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ZAVOD ZA MEHANIZACIJU POLJOPRIVREDE
POLJOPRIVREDNI FAKULTET SVEUČILIŠTA U OSIJEKU
UNIVERZA V MARIBORU FAKULTETA ZA KMETIJSTVO IN BIOSISTEMSKE VEDE
KMETIJSKI INŠTITUT SLOVENIJE
MAĐARSKI INSTITUT ZA POLJOPRIVREDNU TEHNIKU
HRVATSKA UDRUGA ZA POLJOPRIVREDNU TEHNIKU

AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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PRIČA O TRAKTORU S NASLOVNICE

FENDT G 25

Posljednjih godina puno se rasprava vodi o korištenju alternativnih izvora energije i energije iz biomase. U prošlosti su na tu temu bila prisutna mnoga rješenja, na primjer drvo i žetveni ostaci korišteni su za pogon lokomobila u poljoprivredi. Jedna od manje poznatih specifičnosti iz povijesti poljoprivredne tehnike su traktori koji su bili pogonjeni obnovljivim izvorom energije i to drvnim plinom.

Fendt je u drugoj polovici tridesetih i ranim četrdesetim godinama prošlog stoljeća imao uhodanu proizvodnju poljoprivrednih traktora manje snage, te je poput mnogih drugih njemačkih proizvođača traktora napravio preinake za pogon na drvni plin. Njihovi su traktori bili opremljeni generatorom drvnog plina u potpunosti integriranim u prednjem dijelu traktora i povezanim s diesel motorom, tako da se na prvi pogled teško moglo ustanoviti da se radi o traktoru pogonjenom drvnim plinom.

Glavni dio svakog generatora drvnog plina je kotao, koji se odozgo puni komadima drveta (ili ugljenom). Pri vrhu kotla drvo se suši i zagrijava, te se djelovanjem vlastite težine spušta prema dnu. Uslijed manjka kisika u kotlu dolazi do nepotpunog izgaranja i uplinjavanja drveta, a proizvedeni plin se preko izmjenjivača topline hladi i odvodi u motor. Prije ulaska u motor potrebno je ukloniti vodenu paru i nečistoće kako bi se spriječilo oštećenje motora zbog prekomjernog nabiranja čađe. Drvni plin u motoru sagorijeva na sličan način kao tekuće gorivo (benzin ili diesel). Snaga motora smanjena je za 20 do 30%, što može biti problematično na primjer kod oranja, a ukupna masa traktora povećana je za 300-500 kg. Korištenje drvnog plina također ima za posljedicu gomilanje čađe u motoru (iako je prisutan sustav za filtriranje) pa su motori morali biti često otvarani i temeljito čišćeni, što je bio veliki gubitak vremena. Za pokretanje motora koristi se tekuće gorivo, te se nakon nekoliko minuta prebaci na opskrbu drvnim plinom iz generatora. Za loženje je najčešće korištena bukovina, no koristilo se i drvo breze, smreke, bora, ili što god je bilo dostupno. Vlažnost drva morala je biti ispod 25%, optimalno 12-16% vlage. Generatore drvnog plina za ugradnju na nove ili postojeće traktore nudilo je nekoliko proizvođača kao što su Imbert, Miag, Deutz, Wisco, Zeuch, Südgas.

Zašto se uopće generator drvnog plina našao u masovnoj primjeni na traktorima? Za odgovor na to pitanje treba poznavati političku situaciju u Europi na kraju tridesetih i početkom četrdesetih godina prošlog stoljeća. To je razdoblje Drugog svjetskog rata, kada su tekuća goriva postajala nedostupna za civilnu uporabu. Procjenjuje se da je u to doba u Europi bilo gotovo milijun civilnih putničkih i teretnih motornih vozila pogonjenih drvnim plinom. Na početku rata prerada traktora na pogon drvnim plinom još uvijek je bila prepuštena odluci pojedinca. U prvoj polovici 1942. godine Njemačka je izdala naredbu da svi traktori koje pogoni tekuće gorivo moraju biti prerađeni za pogon na drvni plin. Nove su traktore proizvođači već u tvornicama standardno opremali kotlovima za proizvodnju drvnog plina, a traktore koji su već bili u uporabi poljoprivrednici su morali nadograditi.

Ideja o pogonu motora drvnim plinom nije vezana samo na razdoblje Drugog svjetskog rata, već je puno starija, a prvi put je realizirana u Engleskoj 1884. za pogon stacionarnog motora. U dvadesetim godinama prošlog stoljeća pogon na drvni plin se etablirao na osobnim i teretnim vozilima nekih europskih proizvođača. Takav pogon je bio vrlo zanimljiv u svjetlu globalne ekonomske krize, kada je tekuće gorivo zbog visokih cijena postalo teško dostupno. Zanimljivo je da su neki njemački proizvođači nudili izvedbe traktora s pogonom na drvni plin i nakon Drugog svjetskog rata zbog neredovite opskrbe tekućim gorivom. Normag je još 1948. godine na sajmu poljoprivredne mehanizacije izlagao traktor s pogonom na drvni plin.

Traktor sa slike, Fendt G 25, bio je opremljen Deutz-ovim dvotaktnim tekućinom hlađenim diesel motorom zapremine 3979 cm^3, snage 18 kW / 25 KS pri 1500 o/min. Motor je bio povezan s generatorom drvnog plina koji je u cijelosti bio sakriven pokrovom. ZF mjenjač je imao četiri stupnja prijenosa za vožnju naprijed i jedan nazad, a omogućavao je najveću brzinu od 15 km/h. Masa praznog traktora iznosila je 2223 kg u izvedbi s pneumaticima, odnosno 2474 kg u izvedbi s čeličnim kotačima. Prema navodima u stručnoj literaturi, ukupno je proizvedeno 1497 primjeraka modela G 25 u razdoblju od 1943. do 1946. godine.

Tekst: Viktor Jejčič

Slika na naslovnici u tehnici akrila: Dušan Jejčič

PREDGOVOR – PREFACE

Poštovani kolege i čitatelji,

Nakon 40 godina tiskanog izdanja zbornika radova "Aktualni zadaci mehanizacije poljoprivrede", godišnje publikacije, odlučili smo nastaviti mrežnim-elektroničkim izdanjem koje će biti obnavljano svakog 30. Ožujka tekuće godine, a pristup će biti besplatan i to na adresi http://atae.agr.hr. Izdavači se nadaju da će Vam nova izdanja donijeti dovoljno interesantnih članaka kao što je to bilo i s tiskanim izdanjem. 41. Zbornik sadrži ukupno 44 rada od čega: po jedan (1) rad iz Austrije, Bugarske i Mađarske; dva (2) rada iz Italije; tri (3) rada iz Španjolske; pet (5) radova iz Slovenije; šest (6) radova iz Hrvatske; devet (9) radova iz Srbije i šesnaest (16) radova iz Rumunjske. Zahvaljujemo svim autorima, sponzorima i kolegama mehanizatorima za ustrajnu profesionalnu i ljudsku potporu. Želimo svim sudionicima ugodan boravak u Opatiji tijekom održavanja Simpozija.

Dear colleagues and readers,

After 40 years of Proceedings "Actual Tasks on Agricultural Engineering printed version that have been issued annually, we decided to go on further with on-line version which will be available at this web site: https://atae.agr.hr. Update will be done on every 30th of March. Publishers hope that further issues will bring You enough interesting articles as printed version have done before. 41 st Proceedings contains 44 papers among them are: Austria, Bulgaria and Hungary with (1); Italy with (2); Spain with (3); Slovenia with (5); Croatia with (6); Serbia with (9) and Romania with (16) papers. Organiser is grateful to all authors, sponsors and attendees for their continuous professional and colleagues' support. We wish all participants, our colleagues, pleasant time, weather and company during symposium.

Urednik / Editor

Prof. dr. sc. Silvio Košutić

Zagreb, siječanj-January 2013.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

NEISKORIŠĆENI POTENCIJALI ELEKTRONSKOG POSLOVANJA ZA POVEĆANJE PRODAJE POLJOPRIVREDNE MEHANIZACIJE

NEMANJA GAGIĆ

AgroEurope Media Services d.o.o., Imotska 1, 11000 Beograd

SAŽETAK

Elektronsko poslovanje su svi oblici poslovnih transakcija ili razmene informacija koje proizlaze iz korišćenja informacione i komunikacione tehnologije (ICT). Prednosti elektronskog poslovanja u odnosu na tradicionalno poslovanje su virtualno neograničeni broj potencijalnih kupaca, ubrzanje procesa od poručivanja do isporuke, povećanje učinka prodaje kao i smanjenje troškova za tradicionalnu prodavnicu i prodavce.

Uprkos visokom procentu populacije koji koristi internet (Hrvatska 70%, Srbija 56%, Bosna i Hercegovina 60%, Slovenija 72%, Evropa 63%), ovaj ključni alat elektronskog poslovanja još uvek je nedovoljno iskorišćen u oblasti prodaje poljoprivredne mehanizacije. Iskusnije generacije nerado menjaju navike i iskustva stečena u vremenu bez korišćenja alata elektronskog poslovanja, ali za internet portale još uvek ne postoji dovoljno jak marketing i nisu u potpunosti definisana pravila i standardi za oglašavanje.

Internet nudi prednosti brojnih besplatnih ili jeftinih alata koji mogu efikasno da se iskoriste za povećanje prodaje poljoprivredne mehanizacije. Neki od alata su dobar internet portal, optimizacija portala za Google pretraživač, Google analytics, razmena linkova i banera, društvene mreže i oglašavanje na specijalizovanim portalima. Jedan od specijalizovanih veb portala koji objedinjuje prednosti alata elektronskog poslovanja je "AgroPijaca – Portal za poljoprivrednu mehanizaciju". Dok u razvijenijim zemljama Zapadne Evrope ovakve portale koristi veliki broj proizvođača i prodavaca poljoprivredne mehanizacije, na prostorima bivše Jugoslavije ovaj proces je tek na početku.

Ključne reči: *Elektronsko poslovanje, internet, veb portali, poljoprivredna mehanizacija, AgroPijaca*

UVOD

Prethodnih decenija smo mnogo puta bili svedoci brzih promena tehnologije i načina poslovanja. Računari, mobilni telefoni i druga sredstva komunikacionih tehnologija danas su sastavni deo svakodnevnog života i svakog poslovnog procesa. Dobro poznavanje funkcionisanja ovih tehnologija jedan je od najbitnijih preduslova za uspešno poslovanje. Ključni alat savremenog elektronskog poslovanja je internet, bez koga ozbiljna organizacija ne može da funkcioniše. On pruža brojne alate koje olakšavaju svakodnevne poslovne procese, daju informacije od strateškog značaja i omogućavaju efikasno usmeravanje prodajnih aktivnosti.

