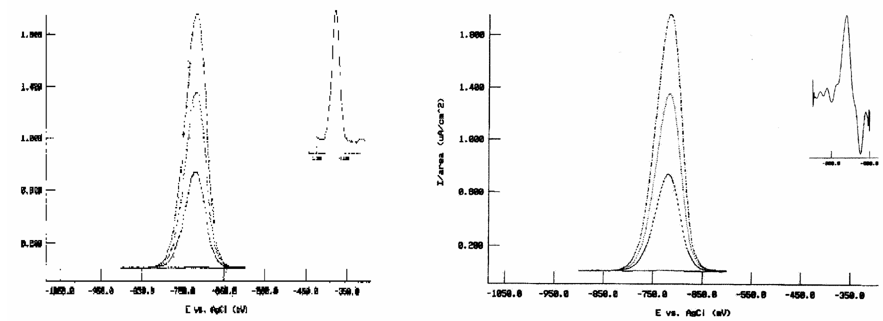

Figure 2 Voltammograms for Zn and Cd in oil

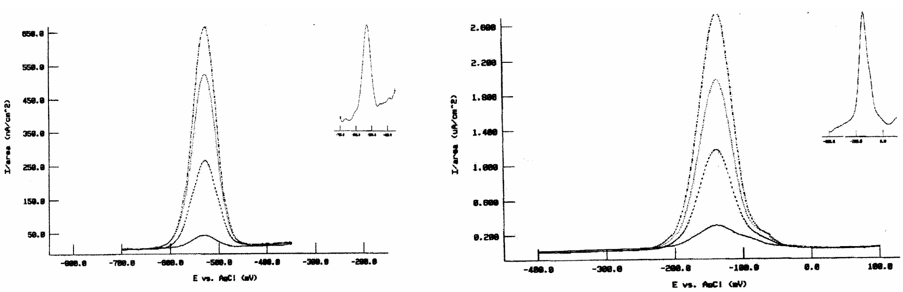

Figure 3 Voltamograms for Pb and Cu in oil

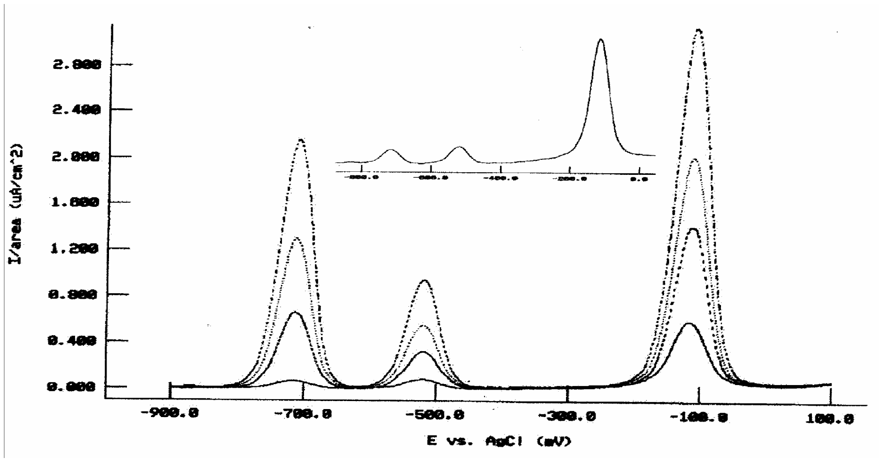

Figure 4 Example of simultaneous analysis for Cd, Pb and Cu in oil

In oil sample marked as I, an average concentration of zinc was 0,22 mg/kg, but in oil sample II, 0,163 mg/kg which is about five times higher than the first one and presents the maximum concentration of zinc in oil samples. Minimum value of zinc content is obtained in oil sample, marked as oil III, 0,1 mg/kg.

With simultaneous analyses for Cd with other two metals, Pb and Cu, a lower value of concentrations was detected. However, individual analysis of cadmium in oil samples showed concentrations ranging from 0,00376 mg/kg, in oil IV, to 0,0083 mg/kg, in oil III with an average value 0,0053 mg/kg.

The content of lead determined in oil was 0,0025 mg/kg for oil sample I what presents minimum, and 0,0063 mg/kg for oil sample II, which is maximal value for lead. An average concentration of lead in oil samples was 0,00458 mg/kg, and copper 0,071 mg/kg.

Minimum copper content in oil was 0,04 mg/kg for sample IV, and maximum value obtained in sample marked as oil sample I, was 0,15 mg/kg. Ratio in copper content shows that its concentration is about five times higher then average value.

The risk index is estimated as the ratio of weekly metal intake by food product and provisional tolerable weekly intake for metals (PTWI) as follows:

$$\text{Risk index} = \frac{\textit{Weekly metal intake by food product per body weight } (\mu g/kg \textit{ b.w./week})}{\textit{Provisional tolerable weekly intake } (\mu g/kg \textit{ b.w./week})} \cdot 100$$

International organisations (FAO/IAEA/WHO, JECFA, US EPA) defined maximum allowed concentrations of heavy metals:

lead 25 $\mu g / kg$ *b.w./week*,

cadmium 7 $\mu g / kg$ *b.w./week*,

copper 1400 $\mu g / kg$ *b.w./week*, and

zinc 7000 $\mu g / kg$ *b.w./week.*

The values of risk indexes computed by above relation and PTWIs for lead, copper, cadmium and zinc are given in Table 2. Risk indexes are calculated on the basis of an average weekly consumption of the mentioned food products and an average body weight of 70 kg. An average weekly consumption of oil is estimated to be about 0,35 kg (50 g per day) (14) .