Tema ovog rada je "Neiskorišćeni potencijali elektronskog poslovanja za povećanje prodaje poljoprivredne mehanizacije". Ona ima za cilj da objasni suštinu elektonskog poslovanja, ukaže na probleme kod korišćenja njegovih alata, kao i da pokaže neka od finansijski povoljnih rešenja za uspešno korišćenje alata elektronskog poslovanja za uspešnu prodaju poljoprivredne mehanizacije širom zemlje i u inostranstvu.

POJAM I PREDNOSTI

Elektronsko poslovanje su svi oblici poslovnih transakcija ili razmene informacija koje proizlaze iz korišćenja informacione i komunikacione tehnologije (ICT). Internet tehnologije su omogućile nove i inovativne poslovne pristupe u prodaji, kupovini i kreiranju poslovnih procesa. Sve zahtevniji potrošači i jača konkurencija utiču na razvoj novih mogućnosti i promene u domenu poslovnih procesa. Elektronsko poslovanje obuhvata interne procese i poslovanje organizacije, sve modalitete elektronske trgovine, potrošačke preferencije, ali i tržišno okruženje koje utiče na ukupne uslove i aktivnosti organizacije.

Tabela 1 Razlika između tradicionalnog i elektronskog poslovanja

	Tradicionalno poslovanje	Elektronsko poslovanje
Reklamiranje, ciljna publika	Uobičajeno lokalni kupci. Može privući 10.000 - 50.000 ljudi.	3,1 miliona korisnika interneta u Hrvatskoj, 4,1 miliona u Srbiji, 2,3 miliona u Bosni i Hercegovini, 1,4 miliona u Sloveniji, 520 miliona korisnika interneta u Evropi.
Učinak prodavca	Jedan prodavac može da usluži do 100 kupaca dnevno.	Veb portal može da informiše i usluži neograničen broj kupaca.
Transfer novčanih sredstava	E-mail ili fizičko lice. Može da traje do 7 dana.	Istog trenutka.
Isporuka	Lična, pošta, kurirske službe.	Tradicionalan način, ili istog trenutka putem elektronske pošte (e-mail) ili preuzimanje (download).
Troškovi	Jedan prodavac godišnje košta nekoliko hiljada do nekoliko desetina hiljada EUR godišnje.	Elektronska radnja može da košta nekoliko stotina do nekoliko hiljada EUR godišnje.

PROCESI ELEKTRONSKOG POSLOVANJA

Elekronsko poslovanje se u oblasti prodaje poljoprivredne mehanizacije može iskoristiti za sledeće aktivnosti:

Prikupljanje podataka i informacija

Korisnicima interneta dostupan je veliki broj internet portala koji sadrže podatke i informacije o firmama, proizvodima, rukovodećim ljudima i drugim korisnim stvarima. Veliki broj firmi u zemlji i širom sveta ima sopstveni internet portal, koji o sebi i svojim proizvodima informiše ljude iz drugih regiona i država, što je tradicionalnim načinom poslovanja teže ostvariti. Zahvaljujući veb imenicima i direktorijima firmi, moguće je prikupiti podatke i informaciji o čitavoj branši.

Marketing miks

Alati elektronskog poslovanja povećavaju efikasnost aktivnosti marketing miksa (cena, proizvod, promocija, plasman). Internet portali, e-mail servisi i društvene mreže (npr. Facebook, Twitter, Linkedin) su neki od elektronskih alata za komunikaciju sa kupcima, predstavljanje proizvoda i isticanje prednosti.

Prikupljanje podataka i informacija opisano u prethodnom pasusu olakšava identifikovanje tržišta, ciljnih potrošača ali i konkurencije.

Online oglašavanje je rastuća branša, firme izdvajaju sve veća sredstva za oglašavanje na veb portalima, društvenim mrežama i Google oglašavanje. Ovaj vid marketinga zahteva manje finansijskih ulaganja i omogućava bolje segmentiranje ciljne grupe. To omogućava kreiranje ciljane kampanje, kao i promovisanje proizvoda i usluga na online medijima sa velikom posećenošću ili specijalizovanim medijima koje posećuju potencijalni kupci.

Promocija i plasman zahvaljujući alatima elektronskog poslovanja sve se više iz "fizičkog prostora" seli u virtuelni prostor. Poručivanje proizvoda je moguće putem elektronske pošte (e-mail) ili preko veb portala, a roba na adresu pošiljaoca stiže u kratkom roku. Promocija i plasman nisu ni geografski ograničeni, jer je moguće da se poruče ili isporuče proizvodi i usluge u više kontinenata u roku od nekoliko dana.

Online prodaja (proizvoda i usluga)

U prethodnom pasusu, opisana selidba prodaje iz fizičkog u virtualni prostor najviše je doprinela online prodavnicama. Sa znatno nižim ulaganjima u odnosu na tradicionalnu radnju sa prodavcima, može da se napravi online prodavnica sa opcijom bezbednog plaćanja proizvoda putem kreditnih kartica. Sadržaji online prodavnice mogu da se prevedu na bilo koji svetski jezik, tako da proizvodi i usluge postanu dostupnije i kupcima u inostranstvu. Razvijeni servisi za online plaćanje poput Paypal-a, koji rade u većini zemalja u svetu, omogućavaju centralizovanu prodaju, kako u lokalu i regionu, tako i izvan granica. Online prodavnice su finansijski isplative jer zamenjuju tradicionalne radnje i radnike, gde se kupci često svode na lokalno stanovništvo.

Komunikacija

E-mail, SMS servisi, društvene mreže i baner oglasi su pored veb portala neki od instrumenata za komunikaciju sa individualnim kupcima i sa grupama kupaca. U zavisnosti od željenog tipa komunikacije, moguća je korespondencija putem dopisivanja (e-mail, društvene mreže, SMS), direktnog razgovora (npr. Skype) ili masovna komunikacija putem oglašavanja banerima na veb portalima.

Korišćenjem alata elektronskog poslovanja, moguće je prikupiti informacije o većini velikih, srednjih i malih proizvođača, uvoznika i prodavaca poljoprivrednih mašina i opreme u zemlji i u inostranstvu. Kompanije iz ove oblasti mogu da poboljšaju procese i efikasnost tokom celog procesa marketinga. Kupci poljoprivrednih mašina, opreme i rezervnih delova, više ne moraju da traže prodavnice ili predstavništva kompanija iz te oblasti, nego preko interneta mogu da se detaljno informišu o specifikacijama proizvoda i dobiju potpunu sliku pre nego što donesu odluku o kupovini.

Alati elektronskog poslovanja pored toga omogućavaju transparentniju, efikasniju i direktniju komunikaciju sa pojedinim kupcima, grupama kupaca i sa javnošću.

PROBLEMI U ELEKTRONSKOM POSLOVANJU

Iako su prednosti elektronskog poslovanja očigledne, njegova primena je i dalje ograničena i nisu u potpunosti iskorišćene prednosti. Sledeći su ključni razlozi za ovo stanje:

Uzrast korisnika, obučenost i informisanost o mogućnostima elektronskog poslovanja

Uglavnom su mlađe generacije bolje upoznate sa savremenim trendovima i alatima elektronskog poslovanja, dok u mnogim kompanijama iskusniji kadrovi preferiraju tradicionalne oblike poslovanja i komuniciranja sa kupcima. Prodaja poljoprivredne mehanizacije je specifična oblast koja zahteva obimno tehničko znanje i iskustvo iz ove oblasti, zbog čega dobro poznavanje alata elektronskog poslovanja mladih ljudi nije iskorišćeno u potpunosti.

Uzrast korisnika alata elektronskog poslovanja ima direktnu vezu sa njihovom obučenošću i informisanošću o istim. Mlađe generacije su odrasle uz računare i druge informacione tehnologije i u stanju su da isprate svaku promenu, odnosno da se služe elektronskim alatima u rešavanju svakodnevnih problema. Iskusniji kadrovi, koji su tokom većeg dela radnog života navikli na rad i komunikaciju elektronskih alata, sporije prisvajaju nove tehnologije i u donošenju strateških odluka se radije oslanjaju na tradicionalne alate poslovanja.

Nedovoljan marketing i nedefinisani standardi

Online ili digitalni marketing još uvek je manje razvijen od tradicionalnih oblika marketinga na televiziji, radiju, novinama, časopisima, plakatima i bilbordima. Sektor online i digitalnog oglašavanja je još uvek mlad i nisu u svim sferama uspostavljeni standardi i najbolja praksa. Da bi prednosti alata elektronskog poslovanja doživeli punu primenu, potrebno je dosta rada na edukaciji stručnjaka za elektronsko oglašavanje i na promovisanju ovog vida oglašavanja kod onih firmi koje preferiraju tradicionalne oblike oglašavanja.

S obzirom da Internet danas koristi sve veći broj ljudi i procenat populacije (Hrvatska: 3,1 miliona ili 70% populacije, Srbija: 4,1 miliona ili 56% populacije, Bosna i Hercegovina preko 2,3 miliona ili 60% populacije, Slovenija: 1,4 miliona ili 72% populacije, Evropa: 520 miliona ili 63% populacije), očigledno je da aktivnijim i efikasnijim korišćenjem alata elektronskog poslovanja može da se ostvari komunikacija sa širokom populacijom i unapredi prodaja poljoprivredne mehanizacije u zemlji i inostranstvu.

ALATI ZA USPEŠNO ELEKTRONSKO POSLOVANJE

Razvojom Interneta i drugih informacionih i komunikacionih tehnologija (ICT) nastali su brojni elektronski alati koji olakšavaju i povećavaju efikasnost poslovanja.

Predstavićemo neke od alata koji se jednostavno mogu primeniti za unapređenje prodaje poljoprivredne mehanizacije:

- Internet prezentacija kompanije;
- Optimizacija veb sajta za Google pretraživač;
- Google analytics za praćenje performansi veb sajta;
- Razmena linkova i banera, povezivanje sa srodnim portalima;
- Društvene mreže;
- Oglašavanje na specijalizovanim veb portalima.

Internet prezentacija kompanije

Da bi veb portal kompanije imao smisla, mora da bude atraktivan i efikasan. To je lična karta kompanije, i u velikoj meri će dobar veb portal uticati na interesovanje posetioca da dalje istraži proizvode i usluge. Internet prezentacija mora da bude pregledna i jasno struktuirana, a slike i animacije su upečatljivije od tekstualnog sadržaja. Stoga tekst treba da sadrži samo ključne informacije za kupca.

Zadovoljan posetilac veb portala će dalje preporučiti sajt. Takve preporuke mogu putem društvenih mreža u kratkom roku privući veliki broj novih potencijalnih kupaca.

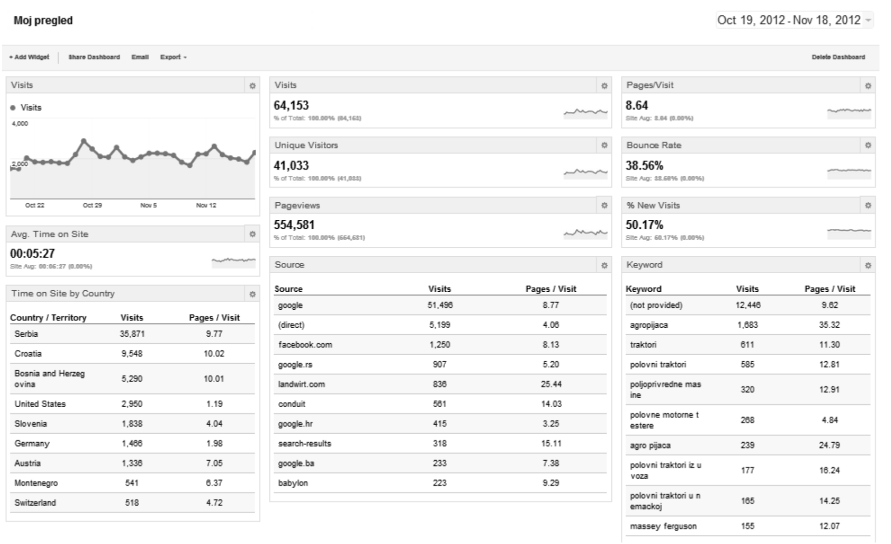
Optimizacija veb sajta za Google pretraživač

Savremeno korišćenje interneta je nezamislivo bez pretraživača (npr. Google, Bing, Yahoo i dr). Oni generišu veliki broj poseta portalu unosom određenih pojmova pretrage.

Postoji čitav niz alata SEO (Search Engine Optimization) koji se primenjuju u podešavanju internet portala kompanije, a čiji je cilj da veb sajt te kompanije bude visoko rangiran prilikom Google pretrage, odnosno da portal bude naveden među prvim rezultatima kad korisnik traži određeni pojam.

Google analytics za praćenje performansi veb sajta

Google analytics je elektronski alat koji omogućava praćenje performansi veb portala i njegovih delova. Google analytics na osnovu algoritma koji se ubacuje u programski kod veb sajta meri njegovu posećenost, broj poseta i posetilaca, broj otvorenih stranica po poseti, prosečno trajanje posete i vernost posetilaca. Pored toga, vlasnik portala dobija uvid u posećenost sajta u pojedinim zemljama i gradovima, najviše pregledane sadržaje, izvora poseta (direktne posete, Google i drugi pretraživači, društvene mreže, linkovi na drugim portalima), tražene reči u Google pretraživaču kao izvor posete portala, kao i mnoge druge parametre.



Slika 1 Google analytics (pregled)

Ovaj alat pruža uvid u prednosti i nedostatke internet portala, efikasnost promotivnih kampanja, pokazuje države i regione u koje treba ulagati veće napore i koristan je alat za donošenje drugih odluka vezanih za veb portal.

Razmena linkova i banera, povezivanje sa srodnim portalima

Na internetu postoji veliki broj besplatnih poslovnih imenika i direktorijuma gde mogu besplatno da se unesu podaci o kompaniji i postave veb linkovi (veze) ili baner reklame ka portalu svoje kompanije. Google i drugi pretraživači pozitivno vrednuju portale čiji se linkovi i baneri nalaze na drugim portalima, što znači da će automatski biti bolje rangirani prilikom pretraživanja određenih sadržaja, pa će samim tim i da poraste posećenost.

Efekat se pojačava ako se razmenjuju linkovi i baneri sa portalima sličnog profila sa sličnim sadržajem. Npr. kad prodavac traktora razmeni linkove i banere sa veb portalima prodavaca plugova, prikolica i opreme za navodnjavanje, svi će zajedno osetiti pozitivne efekte na posećenost svojih veb portala.

Društvene mreže

Komunikacija s javnošću, postojećim i potencijalnim klijentima se u sve većoj meri obavlja putem društvenih mreža (Facebook, Twitter, Linkedin). Danas skoro svi popularni brendovi, kompanije i pojedinci imaju od nekoliko hiljada do nekoliko miliona prijatelja ili fanova na nekoj ili više društvenih mreža. Jedna kreativna ideja, povoljna ponuda ili promocija određenog proizvoda može bez materijalnih ulaganja da se prikaže velikom broju ljudi za kratko vreme i da se prednost takve kampanje proširi velikom brzinom.

Proizvođač novih modela sejalica i plugova može da pokrene kampanju i na društvenim mrežama postavi link na nekoliko desetina profila, stranica ili grupa sa tematikom poljoprivrede i poljoprivredne mehanizacije. Na taj način će promovisati proizvod kod direktne ciljne grupe i ubediti zainteresovane ljude da posete veb prezentaciju i da se dalje informišu o ovim modelima sejalica i plugova.

Oglašavanje na specijalizovanim web portalima

Novija istraživanja su pokazala da u Hrvatskoj ima preko 3,1 miliona korisnika interneta, odnosno 70% ukupne populacije. Veliki deo njih povremeno ili redovno posećuje veb portale za vesti, oglašavanje, forume, blogove (veb dnevnike) i druge portale sa specijalizovanim sadržajem. Kompanija Gemius je istražila najposećenije hrvatske internet portale.

Tabela 2 Hrvatski web portali po broju posetilaca (gemiusAudience istraživanje)

	Portal	Broj posetilaca	Broj poseta	Broj otvorenih stranica
1.	24sata.hr	926.565	16.515.963	96.357.873
6.	njuskalo.hr	852.238	8.157.051	233.268.169
9.	forum.hr	634.549	3.876.375	30.645.353
10.	coolinarika.com	451.869	2.210.571	26.684.080
15.	poslovni.hr	235.916	881.903	3.125.456
19.	blog.hr	204.906	620.269	1.866.411
21.	oglasnik.hr	191.817	708.362	8.528.781
23.	tvrtke.com	171.899	357.376	860.284
32.	imenik.hr	117.501	281.783	1.090.441
75.	agroklub.com	47.063	111.982	438.282

Gornji podaci ukazuju na brojnost ciljne grupe, koliko često su posetili portal i koliko su različitih sadržaja pogledali na tim portalima. Teme ovih portala određuju i sužavaju ciljnu grupu, te je moguće napraviti preciznu selekciju elektronskih portala za oglašavanje i komunikaciju sa klijentima. Za reklamiranje opštih proizvoda za celo stanovništvo (npr. higijenski proizvodi, hrana, finansijske usluge, telekomunikacije) podobni su svi veb portali sa velikom posećenošću.

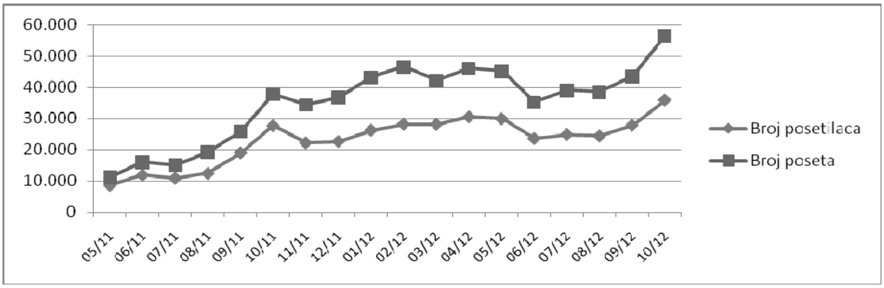
Za oglašavanje specijalizovanog sadržaja poput poljoprivredne mehanizacije postoje specijalizovani veb portali posvećeni delom ili u potpunosti ovoj tematici. To mogu biti oglasnici koji sadrže rubriku poljoprivredna mehanizacija, ili specijalizovani portali za oglašavanje poljoprivredne mehanizacije (npr. *Agropijaca.com, Rabljenistrojevi.com, Mascus.com* i dr.*)*. Ovi portali omogućavaju proizvođačima i prodavcima nove i polovne poljoprivredne mehanizacije da na razne načine zainteresovanim posetiocima predstave asortiman mašina i opreme. Zbog regionalne i međunarodne umreženosti ovih portala, proizvod ili usluga može da se istovremeno predstavi potencijalnim kupcima iz više zemalja.

PRIMER ALATA ZA ELEKTRONSKO POSLOVANJE: AGROPIJACA - PORTAL ZA POLJOPRIVREDNU MEHANIZACIJU

AgroPijaca.com – Portal za poljoprivrednu mehanizaciju je deo međunarodne elektronske mreže "Landwirt.com", koja povezuje kupce i prodavce poljoprivredne mehanizacije u zemljama bivše Jugoslavije, Mađarskoj, Nemačkoj, Austriji i drugih evropskih zemalja.

Proizvođači, uvoznici i prodavci poljoprivredne mehanizacije imaju mogućnost korišćenja profila za oglašavanje svojih mašina i opreme na portalu AgroPijaca i na drugim portalima unutar "Landwirt.com" mreže. Ovde postavljeni oglasi se vide na preko 10 evropskih jezika.

AgroPijaca ima mesečno preko 40.000 posetilaca iz zemalja bivše Jugoslavije, dok ukupna "Landwirt.com" mreža u preko 15 evropskih zemalja ima mesečno preko 1,3 miliona posetilaca. Koncept ove elektronske međunarodne mreže koristi preko 1.200 proizvođača i trgovaca poljoprivredne mehanizacije iz 10 evropskih zemalja, koji oglašavaju preko 50.000 mašina i opreme.



Slika 2 Broj posetilaca i broj posete AgroPijaca – Portala od 05/2011-10/2012

Landwirt je zahvaljujući korišćenju brojnih alata za elektronsko poslovanje imao 2,3 miliona poseta u oktobru 2012. godine. Znanja i iskustva korišćena su za razvoj AgroPijaca portala, koji je pokrenut u maju 2011. godine i posle 18 meseci rada u zemljama bivše Jugoslavije ima preko 40.000 posetilaca, sa trendom konstantnog rasta.