Table 2 An average risk indexes for Cd, Pb, Cu and Zn in oil

Number of sample	Risk index (%)			
	Cd	Pb	Cu	Zn
I	0,37	0,12	0,05	0,03
II	0,27	0,05	0,001	0,01
III	0,60	0,09	0,004	0,007
IV	0,27	0,10	0,001	0,017

As results presented in Table 2. , show, there is no high risk to the consumers if they consume about 50 g oil per a day. The highest risk index was calculated for cadmium in all samples, particularly in oil sample III, 0,60 % which presents the maximal value but its' minimum value was determined for copper in samples II and both I and VI, 0,001 %.

The long-term consumption of oil, with risk indexes for cadmium and lead, obtained in this investigation can not present great danger for the consumer’s health, even if more amounts of oil would be consumed more then 50 g/day.

CONCLUSIONS

- The level of heavy metals and their risk indexes, presented in this work, show that there is no great risks to the health of consumers;
- The importance of regular monitoring of heavy metals content in food have led to application of electrochemical methods in food analyses such as DPASV, which has its own advantages compared to other methods used in trace metals determinations;
- Considering the reproducibility of the results, method DPASV has been shown to be effective for Cd, Pb, Zn i Cu analysis in nitric medium.
- As presented, the application of electrochemical methods, DPASV in determination of heavy metals in oil samples can be very good tool for the quality control of food raw materials, as well as final products, even if the traces of heavy metals are present in very low concentrations (less than 1 ppm);

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 614.31:664.8
Stručni rad
Expert paper

INSURING THE FOOD SAFETY FOR FRUITS AND VEGETABLES IN PROCESSING PURSUANT TO INTERNATIONAL STANDARDS

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SUMMARY

International and national standards tendencies are directed to the safe-for-health food production and processing. Insuring the food safety is achieved with preventive measures and control qualities activities that are determined by GAP, GMP, GHP, GLP.

In fruit and vegetables processing there are two most important demands: technological quality and food safety of raw material that are both defined by a comprehensive legislations and international standards.

This work presents compressive method of quality system integration in accordance with contemporary standards of ISO (22000), Codex Alimentarus and other legislation for production of safe fruits and vegetables for processing in food industry.

***Key words**: GAP, compressive method of quality system, fruit and vegetable processing*

INTRODUCTION

Food safety is defined as the assurance that the food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use [(1)]. Quality is defined by the International Organization for Standardization (ISO) as “the totality of features and characteristics of a product that bear on its ability to satisfy stated or implied needs.”

In other words, good quality exists when the product complies with the requirements specified by the client[(3)]. Safety and quality assurance should be ongoing processes incorporating activities beginning with selecting and preparing the soil and proceeding through to consumption of the product.

Both safety and quality assurance should focus on the prevention of problems, not simply curing them since, once safety or quality is reduced, it is virtually impossible to go back and improve it for that item. It is possible however, to assure that the same problem does not affect future products. In order to assure adequate quality control of the product from seed to harvest to the consumer, a strong, semi-independent quality assurance (QA) program or department is needed. This program needs to be independent of production management.

For companies large enough to have a separate QA department, it should report directly to the corporate president[(6)]. QA requires many diverse technical and analytical skills[(5)]. The production of safe food products requires that the safety assurance system be built upon a solid foundation. Good Agricultural Practices (GAPs) and Good Manufacturing Practices (GMPs) are key to providing a sound safety assurance program [(2)]. GAPs and GMPs are guidelines established to ensure a clean and safe working environment for all employees while eliminating the potential for contamination of the food products.

When applied to fresh produce production, GAPs and GMPs address the issues of production site selection, adjacent land use, fertilizer usage, water quality and usage, pest control and pesticide monitoring (insecticide, fungicide, herbicide, rodenticide), harvesting practices (including worker hygiene), packaging, storage, field sanitation and product transportation. A food safety assurance program often used by the food processing industry is the Hazard Analysis Critical Control Point (HACCP) system.

HACCP is a systematic approach to the identification, evaluation, and control of food safety hazards. Preventing problems from occurring is the paramount goal underlying any HACCP-like system. Programs such as GAPs, GMPs, and HACCP-like approaches provide the basic environmental and operating conditions that are necessary for the production of safe, wholesome fruits and vegetables.

Many of the conditions and practices are specified in federal, state and local regulations and guidelines. The Codex Alimentarius Food Hygiene Basic Texts [(1)] describe the basic conditions for HACCP approach. There are various bodies that set food standards. For products sold internationally, these include the Codex Alimentarius Commission (CAC), the International Standards Organization, ISO (ASQ, 2000), and various markets, such as the European Union. Many individual countries like Australia and the U.S. have been leaders in setting product standards.

For Latin American and Caribbean markets, standards have been established by organizations such as Mercosur, Caricom, and the Andean Pact[(7)]. Many of these standards can be accessed via the Internet [(4)].

The aim of this work is to present the part of quality assurance related to the residue of heavy metals as hazards in food chain. This work also presents the method of laboratory control and monitoring procedure emphasizing the importance of determination of heavy metals content. This approach can be applied on all hazards, including biological, physical and other chemical, with the importance of limits which are determined by international and national legislation.

METHODS

In order to apply the model of GAP, GLP and HACCP concept, or ISO 22000, which includes prerequisite program (PRP) program and HACCP principles on heavy metals as hazards, the cucumbers were sown in laboratory conditions with the previous determination of the content of heavy metals in soil.