Uspešno su primenjivana rešenja Landwirt-a za efikasnost i funkcionalnost veb portala i optimizacija portala za Google pretraživač (SEO), što AgroPijaci donosi visoko rangiranje prilikom pretrage mnogih ključnih reči. Npr. pretragom pojma "traktori john deere" na Google pretraživaču, AgroPijaca portal se na srpskom Google-u nalazi na samom vrhu, čak i iznad portal zvaničnog uvoznika ovih traktora. Na hrvatskom Google pretraživaču je AgroPijaca kod ovog pojma prikazana u prvih 5 rezultata. Slični su rezultati za brojne druge ključne reči u vezi sa poljoprivrednom mehanizacijom.

Slika 3 Rezultat Google pretrage "traktori john deere"

Kreirani su linkovi AgroPijaca portala na brojnim direktorijumima, forumima, blogovima, a i razmenjeni su linkovi sa poljoprivrednim i drugim portalima. Ovim AgroPijaca postiže bolji tretman kod Google pretraživača, što rezultira konstantnim rastom posećenosti od strane potencijalnih kupaca poljoprivredne mehanizacije. Portal vrši i aktivnu komunikaciju preko društvene mreže Facebook, koji je jedan od najvećih generatora posetilaca portala.

Source	Visits	Pages / Visit
google	577,452	6.80
(direct)	23,789	7.28
landwirt.com	15,226	24.55
facebook.com	8,865	6.36
google.rs	6,423	4.16
conduit	3,583	12.80
google.hr	3,271	3.38
google.com	2,778	4.16
search	2,673	10.11
bing	2,060	6.08

Keyword	Visits	Pages / Visit
(not provided)	64,668	7.77
agropijaca	13,915	28.27
agro pijaca	7,070	31.42
traktori	5,389	10.50
poljoprivredne masi ne	4,547	11.91
polovni traktori	4,374	9.05
www.agropijaca.co m	2,970	32.14
polovne poljoprivred ne masine	1,749	9.84
polovne motorne tes tere	1,378	4.84
polovni traktori iz uvo za	1,344	10.57

Slika 4 Google analitika: Izvor poseta AgroPijaci i reči Google pretrage

ZAKLJUČAK

Efikasno korišćenje alata elektronskog poslovanja olakšava izvršavanje aktivnosti duž celog lanca marketing miksa uz manja ulaganja nego kod tradicionalnog poslovanja. Mogućnosti elektronskog poslovanja se još uvek nedovoljno koriste u oglašavanju i prodaji poljoprivredne mehanizacije. Jedan od razloga su starosne razlike – mlađe generacije koje su odrasle uz računare lakše se adaptiraju na brze promene i nove tehnologije nego iskusniji kadrovi u kompanijama, koji su navikli na tradicionalan način poslovanja i komuniciranja bez računara i mobilnih telefona.

Postoji niz alata elektronskog poslovanja koji su besplatni ili jeftini, a mogu da zamene ili nadograde tradicionalnu radnju, prodavce i promotere sa malim ulaganjima. Društvene mreže i veb portali su dobri elektronski alati za komunikaciju sa kupcima i oglašavanje poljoprivredne mehanizacije, jer okupljaju brojne grupe čiji članovi i posetioci mogu biti zainteresovani kupci. Ovo posebno važi za specijalizovane portale za poljoprivrednu mehanizaciju, gde se oglašavanjem za razliku od opštih internet portala mogu direktno ciljati potencijalni kupci. AgroPijaca.com – Portal za poljoprivrednu mehanizaciju je primer za uspešnu implementaciju brojnih alata elektronskog poslovanja, i kao specijalizovani portal za ovu specifičnu oblast omogućava proizvođačima i prodavcima poljoprivredne mehanizacije da efikasno oglašavaju svoje mašine i opremu i komuniciraju sa potencijalnim kupcima u zemlji i inostranstvu.

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UNUSED POTENTIALS OF ELECTRONIC BUSINESS FOR THE INCREASE OF SALES OF AGRICULTURAL MECHANIZATION

NEMANJA GAGIĆ

SUMMARY

Electronic business represents all forms of business transactions and exchange of information that result from the usage of Information and Communication Technology (ICT). The advantages of electronic business compared to traditional business are a virtually unlimited number of potential buyers, acceleration of the process from the order to the delivery, better effects of sales efforts as well as decrease of costs of traditional shops and salespersons.

Despite a high percentage of population using internet (Croatia 70%, Serbia 56%, Bosnia and Hercegovina 60%, Slovenia 72%, Europe 63%), this key tool of electronic business is still not enough used in the field of sales of agricultural mechanization. Experienced generations unwillingly change their habits and experience gained during times without the usage of electronic business tools, but on the other hand web portals still do not have a strong enough marketing and there are still not fully defined standards of advertising on internet portals.

Internet offers advantages of numerous free of charge or cheap tools that can efficiently be used to increase sales of agricultural mechanization. Some of the tools are a good web portal, SEO (Search Engine Optimization, mostly for Google), Google Analytics, exchange of links and banners, social networks and advertising on specialized internet portals. One of the specialized web portals is "AgroPijaca – Portal for Agricultural Mechanization". While in developed countries such specialized portals are used by a huge number of producers and dealers of agricultural mechanization, in countries of former Yugoslavia this process is still in the beginning.

Key words: *Electronic business, internet, web portals, agricultural mechanization, AgroPijaca*

41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.153.4
Pregledni rad
Review paper

DETERMINATION OF RESOURCES NECESSITIES IN AGRICULTURAL PRODUCTION

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SUMMARY

The main features of specific and common resources for agriculture are considered. Their impact on farming efficiency is often difficult to predict because of their stochastic characteristics and combined action. That's why, using of economic and mathematical models for solving of such sophisticate problems may lead to significant errors. Special attention is paid to such important natural and artificial sources, supplies, funds like time, human and biological, technical and energetic, financial and informational, land and soil resources. An algorithm and program for step by step decision support is suggested. The criteria have to be some obligatory among these typical for situations of risk and uncertainty. Particularly in plant production farm machinery is possible to use depending on soil and crop condition and usually not 24 hours. Tractors', harvesters', cars' and other machines' operators can work only a shift in 24 hours and not all week days. For example at the same time a tractor may be used in first shift with bean harvester and in the others – with trailers or disk harrows. To reach technological objectives farmers can practice hand, machinery, biological or chemical methods and tools. For better resources use it is possible some farm practices like tillage, seeding, transportation to start earlier or later than usually. To take in attention meanwhile so many and various factors, situations and decisions, a heuristic approach is recommended. A lot of different technological, technical, labor, time, financial means are considering and comparing for various possibly natural and economic situations. For fast and unbiased estimation, each suggesting for problem solving is provided with a lot of information by interconnected Excel spreadsheets. Moreover a lot of diagrams show resources use each day and/or shift. That helps to reduce the number of required agricultural machines, operators, fuel, money, etc. After introducing of final decision, some of *initial information can be further specify and update. This makes the next determination of resources necessities easier and more precise.*

***Key words**: resources, agriculture, determination, method, simulation, spreadsheets*

INTRODUCTION

It is well known that agricultural production even in small farm is a large complex multifactor system. A lot of groups of factors as human, machinery, meteorological, biological, soils, crops and animals' protection, water and nutrition supply affect cost and revenue. Moreover the final result depends on many reasons beyond human. On the other hand people need more clarity and plainness for easer and effective farm management. That's why exist a lot of methods for this aim based on simplifying and decomposition of farming activities.

Sample of such approach is so called machine-tractor fleet design. With other words it sounds like farm machinery selection. The difficulty of the answer is a result of wide diversity of agricultural equipment that is currently used or can be bought. On the other hand the way of these machines using is different for various particular farms. Moreover, each of production years, weather conditions, economic situations, cultivated varieties and hybrids, etc. are very dissimilar.

Typically, the following approaches for problem solving exist:

- Heuristic - based on professional knowledge, skills and experience of farmers,
- Operations research - problem-solving techniques and methods applied in the pursuit of improved decision-making and efficiency,
- Technical – as combination between heuristic approach and using of models for calculation of expected performance (productivity, energy consumption, labor spending...) for proposed machines on the market.

The experience-based techniques and methods as rule are fast, not using special mathematical apparatus although not always well-founded. Often they are recommended in some textbooks about tractors and agricultural machines exploitation – [15], [6]. For harvesters offers special method.

Technical approach is based on balance of forces and energy for agricultural aggregates. Each tractor, self-propelled harvester or other energy unit is characterized by its engine, transmission, hitch and other applications indices. At the other side of balance are machine resistance forces. The right combination between energy unit and machines is a good precondition for farm machinery efficiency - [3], [8], [2].

The next step for determination of machine type is a comparison based on the specific costs for different units, often unfortunately based on results of previous years (rather than forward-looking information). The following machines' parameters are preferred: prices, costs of fuel, labor per area, filed capacity, throughout, reliability indicators, availability of service, and facilities for work. Unfortunately, in most countries of Central and Eastern Europe there are no more authorities for research and testing of this machinery. In addition to this, its exceptional diversity also makes difficult its full assessment due to lack of time, labor and financial resources. Since economic comparisons used mainly for previous period of work, they are not sufficiently acceptable. Moreover, various farm conditions can be significantly differ (agrometeological, economical, varieties, hybrids), which makes it impossible to apply the correct analogy. As regards to technical comparisons, they are based often on empirical and theoretical relationships, fundamental to the performance of agricultural aggregates.

Among operations research methods most used for agricultural resources determination are simulation, mathematical optimization, queueing theory and other stochastic-process models. Some of more suggested method is that one of linear programming – [5] or more sophisticate – [1]. Unfortunately such methods take a lot of time and cost, evaluate mainly quantifiable factors, are difficult implemented and depend on computers and software.

Hereinafter an approach based of some advantages of heuristics and of one of methods of operations research will be presented.

METHODS

Because of requisite to make decisions often under conditions of risk and uncertainty, with no or little information, first we need to specify *criteria* for achieving the desired result as in [7]. For example some farmers prefer Minimax criterion (Savage criterion of regret). It can ensure the least possible losses. The particular criterion choice is a matter of the decision-maker discretion.

However, regardless of the selection criterion, it is desirable first in detail to be described the *number of possible situations* (conditions that will show the effectiveness of the decision).

It is imperative to be given information about crops' areas, yields, number and kind of breeding animals, necessities of respective resources for them like seeds, fertilizers, water, forage, pesticides and herbicides, etc. Only then the need of equipment and energy for its work can be determined regard to the time of each operation. This includes the start and end of the process, the amount of working days and hours, number of shifts per day and the duration of each shift. The relationship between the length of the harvesting period and the number of working days is given by the ratio of meteorological conditions (numerical value to 1). Data of timeliness loss factors (coefficients) is based on statistics from the closest agrometeorological stations can be found for example in [18]. More accurate determination of possibilities (working days) can be made based on objective parameters such as temperature and humidity of soils, rainfall, information in phenological cards, etc. Thus the results will provide not only average values, but also random variables. According to working hours in 24 hours they are determined by the technological requirements of the process and personnel provision for work in two or three shifts. For example, rape seed harvesting is has to be done when there is desired grain moisture in order to limit grain losses. The availability of good natural lighting can also be important if you do not use autopilots or laser guidance of harvesters. Deadlines for work should guarantee optimal balance between loss of production (due to an extension of time to work on the one hand) and the cost of buying and maintaining harvesters and workers paying (on other hand) -

[18]. Thus, by simple calculations based on time resources (days, number of shifts and their duration), the amount of work (e.g, in areas) may in advance approximately to be determined the required number of specific brands, models and modifications of farm machinery based on their performance. Usually such computing is good to make for average and border conditions (i.e. best and worst natural and meteorological environment for machinery performance, highest and smallest yield).

This information should be summarized in a *number of possible solutions*. Simply machines have to be described by type, models, modifications and numbers. Moreover every decision needs to be presented by final set of indicators such as cost, fuel and labor expenditure, to ensure the safety and reliability of the process. These data are the basis for the comparison and selection of the most appropriate equipment. Unfortunately, in the prospects of the machines' field capacity (if available) is technical, i.e. without considering the shift time factor. In fact, effective time coefficient of combines depends on the coordination of interactions between harvesters, spreaders, transport and storage (organizational and technical solutions) and varies between 0,60 and 0,85. Generally, the technical capabilities shall be presented by the field capacity (productivity) and fuel consumption per unit of harvested or spread production or area. Such norms, as there are a long established, are for machinery usually long time in use. Thus determination of new machinery performance is a problem and obstacle for objective evaluation and comparison of different agricultural machines. Besides the difficulties in describing the huge numbers of possible situations and possible solutions, there are problems in modeling the influence of various factors (conditions and decisions) on the values of the criteria, i.e. goals.

The elements of the system are objectified after its decomposition. Each element must be relatively autonomic and additionally described by its functional relation with other elements. A simulation of all system and its elements will allow a better modeling for determination of resources necessities in agricultural production. Such approach makes easier data updating and step by step actualization of main information depending on weathers, soils, crops and economical conditions' changes. For process of simulation spreadsheets are using.

PROCEDURE, RESULTS AND DISCUSSION

Besides adequate method for problem solving using of right date for selected model is crucial. That's why each of need information is checked for inconsistency in advance. Then it is putted in relative cell of the spreadsheet. Key parts of the workbook are:

- main sheet for base calculations,
- sheets with reference data, i.e. about timeliness factor, handbook with filed capacity and fuel consumption, samples of technology for crops, animals,
- instruction for data entering and processing,
- illustrations for visual convenience by some of problem solving steps,
- summary table for needed resources for a production period,
- motivation, explanation, comments about sources of initial information, way of its using and each step of problem solving.

At the beginning i.e. for crop production specialist must describe plants varieties, hybrids and relative areas. Then a crops technology has to be entered. Usually it is a list of possible combination of various actions on soils and plants create the right conditions for growing, harvesting and storage of agricultural products. A sample for field plants growing in a farm may includes:

- cleaning of filed after harvest from plant residues,
- land preparation for sowing or planting,
- sowing or planting,
- mechanical, chemical or biological weeds, pests, diseases control,
- fertilizing, manure application,
- watering,
- reaping or harvesting,
- transportation of products to and from field, stores, etc.,
- preparing of crop products before storage (cleaning, drying, etc.),
- storage.

Each of such activity has a specific goal, which can be got by different technological ways. For example weed control may be done by row cultivators and spreaders, watering – by drip, overhead, sub-irrigation, land preparation for sowing or planting – by cultivation, disking, leveling. Depending on the crop to be planted, the initial condition of the soil, or the time of year, farmers may use several different techniques: intensive, reduced or conservative tillage. It is good in some cases drip to be combined with delivery of fertilizers, so-called fertigation.

The base aim of this step is to describe all combination between desired technologies goals and rational modes of theirs realization. It is not recommended to reduce that list without serious reasons for this.

After that it is time to inset the list with agrotechnical period when soil, crop stage, meteorological condition allow getting the goals with desire quality as a prerequisite for next crop development and operations. Other needed data is about amount of work. It is calculating by formula including area of growing crop and yield (grain, crop residues, etc.) or sowing rate or fertilization rate or irrigation norm or distance and amount of transported goods, etc. In such way most of information about possible situations is specified (goals that must rich).

Now (second step) to each goal (eventual operation) possible means to achieve it are correlate. Here “means” is something material by which operation is done and its goal is obtained. Means can be farmers, employee with agricultural implements; draft animals with relative agricultural tools; farm tractors and machinery; transport; aircraft, etc. When an operation is linked a means can include i.e. harvesters, transport, cleaners, dryers and front-loaders. Below relative part of table and two samples are given for simple and linked operations.

Table 1 Part of the spreadsheet for possible solutions

16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	norms	
																	33	34
1. resource	number in 1 means	2. resource	number in 1 means	3. resource	number in 1 means	4. resource	number in 1 means	5. resource	number in 1 means	6. resource	number in 1 means	7. resource	number in 1 means	8. resource	number in 1 means	energy source	energy source consumption	Field capacity

For simple operation i.e. sowing of wheat seeds for first row of this operation in column:

16 – (tractor) TK-80, 17 – 1, 18 – (seeder) СЗУ-3,6, 19 – 1, 20 – tractor-driver, 21 – 1, from 22 to 31 – empty, 32 – diesel fuel, 33 – (kg per ha) – 2,8, 34 – (ha per shift) – 17,0.

For next row for the same operation (if there are alternative means) in column:

16 – (tractor) DT-75M, 17 – 1, 18 – (squadron) СС-7,2, 19 – 1, 20 – (seeder) СЗУ-3,6, 21 – 2, 22 – tractor-driver, 23 – 1, from 24 to 31 – empty, 32 – diesel fuel, 33 – (kg per ha) – 3,0, 34 – (ha per shift) – 24,0.

There only two eventual means for this operation. Decimal sign is comma.

For liked operation, i.e. harvest of wheat for first row of this operation in column:

16 – (combine harvester) Claas Avero, 17 – 1, 18 – (header) C490, 19 – 1, 20 – (tractor) TK-80, 21 – 2, 22 – (trailer) – PC-6, 23 – 2, 24 – combine-operator, 25 – 1, 26 – tractor-driver, 27 – 2, from 28 to 31 – empty, 32 – diesel fuel, 33 – (kg per ha) – 21,1, 34 – (ha per shift) – 12,0.

For next row for the same operation (if there are alternative means) in column:

16 – (combine harvester) Claas Avero, 17 – 1, 18 – (header) C490, 19 – 1, 20 – (tractor) T-150K, 21 – 1, 22 – (trailer) – 3ПТС-12, 23 – 1, 24 – combine-operator, 25 – 1, 26 – tractor-driver, 27 – 1, from 28 to 31 – empty, 32 – diesel fuel, 33 – (kg per ha) – 17,3, 34 – (ha per shift) – 10,5.

For next row for the same operation instead tractor may be used a truck IFA-W60L instead trailer PC-6 – trailer PC-4, etc.

Field capacity and energy source consumption must be calculated for all combines, tractors, cars, etc. For this element of system such information can be obtained by simulation depending on crop condition, yield, distance of haulage, etc. too. The sum of all means forms number of possible solutions. It is a datum for further calculations and problem solving.

A subsequent step is preparation of initial decision. It is based of choose of one (local optimal, the best) means for each operation. For example for sowing it is [1 tractor TK-80, 1 seeder СЗУ-3,6, 1 tractor-driver], because of less diesel fuel consumption in compare with [DT-75M, 1 squadron СС-7,2, 2 seeders СЗУ-3,6,1 tractor-driver] (2,8 < 3,0 kg/ha). Then by a formula is calculated needed number of means to realize all quantities for specific operation, to achieve the desire amount and quality. For this calculation except filed capacity working time is imperative to identify. It is known that the maximal working hours depend on working days (as a function period duration and of weather factor), working hours per day - Whd. The last magnitude depends on acceptable duration of operation in 24 hours. Such duration is various according to possibility to work within the range of desired means' performance – Pwdp and availability of workers for multi-shift activity. It is calculated by next formula

$$Whd = \min \{Pwdp, Ns*Hs\}$$

where Ns is available number of shifts, Hs – duration of a shift.

According to Bulgarian Low Hs must be at most 12 hours. Of course Hs is less for operation in bad weather and by more sophisticated equipment. The amount of relative means' number is presented with one digit after decimal sign for small farms. This numerical result is starting position for further improvements of decision about resource necessities.

The most important step is analyzing of last decision and changing for its improving. It is making by resource balance. According to their using resources can be classified in two groups. First group is that of workers and draft animals. This kind of resource can be used only a few hours in one day and night and after that it have to rest before next operation. An example for workforce was given above. Except of minimal rest time between two shifts worker needs free weekends too. A little different is situation with working cattle. Their field capacity is less for operation in field widely separated from farmyards. This is because their low speed and relatively large time for a round trip to such fields. Thereat after "using" of such resource it can be use again only at least after some time for rest (i.e. 24 hours). The other group of resources is that of machinery, storages, special agricultural buildings, energy sources. Their balance typically is drawing for a day. However, there are exceptions. For example a tractor with seeder can be used in daylight, in other part of the 24 hours the same tractor with a trailer – for transportation (usually with other tractor-driver). A combine can harvest wheat when air humidity is low, in other part of the 24 hours the same harvester can reap rapeseed. These resource peculiarities are taken into account on their balance sheet. There is also possibility to exclude it from balance sheet of owned resources if it is hired.

The obtained resources' balances are illustrated by column type charts. Now it is time to search for peak shortage of resources. It is good to start with search such problems for most expensive and scarce machinery.

Now it is time to reduce these peaks.

Often the reason is that in the same time two or more operations for two or more plants have to be performed. First exit from this situation is to change one of the crops with the same but with shorter or longer growing season. This is a good solution i.e. when harvest of wheat and rapeseed coincides. It is possible to start harvesting of one of crops later (that means its finish will be later too) if this not leads big losses. In the same case it is better to start earlier, i.e. by swathing or/and desiccants application of rapeseed. Using of two operations instead one in some cases can reduce peaks because of bigger filed capacity of each means and their using not in the same time.