After growing, the concentration of heavy metals, lead, zinc, copper and cadmium in cucumbers was also determined by the application of electrochemical method, DPASV.

Samples of cucumbers were washed by distillated water and then dried at 105 °C about one hour. The gram of each sample was burned at 550 °C, lasting one hour. After burning, samples were solved in supra-pure HNO_3 and taken into vessel of 25 ml by filling with redestilated water to the top.

Soil analyses were performed by standard methods, and determination of lead, zinc, cadmium and copper was performed by differential pulse anodic stripping voltammetry, DPASV. Analyses of lead, copper and cadmium were performed in 0,1 M KNO_3, and zinc in acetate buffer, pH = 4,7, with the following instrumental parameters:

- Working Electrode (WRK): HMDE
- Referent Electrode (REF): Ag/AgCl (1 M KCl), E = 0.22 V
- Potentials:

Metal	Initial	Final
Copper	-0,3 V; -0,2 V	0,1 V
Lead	-0.65 V; -0,6 V	-0.4 V; 0,3 V
Cadmium	-0,9 V	-0,6
Zinc	- 1.3 V; - 1.2 V	-0.9 V ; -1 V

- Deposition Time 300 s
- Speed of Scanning 2 mV/s
- Deaereration Time 120 s
- Amplitude 0.05 V

Equipment:

- Electrochemical Cell, Princeton Applied Research (EG & G) model 303A with Working (HMDE), Referent (Ag/AgCl) and Supporting (Pt-wire) Electrode.
- Potenciostat/Galvanostat, PAR, model 263 A.
- Computer P II with software Model 270/250 Research Electrochemistry Software, version 4.3.

RESULTS AND DISCUSSION

Table 1 The content of heavy metals in soil used for laboratory conditions

Metal	mg/kg DM
Copper	23,561
Lead	7,764
Zinc	125,429
Cadmium	0,347

In Table 1., the content of heavy metals in soil is presented, where zinc had the highest value, 125, 429 mg/kg dry matter and the lowest, cadmium, 0,347 mg/kg dry matter.

Table 2 The content of heavy metals in nutrients, mg/kg dry matter

Metal	Humus	NPK	KAN	Coal dust
Copper	10,0136	13,6775	19,5772	26,3472
Lead	3,1304	9,8562	11,8906	18,8327
Zinc	16,8389	30,5152	24,8147	43,8152
Cadmium	0,7861	1,4827	0,5346	2,0316

In nutrients, the copper had the maximal value in coal dust, 26,3472 mg/kg dry matter and minimal in humus, 10,0136 mg/kg dry matter. The content of lead in nutrients was also the highest in coal dust with value 18,8327 mg/kg dry matter and the lowest in humus, 3,1304 mg/kg dry matter. Zinc concentration was also the highest in coal dust, 43, 8152 mg/kg dry matter, but minimal value it had in humus, 0,7861 mg/kg dry matter.

In all nutrients used for cucumbers in laboratory, cadmium had the lowest value in KAN, 0,5346 mg/kg dry matter, but maximal concentration of cadmium was in coal dust, 2,0316 mg/kg dry matter.

Table 3 The content of heavy metals in cucumbers, mg/kg dry matter

Metal (mg/kg DM)	Humus addition	Mineral fertilizer, NPK	Mineral fertilizer, KAN	Coal dust
Copper	1,5816	4,1399	3,1500	0,9671
Lead	1,9041	0,4567	5,9078	1,0349
Zinc	12,0973	17,24	12,34	5,461
Cadmium	0,0872	0,0387	0,0024	0,051

Results in Table 3., show that the content of copper was the highest in cucumbers grown with NPK fertilizer, 4,1399 mg/kg dry matter, and the lowest in sample grown with coal dust, 0,9671 mg/kg dry matter. Lead determination in cucumbers shows that its' maximal value was in sample grown with KAN fertilizer, 5,9078 mg/kg dry matter, and minimal in sample grown with NPK fertilizer, 0,4567 mg/kg dry matter.

In all samples of cucumbers grown with fertilizer, zinc had the maximal value with NPK addition, 17,24 mg/kg dry matter, and lowest in sample grown with coal dust addition, 5,461 mg/kg dry matter. The concentration of cadmium in cucumbers is several times less than the content of other metals, and its maximal value was determined in sample grown with humus, 0,0872 mg/kg dry matter and the lowest in sample grown in KAN fertilizer, 0,0024 mg/kg dry matter.

In Table 4., the application of GAP, good agricultural practices, was applied on heavy metals as hazards with sources from where they could enter into cucumbers. This was only way how to apply the GAP as the part of preventive measures for safe and healthy food products.

Table 4 Heavy metals as hazards with the application of GAP

Source of hazard	Way to prevent hazard
Soil	Analysis of heavy metals as hazards in soil
Water resources and irrigation practices	The application of distillated water
Organic and inorganic fertilizer	Analysis of heavy metals as hazards in fertilizers
Pests	No were pests because it was laboratory
Pesticide	No use of pesticides
Worker health and safety	Only one person was allowed to enter the laboratory
Harvesting	Cucumbers for analysis were taken with palstic
Packaging	Cucumbers were not packed

Table 5. presents the HACCP plan applied for heavy metals as hazards, and preventive and corrective measures which could be applied for raw materials. In concrete example, HACCP plan is created for cucumbers.