Another solution is using of other resources unoccupied at the same time. A list of such machinery i.e. can be found in the next row for the same operation. Let for sowing of wheat seeds need more tractors TK-80 than are available. At the same time there are unoccupied seeders СЗУ-3,6, tractors DT-75M and tractor-drivers. There are included in another possible means for this operation – see the row next to the means with TK-80. A possible solution is to reduce planned amount of area to be sowing with [1 tractor TK-80, 1 seeder СЗУ-3,6, 1 tractor-driver] and to transfer it to [DT-75M, 1 squadron CC-7,2, 2 seeders СЗУ-3,6, 1 tractor-driver]. If this is not possible it can try with next means, etc.

After performing of possible peaks' reducing some changes are making for less intensive machinery, workers and animals using. This is doing first by reducing of numbers of shifts in a day and night, second – by reducing of shift duration, and third - by changing of date of starting (usually later on) and/or date of finish (usually early). It is possible to redistribute amounts of work between all means for specific operation too.

All these improvements also aim to have integer number for needed resources like machinery, workers, and animals.

Redistribution of work between all means for specific operation in order to reduce peak demands is a complex and some time long process. It requires wide experience and special knowledge for the particular farm. This is the most significant disadvantage of the proposed approach and relative method.

Naturally the last step of the procedure is presentation of final decision. This includes numerical data which can be seen in spreadsheets cells, a list of indices, summary table for needed amounts of machinery, workers, animals, energy sources (fuel), fertilizers, seeds, herbicides, pesticides.

The analysis, assessment of possible changes and results' illustration are assisted and facilitated most by resource charts. Such a diagram – schedule for tractor TK-80 is shown in figure 1. The chart above shows planned using of tractor before (as background) and after (at the front) changes and below – on contrary. With blue color is presented initial, with magenta - intermediate decision. It is clear that achieved reducing is almost double. This is result only of changing for later period of crops production – summer and autumn.

For describing of above mentioned procedure real information is given. In specific farm four crops are cultivated: wheat -140 ha, sunflower – 70 ha, maize for grain – 140 ha, rapeseed – 80 ha. As it well known spreadsheet is a good tool when some calculations have to be done several times. Such situation exists after each new change. Moreover using of charts as that one showed in figure 1 make its evaluation easier and faster. Another possibility is this one for studying various solutions for worst, average and best meteorological and economical conditions.

CONCLUSIONS

Proposed ergatic (man-machine) scheme for problem solving allows testing various possible decisions for resource reducing. It is appropriate for simulation of effect of some natural and artificial factors on resource necessities such as yield, crop condition, kinds of varieties and hybrids, models and modifications of machinery and their number. Using of spreadsheets can not eliminate participation of specialist in problem solving and makes it only easier, faster and more substantiated.

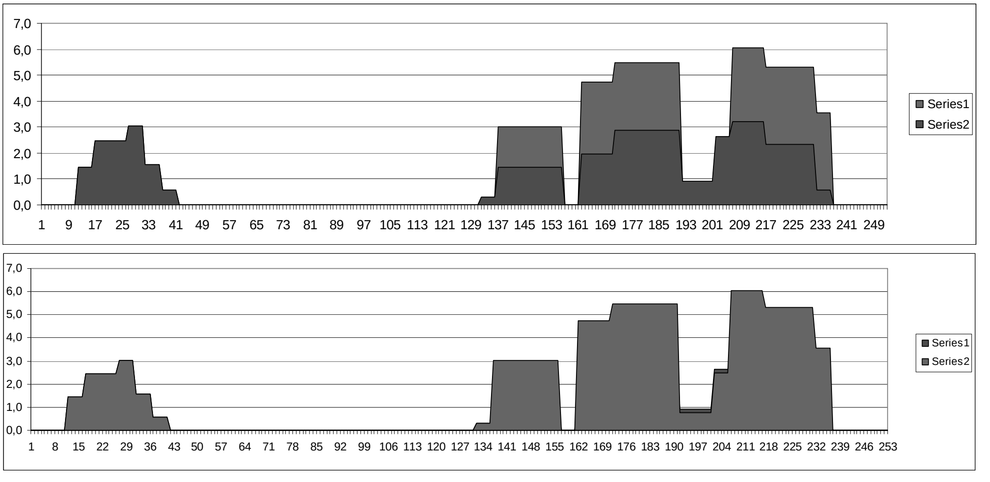

Figure 1 Initial decision with blue color and intermediate decision – with magenta color for tractor TK-80

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Review paper

ANALIZA OPREMLJENOSTI OBITELJSKIH GOSPODARSTAVA ZAPADNOG KOSOVA POLJOPRIVREDNIM STROJEVIMA

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SAŽETAK

U cilju razvoja poljoprivredne proizvodnje u zapadnom djelu Kosova u radu su analizirani proizvodni potencijali u općinama Istok, Dečane, Đakovica, Peć i Junik. U radu su korišteni statistički podaci Kosova, informacije dobivene anketom farmera i osobnim uvidom stanja na terenu. Istraživanjem, metodom slučajnog uzorka, odabrana su za anketiranje sela i obiteljske farme. Na temelju prikupljenih i analiziranih podataka izveden je zaključak o prosječnoj veličini farme, raspoloživom zemljištu, broju traktora i priključnih strojeva.

U pet općina ovoga područja anketirano je ukupno 58 sela i 215 kućanstava. Od ukupno raspoloživog zemljišta od 2044,53 ha na farmi, sijane livade i lucerišta zauzimaju 44%, oranice 32 %, a ostalo su šume. Prosječna površina posjeda obiteljskog kućanstva je 9,50ha.

Ukupna površina poljoprivrednog zemljišta kod anketiranih farmera iznosila je 1556,03 ha a prosječna veličina kućanstva 7,24 ha.

Razina opremljenosti farmi sa jednoosovinskim i dvoosovinskim traktorima je različita i varira ne samo između općina, već i samih sela unutar općina. Prosječna snaga dvoosovinskog traktora je 36,84 kW. Od ukupno 183 traktora, jednoosovinski su bili zastupljeni sa samo 8,93%.

Ukupna energetska opremljenost, izražena kroz ukupnu nominalnu snagu motora po hektaru poljoprivrednog zemljišta iznosila je u prosjeku 4 kW/ha.

Ispitivana obiteljska kućanstva nisu u dovoljnoj mjeri opremljena potrebnom priključnom mehanizacijom, što ograničava unapređenje poljoprivredne proizvodnje. Od ukupnog broja anketiranih farmi samo 78% posjeduje dvoosovinski *traktor koji u prosjeku dolazi na 9 ha ukupnog posjeda, a po traktoru su 2,6 priključna stroja.*

Ključne riječi: *veličina gospodarstva, broj traktora, energetska opremljenost, priključni strojevi*

UVOD

Poljoprivredna proizvodnja na Kosovu se dobrim dijelom odvija na obiteljskim farmama. Nivo opskrbljenosti mehanizacijom na obiteljskim farmama često je nedovoljan za bavljenje komercijalnom proizvodnjom. Kao limitirajući problemi za opremanje poljoprivrednih gospodarstava potrebnom mehanizacijom ističu se raspoloživo poljoprivredno zemljište i financijska sredstva za kupovinu skupe mehanizacije. Istovremeno treba istaknuti da je za postizanje pozitivnih ekonomskih rezultata neophodno i racionalno korištenje poljoprivredne mehanizacije odnosno stupanj iskorištenja traktorskih agregata i specijaliziranih strojeva na malim poljoprivrednim površinama.

Prosječni zemljišni posjed po poljoprivrednom gospodarstvu na Kosovu iznosi 2,2 ha, usitnjen u 8 parcela. Podaci iz statističkog ljetopisa SOK (2004.) pokazuju da je oko 80% farmi veličine od 0,5-2 ha. Prema ispitivanjima obiteljskih gospodarstava koje je sproveo Riinvest institut 2004. godine poljoprivrednom mehanizacijom je opskrbljeno 49% gospodarstva koja posjeduju traktore, 8,5% posuđuje, 23% unajmljuje i 19% gospodarstva ne koristi traktore, a velika je potreba za adekvatnim priključnim strojevima.

Analizom porodičnih gospodarstva u zapadnom dijelu Kosova, koja su i glavni nosioci poljoprivredne proizvodnje, ukazujemo na stepen opskrbljenosti potrebnom mehanizacijom prema veličini farme, što je ujedno i bitan preduvjet za bavljenje intenzivnom poljoprivrednom proizvodnjom.

MATERIJAL I METOD RADA

Istraživanjima je obuhvaćeno pet općina ovog područja i to Peć, Đakovica, Istok, Dečani i Junik. U radu su korišteni podaci dobiveni anketom farmera i osobnim uvidom stanja na terenu. Po metodologiji Lazić i Turan (1996) i Veljković i sur. (2011) odabrana su za anketiranje sela i farme. Obuhvaćeno je 58 sela i 215 privatnih obiteljskih gospodarstava. Anketa je sastavljena u vidu upitnika u kojoj su vlasnici farme unosili tražene podatke: o veličini farme, raspoloživim površinama, (šume, oranice, livade i pašnjaci) sjetvenoj strukturi, broju stoke, broju traktora, njihovoj snazi, njihovoj dobi, proizvođačima i tipovima traktora i broju priključnih strojeva. Nakon izvršene ankete podaci su grupirani i obrađeni matematičko statističkim metodama i prikazani tabelarno i grafički.

Razina opremljenosti poljoprivredne površine snagom traktora u anketiranom području definirana je izrazom:

$$Pa = \frac{\sum_{i=1}^{n} Pe(i)}{\sum_{i=1}^{m} Ai} \,(kW\,/\,ha)$$

gdje je:

Pa – opremljenost poljoprivredne površine snagom traktora

A (ha) – poljoprivredna površina

Pe (kW) – efektivna snaga motora traktora

Pored toga korišteni su statistički podaci Agencije za statistiku Kosova, kao i rezultati istraživanja do kojih su došli domaći i inozemni autori. Cilj istraživanja je da se na temelju analize postojećeg stanja na obiteljskim farmama utvrdi broj traktora po farmi, obradivoj površini po traktoru, prosječnoj snazi traktora, specifičnoj instaliranoj snazi po hektaru, opremljenosti farmi sa priključnim strojevima, broju priključnih strojeva po traktoru i korištenoj površini zemljišta po priključnom stroju.