In this sample, the GMP is not presented as prerequisite program for successful HACCP application. The newest version of ISO standard, ISO 22000 aimed for food industry, which is based on processing, integrates GMP, GLP as prerequisites program for the application of HACCP concept, which is also integrated in ISO standard, 22000 series.

Table 5. HACCP plan for the technological conserving of cucumbers

Control point (raw material or step in process)	Risk	Control measure	CCP parametar	Critical limit	Target value	Monitoring	Corective measure	Responsible person
Cucumbers – raw material	Copper, lead, zinc and cadmium	Chemical analysis by the application of DPASV method	The content of heavy metals less for 20 % then maximal allowed value	Valid regulation about the content of metals in vegetables	CCP parameter	The determiantion of heacvy metal content in CCPs	To discard	Technologists in proccesing
Water addition (mixture of additives)							To prepare new additive mixture with determination of heavy metal content	
Cucumbers after inspecting							To discard	
Final product								

CONCLUSIONS

Based on the above mentioned, the following can be concluded:

- ensuring of the food safety for fruits and vegetables processing can be achieved by establishing the control measures based on the lab analyses by electroanalytical method and HACCP monitoring procedure
- the GAP, good agricultural practice can be separately applied for vegetables and fruits, but when HACCP system or ISO 22000 is applied in food industry, then it should not be avoided;
- laboratory model which is applied in this work for cucumbers and heavy metals can be a good tool and presents advantage for the production of healthy and safe for consumption both vegetables and fruits, no matter what kind of hazard appears;
- DPASV method used for heavy metal determination as part of GLP showed to be successful tool for identification and determination of hazards such heavy metals;
- the model of GAP which is applied on heavy metals in this work with analytical methods for determination of any kind of hazards can be very good preventive measure for the providing of safe raw materials used for the processing in food industry.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Izvorni znanstveni rad
Original scientific paper

INFLUENCE OF ADDITIVES ON RHEOLOGICAL PROPERTIES OF MAIZE AND TAPIOCA STARCH PASTES

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SUMMARY

The knowledge of rheological properties of food products is important for characterisation of process and quality parameters, as well as for new products development. Starch and hydrocolloids are often added during processing of different food products to achieve specific properties such as thickening or gelling, adhesion of different food components, film forming, inhibition of crystallisation, etc. One of essential criteria for the choice of hydrocolloids in achieving certain food properties is the compatibility with other food constituents and/or other hydrocolloids.

The objective of this work was to investigate the influence of hydrocolloids, carrageenan and locust bean gum (0.5% w/w) on rheological properties of maize and tapioca starch pastes, and their mixtures. The rheological measurements were carried out with rotational viscometer. Rheological parameters (flow behaviour index and consistency index) were calculated from rheological data.

Results showed that hydrocolloids have an important influence on rheological properties of maize and tapioca starch pastes, as well as their mixtures. The greatest influence on viscosity of pastes had addition of locust bean gum to tapioca starch paste.

Key words*: maize starch, tapioca starch, hydrocolloids, gelatinisation, rheological properties.*

INTRODUCTION

Viscosity of starch dispersions is strongly influenced by swelling properties of starch granules, and primarily depends on the variety and source of starch. In food production a combination of starch and hydrocolloids have a special importance and wide variety of applications. In general, they are used to provide control moisture and water mobility, improve overall product quality and/or stability, reduce cost, and/or facilitate processing [1]. From a rheological point of view, it is well known that addition of a hydrocolloid (e.g., guar gum, locust bean gum, carageenans…) strongly influences the gelatinisation and retrogradation of starch. Earlier studies on starch-hydrocolloid systems have indicated a synergistic effect resulting in a much higher viscosity of the mixtures compared with the starch or hydrocolloid alone [2,3,4]. To Christianson (1982), such effects is result of interactions between the solubilized starch, amylose, and the other polysaccharide, and secondly, the addition of the thickening agent increases the forces exerted on the granules, thus affecting granule breakdown and the amount of solubilized starch [2].

In many applications the properties of native starch are not optimal, and therefore starch is often chemically modified in order to improve its performance [5]. Native starches can be modified in different ways to change and improve their functions. It is therefore of interest to find new ways to improve the properties of native starches without chemical modification. Different additives and ingredients have been used to modify pasting properties of starch. Some authors [6] investigated addition of sugars to starch mixtures in order to increase the gelatinisation temperature by decreasing the availability of water. Ferrero and co-workers (1996) studied the effect of hydrocolloids on starch thermal transitions [7]. The results showed that addition of hydrocolloids changed gelatinisation temperature, especially endset temperature. Also, gelatinisation temperature ranges increased with increasing gum:starch ratio.

Many studies showed that starch gelatinisation is temperature and time dependent and can be explain by pseudo-first-order Arrhenius kinetics [8]. Härröd (1989) studied the thixotropic and antitixotropic behaviors in 3-10% modified potato starch pastes and concluded that the behavior was strictly related to the magnitude of shear stress [9]. Dintzis and co-workers (1996) pointed out that shear-thickening properties were also sensitive to the solvent system, sample treatment and starch composition [10].

The objective of the study was to investigate the influence of addition of hydrocolloids, carrageenan and locust bean gum (0.5%), on the rheological properties of maize and tapioca starch pastes. The rheological measurements were carried out with rotational viscometer. From the obtained results, rheological parameters, flow behavior index and consistency index, were calculated.