REZULTATI ISTRAŽIVANJA

Tijekom istraživanja u pet općina anketirano je ukupno 58 sela i 215 farmera. Najviše je anketom obuhvaćeno u općini Đakovica i to 16 sela i 79 farmi, a najmanje u novo formiranoj općini Junik 10 sela i 15 farmera.

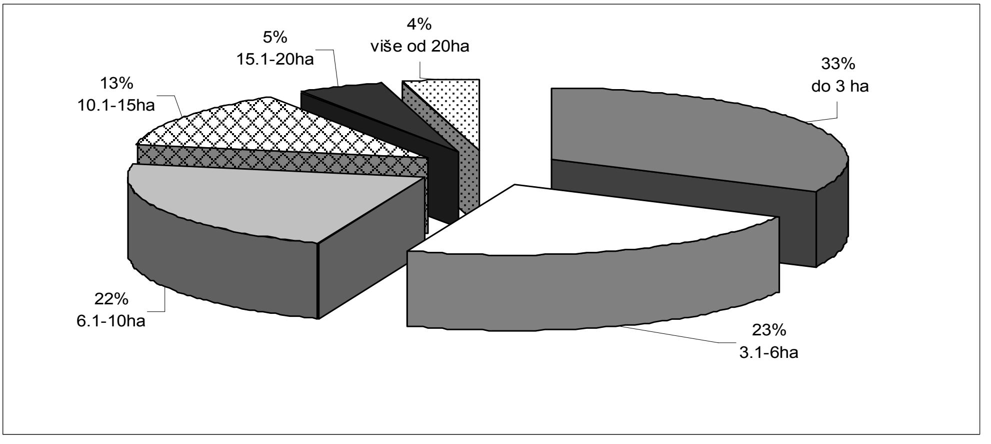
Tablica 1 Osnovni podaci o obiteljskim farmama u anketiranom području

Općina	Broj anketiranih sela	Broj anketiranih farmera	Ukupna površina u ha	Prosječna veličina farme
Peć	11	27	256,9	9,51
Đakovica	16	79	647,51	8,2
Istok	14	60	885,1	14,75
Dečane	7	34	162,72	4,78
Junik	10	15	92,3	5,15
Ukupno	58	215	2044,53	9,51

Izvor: Vlastito istraživanje

Na temelju rezultata ankete prikazanih u tablici 1. može se konstatirati da obiteljska gospodarstva raspolažu sa ukupno 2044,53 ha zemljišta, od čega 23,89% pripada šumama, a ostalo 1556,03 ha je poljoprivredno zemljište. Prosječna veličina posjeda računajući i šume je 9,51 ha, a ako se uzme samo poljoprivredno zemljište 7,24 ha što čini 76% od ukupnog raspoloživog zemljišta. Slična poljoprivredna struktura zemljišnog posjeda susreće se u Portugalu 8,2 ha, Italija 8,4 ha, a manje posjede imaju u Sloveniji 6,3 ha, (Poje 2006), u sjeveroistočnom dijelu Crne Gore 5,38 ha (Koprivica i sur. 2009), Grčkoj 4,2 ha, (Radmanović 2003) u Srbiji 3,5 ha, Hrvatskoj 2,59 ha. Prosječna površina poljoprivrednog gospodarstva u Europskoj Uniji iznosi 17,5 ha, pri čemu 43,2% farmera raspolaže sa više od 5 ha (Čuljat 1999). Jako važan problem je i usitnjenost samih parcela. Prosječna veličina parcela na razini Republike Srbije 0,83 ha, središnje Srbije 0,74 ha, a u Vojvodini iznosi 1,25 *ha* (Nikolić i sur. 2010). Prema (Filipoviću i sur. 2005) jedno poljoprivredno kućanstvo u Hrvatskoj raspolaže sa 2,59 ha, od čega se 1,9 ha upotrebljava u poljoprivredne svrhe, pri čemu je prosječna veličina parcele 0,45 ha i ovisi od regije (Grgić i sur. 2009).

U kontekstu razmatranja posjedovne strukture na farmama u anketiranom području treba istaknuti da je posjed usitnjen na više manjih parcela udaljenih od ekonomskog dvorišta što predstavlja zapreku sa stajališta racionalnog korištenja mehanizacije.



Izvor: Vlastito istraživanje

Graf 1 Veličina posjeda obiteljskih gazdinstava u anketiranom području

Najzastupljenija je grupa farmera sa posjedom do 3 ha, no njihovo sudjelovanje u ukupnim površinama je najmanje. Gotovo je jednak broj farmera sa posjedom veličine od 3,1-6 ha i od 6,1-10 ha. Naime farme sa veličinom do 10 ha zastupljene su s oko 78,1% i raspolažu sa više od trećine dostupnog zemljišta odnosno 37,08%. Sa posjedom većim od 20 ha je svega 9 farmi no njihovo učešće u ukupnim površinama je oko 38%.

U usporedbi sa podacima u Europskoj uniji, Belgiji, Danskoj, Francuskoj, Italiji, Švedskoj, Njemačkoj i Velikoj Britaniji, preko 50% farmi je veće od 10 ha. Dok je u Austriji, Španjolskoj, Irskoj, Portugalu i Grčkoj više od polovice farmi manje od 10 ha (Nikolić i sur. 2005).

U strukturi poljoprivrednog zemljišta dominiraju livade sa 897,92 ha ili 43,92%, u prosjeku po jednoj farmi dolazi 4,18 ha livada. Oranice sudjeluju sa 657,36 ha ili 32, 5%. U sjetvenoj strukturi najzastupljeniji je kukuruz, koji se gaji na preko 50% oraničnih površina odnosno na 332,06 ha, zatim pšenica sa 39 % ili 254,15 ha, ostale površine su zasijane sa ovsom, ječmom i povrćem.

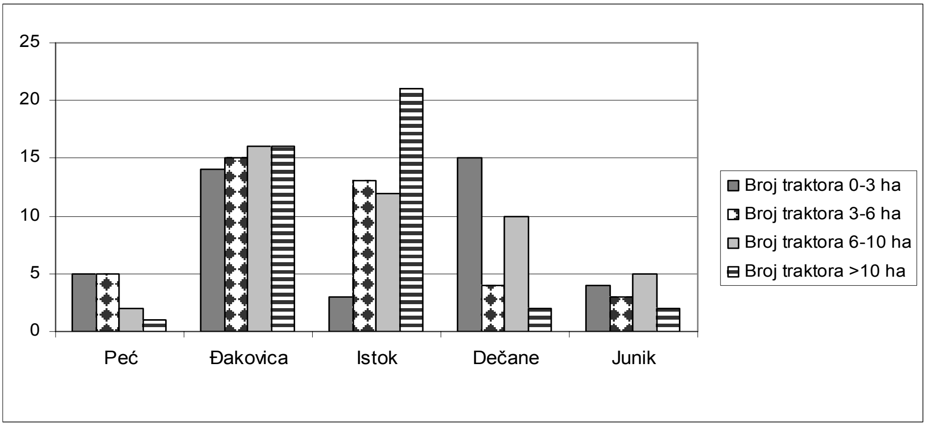
Radi lakšeg uspoređenja i ocjene razine opremljenosti kućanstava poljoprivrednom mehanizacijom, analizirana je zastupljenost jednoosovinskih i dvoosovinskih traktora, kao i energetska opskrbljenost po jedinici površine i broj priključnih strojeva (tablica 2).

Ispitivana kućanstva u spomenutim općinama posjeduju ukupno 183 traktora, pri čemu je dvoosovinskih 91,80 % i 15 jednoosovinskih ili 8,20 % od ukupnog broja traktora.

Tablica 2 Ukupan broj i snaga traktora na anketiranim farmama po općinama

Općina	Dvoosovinski traktori		Jednoosovinski traktori		Ukupno traktora	
	Broj kom.	Ukupna snaga kW	Broj kom.	Ukupna snaga kW	Broj kom.	Snaga kW
Peć	13	449,39	2	20,60	15	469,99
Đakovica	61	2179,86	6	60,9	67	2240,76
Istok	49	2105,3	1	9,4	50	2114,70
Dečane	31	1051,35	6	59,92	37	1111,27
Junik	14	404,40	/	/	14	404,4
Ukupno	168	6190,03	15	150,82	183	6341,12

Obiteljske farme u ispitivanim općinama posjeduju 168 dvoosovinskih traktora, što čini 78,14% od ukupno anketiranih farmera, odnosno na 100 gospodarstava 78 traktora. Usporedbe radi u Sloveniji na 100 gospodarstava dolazi 116, u Austriji 132, Francuskoj 158, a u Velikoj Britaniji 205 traktora (Cunder 2001, Filipović i sur. 2005). No ima i zemalja koje su i slabije ošskrbljene sa traktorima, kao što je Portugal sa 51, Italija sa 59, Hrvatska 61 traktor na 100 gospodarstava (Filipović i sur. 2005, Poje i sur. 2006).



Graf 2 Broj traktora prema veličini posjeda po općinama

U općinama obuhvaćenom anketom zastupljenost traktora po farmama, prema veličini posjeda je različita, no zamjećuje se da traktore posjeduju sva kućanstva koja imaju više od 1,5 ha poljoprivrednog zemljišta. Zanimljivo je, da je u općini Đakovica približni broj traktora na svim farmama bez obzira na veličinu posjeda. U svim općinama kućanstva veličine posjeda do 3 ha ukupno raspolažu sa 41 traktorom, gotovo toliko (42 traktora) imaju i farme veličine preko 10 ha (grafikon 2.). Farme sa većom obradivom površinom posjeduju traktore veće snage motora od 60 kW.

Prosječna snaga dvoosovinskih traktora je 36,84 kW, a njihova ukupna snaga iznosi 6190,03 kW. Traktor se rabi na 9,26 ha korištenog poljoprivrednog zemljišta. Razina opskrbljenosti poljoprivredne površine snagom traktora je 3,98 kW/ha. Usporedbe radi, na privatnom sektoru u Srbiji energetska opremljenost je 2,88 kW/ha, a na jedan traktor prosječne snage 32,27 kW dolazi 11,18 ha (Nikolić i sur. 2010). Korištenje mehaničke snage traktora po jedinici poljoprivredne površine iznosi u Americi 1 kW po ha korištenog zemljišta, a u Europi 0,7 kW, u Njemačkoj 1,7 kW, a u Francuskoj 3,2 kW. U Sloveniji na jedan traktor dolazi 4 ha a u Hrvatskoj 5,32 ha (Poje i sur. 2006. i Stojanović i sur.2000).