MATERIALS AND METHODS

Native tapioca starch (TS) was product of International Starch Trading, Aarhus, Denmark. Native maize starch (MS) was product of Collamyl, Agrana, Austria. Carrageenan Aquagel GU (CAR) 805 was obtained from Herbstreith & Fox KG Neunburg, Austria, and locust bean gum from (LBG) Giulini Chemie, Ludvigshafen, Germany.

Rheological measurements of the starch pastes were done on a computer controlled rotational viscometer (Brookfield Engineering Laboratories, Model DV-III + Digital Rheometer), using spindle SC4-27 and SC4-29.

Maize, tapioca or maize:tapioca starch mixtures were suspended in distilled water or 0.5% gum solution to prepare suspensions of 3% starch solid. Starch mixtures were prepared in ratio of 1:1, 0.25:0.75 and 0.75:0.25 maize: tapioca starch. Suspensions were heated in boiling water bath under continuous stirring for 20 min, and than on cooker to boil for 10 min to assure complete gelatinization. Obtained pastes were cooled at room temperature and stored for 24 h previous to analysis to avoid the presence of bubbles formed during heating and mixing. Samples were loaded into the sample cup and allowed to equilibrate for 20 min at 25 °C and were subjected to a programmed shear rate linearly increasing from 0-185 rpm and a linearly decreasing from 185-0 rpm. All samples were performed in triplicate.

Flow curves were evaluated by the instrument operating software (Rheocalc version 3.2) using the power law model:

$$\tau = k \cdot D^{n} \tag{1}$$

where, τ is shear stress (Pa), k is consistency coefficient (Pa s ^{n}), D is shear rate (s^{-1}), and n the flow behavior index.

Logarithmic plots of shear stress versus shear rate were used to calculate the consistency coefficient and flow behavior index.

Apparent viscosity, μ (mPas) at 50 s^{-1} was evaluated using equation (2):

$$\mu = k \cdot D^{n-1} \tag{2}$$

RESULTS AND DISCUSSION

The parameters obtained for the power-law model for starch pastes with and without addition of hidrocolloids (Eq. 1) and apparent viscosity at 50 s^{-1} (Eq. 2) are summarized in table 1. The low shear rate of 50 s^{-1} was selected because it has been reported as an effective oral shear rate [11]. Tapioca starch (TS) paste had the highest value of apparent viscosity among all investigated starch pastes without addition of hidrocolloids at 50 s^{-1}, while maize starch (MS) paste had the lowest value. Mixture TS:MS=0.5:0.5 paste had a greatest coefficient of consistency among mentioned starch pastes.

Addition of hidrocolloids had a significant influence on rheological properties of all starch pastes. Carrageenan (CAR) and locust bean gum (LBG) increased consistency coefficient and apparent viscosity of all starch pastes. Upon that, LBG considerably more increased mentioned parameters. Comparatively, the flow behavior index was the lowest for MS paste with addition of carrageenan and the highest for TS:MS=0.75:0.25 paste with addition of LBG. Tapioca starch paste with addition of 0.5% locust bean gum had the highest consistency coefficient (10052.9 mPs^{n}) and apparent viscosity (1688.1 mPas), among all samples.

Addition of carrageenan had a lower impact on viscosity of starch pastes than expected. In the present study starch pastes were prepared at high temperature (around 110 ˚C) for relative long time, what probably caused slightly depolymerisation of hydrocolloid.

Table 1 Power low parameters for waxy maize and maize starch pastes, with and without addition of hydrocolloids at 25°C.

Samples	n	k [mPs^n]	μ (at 50 s^{-1}) [mPas]	R^2
TS	0.5163	2929.27	441.54	0.9982
TS + CAR	0.3719	6533.61	559.79	0.9991
TS + LBG	0.5439	10052.95	1688.08	0.9992
MS	0.4311	2409.81	260.28	0.9877
MS + CAR	0.3421	6489.04	494.79	0.9994
MS + LBG	0.5324	6797.08	1091.15	0.9992
TS:MS=0.5:0.5	0.4625	3258.86	397.99	0.9982
+ CAR	0.3574	6398.36	517.97	0.9995
+ LBG	0.5265	9063.28	1421.75	0.9993
TS:MS=0.25:0.75	0.4807	2105.86	276.16	0.9964
+ CAR	0.4939	3479.67	480.49	0.9687
+ LBG	0.5045	8263.75	1189.43	0.9985
TS:MS=0.75:0.25	0.6044	1337.49	284.56	0.9976
+ CAR	0.3871	6342.590	576.72	0.9909
+ LBG	0.5495	7728.466	1326.50	0.9997

Power low parameters: n, flow behavior index, k, consistency coefficient; μ, apparent viscosity.

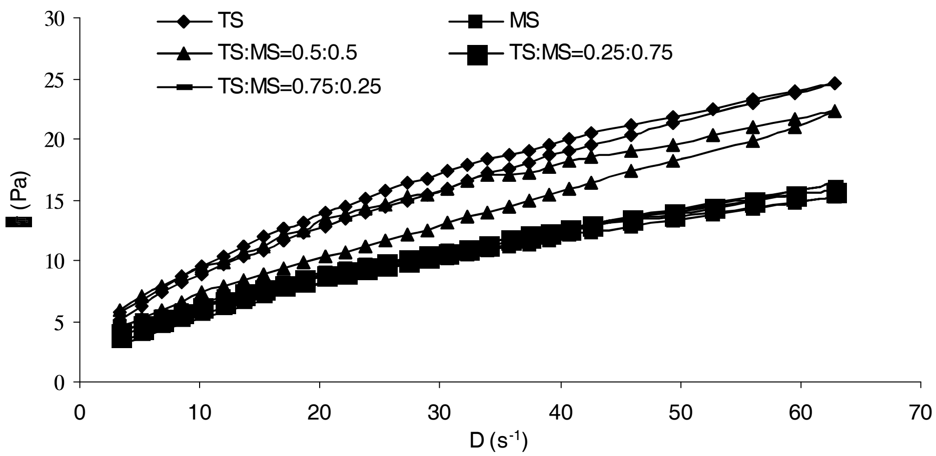

Fig. 1 Shear stress versus shear rate curves of maize and tapioca starch pastes and their mixtures measured at 25°C.

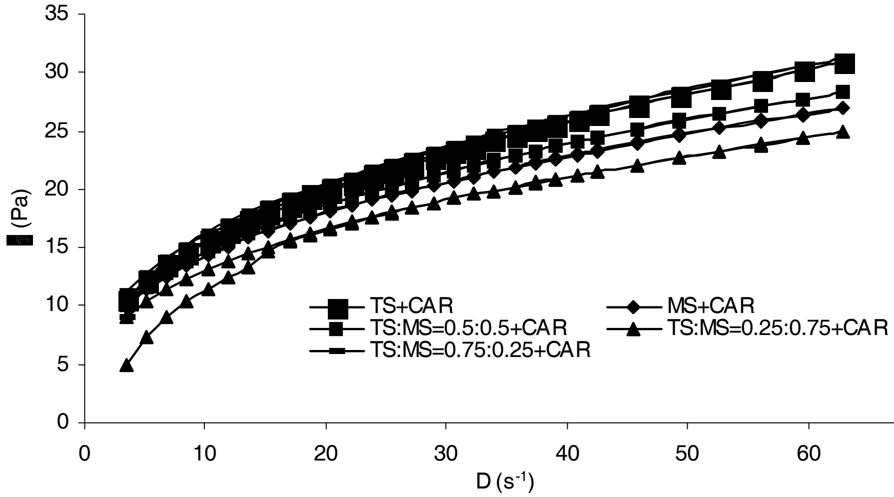

Fig. 2 Shear stress versus shear rate curves of maize and tapioca starch pastes and their mixtures with addition of carrageenan, measured at 25°C.

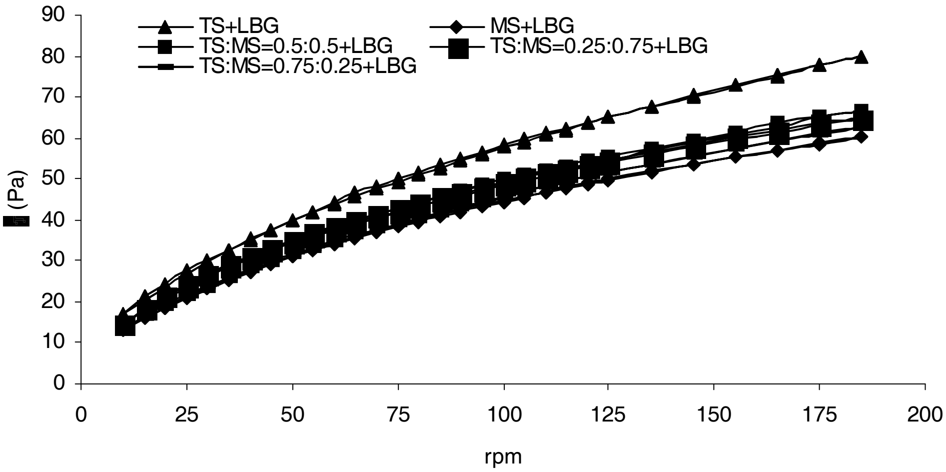

Fig. 3 Shear stress versus rotation per minute curves of maize and tapioca starch pastes and their mixtures with addition of locust bean gum, measured at 25°C.

CONCLUSIONS

- Tapioca starch paste, with and without addition of hydrocolloids (carrageenan and locust bean gum) had the highest value of apparent viscosity at measured condition.
- Addition of 0.5% carrageenan and locust bean gum had significant influence on rheological properties of starch pastes. Upon that, addition of hydrocolloids considerably more increased consistency of tapioca starch paste.
- Tapioca starch paste with addition of locust bean gum had a four time greater value of apparent viscosity at 50 s^{-1} than tapioca starch paste without addition.

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34. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 621.56
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Original scientific paper

EFFECT OF HOLDING TIME ON CO_2 PRODUCTION AND RHEOLOGICAL PROPERTIES IN YEASTED FROZEN DOUGH

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SUMMARY

The CO_2 production and rheological properties of frozen dough are importance for breadmaking. Measuring the rheological properties of yeasted dough is particularly complicated and time consuming. A major difficulty is that the yeast continues to ferment and produce CO_2 during the measuring process. The simple technique of holding dough at low temperature (0^oC) in an ice/water bath was applied to control or delay yeast fermentation. After 24 hours frozen storage at -20^oC, dough samples were thawed at 0^oC in a water bath for 90 minutes. Thawed dough samples were held at 0^oC in an ice/water bath for 0, 30, 60, 120, 180 or 240 minutes before measurement of CO_2 production using a risograph and rheological properties using the large deformation technique with a SMS/Kieffer probe on a TA-XTplus texture analyzer. The CO_2 production level did not significantly change for holding times up to 240 minutes. The large deformation rheological properties were significantly different for holding times greater than 90 minutes. With increasing of holding time, the maximum force before rupture of the dough decreased and the dough extensibility increased. It was concluded that holding yeasted dough for up to 90 minutes at 0^oC did not significantly affect CO_2 production and rheological properties.

Keywords: *holding time, CO_2 production, rheological properties, dough*

INTRODUCTION

The frozen dough market has steadily grown in recent years due to consumer demand for convenience and high quality baked products (Bhattacharya *et al*., 2003). Quality problems associated with frozen dough include long proofing time, low bread volume, poor bread texture and variable baking performance. The CO_2 production and rheological properties are important indicators of the quality of frozen dough. Damage of yeast cells during frozen storage results in a decrease in gas production and loss of baking performance (Inoue *et al*., 1994). The rheological properties of gas cell walls in bread doughs affect the stability of gas cells and gas retention during proofing and baking. Dough rheological studies show how these properties changes with ingredients or other process conditions (Autio and Sinda, 1992; Lee *at al*., 2001). Weakening of the dough structure through damage to the gluten network during frozen storage can reduce gas-retaining ability (El-Hady *et al*., 1996).

There are several methods for determining the rheological properties. Generally, rheological measurement of the dough use either small deformation or large deformation techniques. In order to obtain information about the structure of both flour and gluten doughs, mechanical tests involving small deformations are most useful. However, if information on the mechanical properties of dough under conditions similar to those in fermenting bread dough is required, biaxial extension tests involving large deformation are preferred (van Vliet *et al*., 1992). Kieffer *et al*. (1998) and Uthayakumaran *et al*. (2002) indicated that the elongational properties of the dough measured using uniaxial extension gave a good correlation with baking performance.

Measuring the rheological properties of yeasted doughs is not easy and can be time consuming. The major problem is that the yeast continues to ferment during the measuring process producing CO_2 and thereby changing the rheological properties. Although fermentation is clearly important in breadmaking, research into dough rheological properties has often used non-yeasted dough to avoid yeast fermentation during the measurement (Amemiya and Menjivar, 1992; Morgenstern *et al*., 1996; Tronsmo *et al*., 2003). Newberry (2003) used an extreme freezing and thawing procedure to inactivate the yeast. However, such a method does not make sense in a study of the quality of frozen yeasted-dough. Another option is to control yeast activity by keeping the dough cool using ice in the recipe, cooling the dough during mixing and by holding in an ice/water bath between thawing and measurement of the rheological properties and CO_2 production. The aim of this work is to evaluate the effect of holding time at $0^{o}C$ post thawing on CO_2 production and rheological properties of frozen yeasted dough.

MATERIALS AND METHODS

Dough Recipe

Dough samples were prepared using the straight dough formula described by Miller *et al*. (2005). The dough recipe comprises 60% w/w flour, 2% w/w compressed yeast, 1% w/w salt, 2% w/w sugar, 2% w/w canola oil and 33% w/w water (40% w/w as ground ice).

Dough Preparation

All ingredients were mixed in a dough mixer (Model 7MX, Delta Food Equipment, New Zealand) for 4 minutes at low speed and for 10 minutes at high speed. Dough temperature was 15±1°C at the end of mixing. After mixing, the dough was divided into 100±2 g pieces, manually molded into round shapes (ca 5 cm diameter), and placed into 170x180 mm snaplock polyethylene bags before freezing.

Freezing

The freezing process used an air blast freezer (Long Beck Panel Systems Ltd., New Zealand) operating at about -30°C with an air speed of 4 m/s for 60 minutes. The freezing rate was estimated to be about -0.51°C/min between 0°C and -20°C.

Thawing

After 24 hours frozen storage at -20°C, frozen dough samples were thawed for the quality assessment. The dough pieces were thawed by transferring them to a water bath (Neslab Istruments, Inc., Newlington, U.S.A) at 0°C for 90 minutes. After thawing, the doughs were held in an ice/water bath at 0°C for 0, 30, 60, 120, 180 or 240 minutes before measurement of CO_2 production and rheological properties.

Carbon Dioxide Production Measurement

CO_2 production was measured using a risograph (R-Design, W. 700 Pullman, WA) according to method of El-Hady *et al*. (1996). Three samples of 50 g of dough with core temperatures of 0°C were placed into fermentation jars in a water bath at 30°C. The gas level was measured every minute for 120 minutes after a 10 minute delay. Average rate of gas production and total of gas production were expressed as ml CO_2/minute and ml CO_2 respectively.

Rheological Measurement

Uniaxial extension measurements were made using the SMS/Kieffer dough and gluten extensibility rig for the TA-XTplus texture analyzer (TA-XTplus, Stable Microsystems, Surrey, UK) following the large deformation method of Bhattacharya *et al*. (2003). Twenty grams of thawed dough at 0°C was placed into a Teflon-coated block, lined with parafilm, and cut into dough strips using a mould. The dough strips were allowed to rest for 30 minutes in air at 20°C, before being stretched by a hook extension at the speed of 3.3 mm/s for a distance of 100 mm (Suchy *et al*., 2000). All tests were carried out at a constant room temperature of 20°C. Dough extensibility (mm) from start to rupture and maximum force before rupture (g) were automatically calculated by the data processing software supplied with the TA-XTplus.

Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) using PROC GLM (SAS Institute, Cary, NC, USA.). Duncan's multiple range test ($p \leq 0.05$) was used to detect differences among treatment means.

RESULTS AND DISCUSSION

Carbon Dioxide Production

Decrease in the total CO_2 production indicates the loss of yeast activity or prefermentation during the holding time (Hsu *et al.*, 1979). Figure 1 and 2 show the rate of CO_2 production (ml/min) and cumulative CO_2 production (ml) after each holding period. It was found that the rate of CO_2 production and cumulative CO_2 production did not significantly change with increasing holding time. These results showed that the yeast activity did not reduce during holding in an ice/water bath. The yeasted dough could be held in an ice/water bath for up to 240 minutes without significant loss of yeast activity.

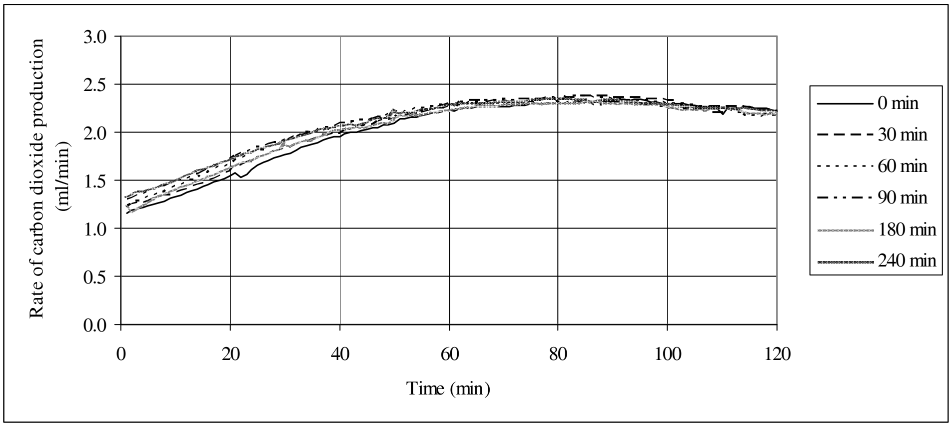

Figure 1 Rate of CO_2 production of yeasted dough after different holding time in an ice/water bath

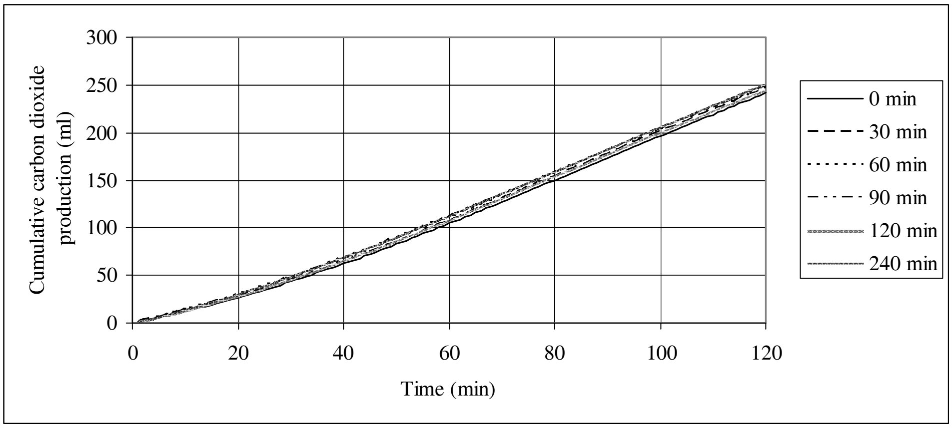

Figure 2 Cumulative CO_2 production of yeasted dough after different holding time in an ice/water bath

Rheological Properties

The CO_2 gas bubbles from yeast fermentation play a highly significant role in the development of dough protein structure due to increased cross-linking between dough proteins. However, the rheological properties of the yeasted dough deteriorate with fermentation. Although the dough proteins become more cross-linked increasingly large gas bubbles interrupt the dough protein network and weaken it (Newberry, 2003).

Table 1 gives the maximum force before rupture and dough extensibility using the large deformation technique. The rheological properties of yeasted dough were significantly affected by different holding time in an ice/water bath. The maximum force before rupture decreased significantly after holding in an ice/water bath for more than 120 minutes. In contrast, the dough extensibility increased significantly after more than 90 minutes. Decreases in maximum force and increase in dough extensibility clearly indicated deterioration in the quality of the gluten (Inoue and Bushuk, 1992). An increase in dough extensibility would be expected to result in poorer gas retention of the dough and consequently, increased proofing time (Sharadanant and Khan, 2003).

Table 1 Rheological properties of yeasted dough after different holding time in an ice/water bath

Holding time (minutes)	Maximum force before rupture (g)	Dough extensibility (mm)
0	39.79±0.69 a	38.77±1.07 a
30	38.99±1.94 a	40.80±2.48 ab
60	38.08±1.35 ab	39.33±1.84 a
90	37.97±0.98 ab	41.41±1.05 ab
120	36.38±1.66 b	43.36±1.78 b
180	31.25±1.98 c	46.69±5.39 c
240	32.07±2.08 c	56.68±3.97 d

Means within the same column with different letters are significantly different ($p \leq 0.05$).

CONCLUSIONS

The yeast viability, CO_2 production and rheological properties of dough are all important for dough quality. However, yeast fermentation affects rheological measurement. Although the CO_2 production rate did not change after holding at 0^oC for up to 240 minutes, the rheological properties changed by the effect of yeast fermentation when held for greater than 90 minutes. Holding yeasted dough in an ice/water bath for up to 90 minutes was therefore recommended to minimize the effect of fermentation on rheological measurement.

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