Tablica 3 Pokazatelji opremljenosti po općinama

Općina	Prosječna snaga Dvoosovinskog traktora kW	Energetska opremljenost kW/ha	Poljoprivredne površine ha/traktoru
Peć	34,57	2,31	14,94
Đakovica	35,73	4,84	7,39
Istok	42,96	2,95	14,56
Dečane	33,91	8,46	4,01
Junik	28,89	5,55	5,20
Prosjek	36,84	3,98	9,26

U Sloveniji snaga traktora tijekom 1952-2010. godine povećala se sa 19,6-60,8 kW. Prosječna dob traktora u Sloveniji je 2002. godine bila 18,8 godina i godišnje angažiranje bilo je 280 radnih časova (Poje 2012). U Austriji tijekom 1995-1999. godine broj traktora snage do 40 kW smanjen je za 10%, dok od 40-80 kW je povećan za 19%, a preko 80 kW povećan za 46% (Schrottmaier and Handler 2001).

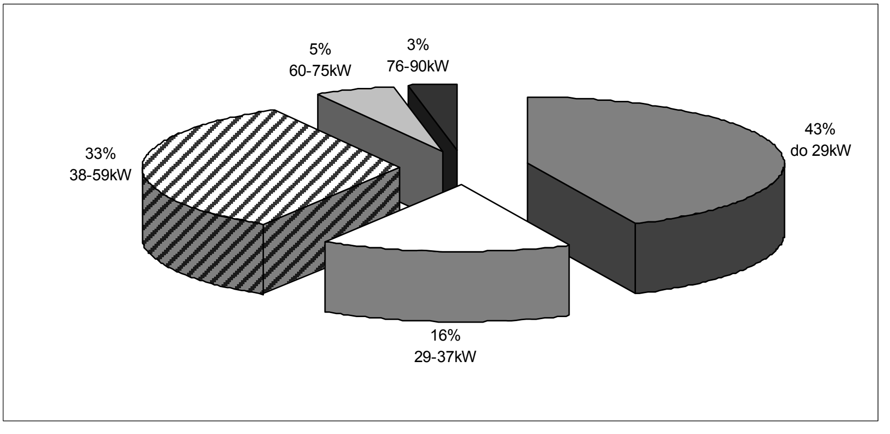
U Slovačkoj smanjenjem broja traktora i povećanjem snage motora povećava se i površina koju jedan traktor obrađuje od 66,4 ha u 1989.godini na 102,1 ha u 1999. godini (Markovič i Zacharda 2001). U Hrvatskoj 35,5% gospodarstva posjeduju dvoosovinske traktore čija je prosječna snaga 34,0 kW, koji obrađuje prosječno 5,32 ha (Filipović i sur. 2005, Šumanovac i sur. 1997). U Poljskoj 8% traktora ima snagu motora veću od 44 kW (Golka 1998). U Mađarskoj prosječna snaga traktora u vlasništvu poljoprivrednih poduzeća je 74 kW a na obiteljskim gospodarstvima 45 kW prosječne dobi 15,3 godine (Hajdu i Mago 2001). Vuković i sur. (1995) navode da je u 1994. godini ukupan broj dvoosovinskih traktora na Kosovu na privatnom sektoru bio 28599. U usporedbi sa 1991. godinom ukupan broj traktora smanjen je za 14,70%. Najzastupljeniji su traktori snage motora od 27-37 kW 48,11%, potom 19-26 kW 29,67%, preko 37 kW 17,64 kW i do 18 kW 4,56%.

U anketi su dvoosovinski traktori prema snazi motora podijeljeni na 6 skupina (tablica 4.).

Tablica 4 Struktura i broj dvoosovinskih traktora po općinama

Kategorija traktora kW	Peć	Đakovica	Istok	Dečane	Junik	Ukupno
do 29	7	28	19	22	13	89
29-37	2	14	9	3	1	29
38-59	4	18	14	5	/	41
60-75	/	1	2	1	/	4
76-90	/	/	2	/	/	2

Najzastupljeniji su traktori u kategoriji do 29 kW kako po broju traktora (52,98%) tako i po ukupnoj snazi motora (41,26%), što je uvjetovano usitnjenim posjedima (grafikon 3.).



Graf 3 Učešće traktora po kategorijama na osnovu ukupne snage

Potom slijedi skupina traktora snage od 38-59 kW sa 24,40% i 29-37 kW sa 17,26% od ukupnog broja dvoosovinskih traktora. Traktori drugih kategorija su zastupljeni u manjem postotku.

U strukturi traktora uglavnom su zastupljeni dvoosovinski traktori sa pogonom na stražnje kotače (87,88%). Evidentirano je samo 16 (12,12%) traktora sa pogonom na sva četiri kotača, čija je prosječna snaga motora 46,55 kW. Deset ovih traktora je u kategoriji između 38-59 kW. Zamjećuje se tendencija povećanja broja ovih traktora u posljednjoj dekadi, osobito uvozom rabljenih traktora iz raznih europskih zemalja od različitih proizvođača.

Anketom je utvrđeno da ima 27 tipova traktora od 11 proizvođača uglavnom 62,52% iz bivših republika SFRJ**.** Najzastupljeniji su traktori Industrije Motora i Traktora 115 ili 68,4% gdje IMT-539 sudjeluje sa 52,98% a IMT-542 sa 10,72% od ukupnog broja dvoosovinskih traktora. Pored ovih traktora farmeri posjeduju još i traktore drugih fabrika Rakovice 9,54%, Masey Ferguson 7,14%, Fiat Agri 4,77%, Universal 3,58% , Deutz-Fahr 2,38% i drugi.

U anketiranom području, pored dvoosovinskih traktora sa kotačima rabe se i 15 jednoosovinskih traktora ili 8,20% od ukupnog broja traktora. To su traktori male snage oko 10 kW, a najzastupljeniji je Labin-progres 140D sa 73,33% od ukupnog broja i ostalo su IMT-509.

Tablica 5 Broj priključnih strojeva na anketiranom području

Općina	Broj priključnih strojeva	Broj priključnih strojeva po traktoru	Broj hektara poljoprivredne površine po priključnom stroju	Broj priključnih strojeva po farmi
Peć	25	1,92	7,77	0,93
Đakovica	174	2,85	2,59	2,20
Istok	112	2,28	6,37	1,87
Dečani	77	2,48	1,61	2,26
Junik	48	3,43	1,52	3,20
Ukupno/ prosjek	436	2,60	3,57	2,02

Podaci iz tablice 5. pokazuju da farmeri u istraživanom području ukupno posjeduju 436 priključnih strojeva, na svakoj farmi po dva. Najviše su zastupljene prikolice 133 ili 30,51% od ukupnog broja priključnih strojeva, što ukazuje na činjenicu da se traktor najviše koristi u transportu. Traktorske prikolice posjeduje 61,86% obiteljskih gospodarstava, ili na svakih 100 dvoosovinska traktora dolazi 79 prikolica. Poslije prikolica najzastupljeniji su plugovi sa 28,44%, traktorske kosilice 19,0% i sakupljači sena sa 12,39% od ukupnog broja priključnih strojeva. U anketiranom području po traktoru dolazi 2,60 stroja sa kojima se obradi u prosjeku 9,26 ha poljoprivrednog zemljišta. U Vojvodini jedan traktor na privatnom sektoru obrađuje 10,25 ha prosječno sa 4,46 stroja. Pored toga na 100 ha obradive površine u Vojvodini dolaze 43,6 priključna stroja (Bošnjak Danica i sur. 2003) dok u anketiranom području 28. Opremljenost traktora sa priključnim strojevima je nedostatna za intenzivniju proizvodnju i postoji potreba osobito za strojevima vijeće širine radnog zahvaća i učinkovitosti.

ZAKLJUČAK

Na temelju iznijetih podataka može se zaključiti da su farme na području zapadnog dijela Kosova dobro opremljene traktorima jer 78 % farmera posjeduje traktor**.** Traktore posjeduju podjednako farmeri koji imaju do 3 ha i oni preko 10 ha zemljišta. Samo je razlika u tome što farme sa većom obradivom površinom raspolažu sa traktorima jače snage motora od 60 kW. Traktor prosječne snage motora od 36,84 kW obrađuje 9,26 ha poljoprivrednog zemljišta. Energetska opskrbljenost oranične površine snagom traktora je dobra jer na hektar obradive površine dolazi 3,98 kW raspoložive snage motora traktora.

Opskrbljenost traktora sa priključnim strojevima je nedostatna i jednom dvoosovinskom traktoru pripada 2,6 priključnih strojeva**.** Uz traktor, najčešći strojevi koje posjeduju poljoprivredna gospodarstva su traktorske prikolice i plugovi, što uvjetuje i malo iskorištenje traktora u toku godine**.** Većina farmera koristi traktore i priključne strojeve samo za svoje potrebe, dok manji broj pruža usluge drugima - susjedima.

Uz pomoć inozemnih projekata, potpore države i povoljnih kreditnih uvjeta nabave poljoprivrednih strojeva, mogao bi se njihov broj povećati čime bi se pozitivno djelovalo na opremljenost obiteljskih farmi i povećanog angažiranja traktora na godišnjoj razini.

ZAHVALA

Rad je dio istraživanja na projektu br.31051 pod nazivom Unapređenje biotehnoloških postupaka u funkciji racionalnog korištenja energije, povećanja produktivnosti i kvaliteta poljoprivrednih proizvoda financiran od strane Ministarstva prosvete i nauke Republike Srbije.

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ANALYSIS OF FAMILY FARMS EQUIPPEDNESS WITH AGRICULTURAL MACHINERY IN WESTERN KOSOVO

RANKO KOPRIVICA, AFRIM SHARKU, BILJANA VELJKOVIC, ASIM THAQI, EMRULLAH SPAHIU, BEKIM CIKAQI

SUMMARY

In order to facilitate the development of agricultural production in western Kosovo, production potentials in the Municipalities of Istog, Decane, Gjakova, Peja and Junik were analysed using statistical data on Kosovo, farmer poll results and information gathered through a personal insight into the situation on the ground. Random sampling was the method used to select villages and family farms for poll purposes. The data collected and analysed showed the average farm size, available land area and number of tractors and attachment machines.

In the five municipalities of the area surveyed a total of 58 villages and 215 private farms.Total area of agricultural land in the surveyed farmers was 1556.03 ha, so that the average size of farms was 7.24 ha. Sown meadow and alfalfa stands, and arable land account for 44% and 32% of the 2044.53 ha total farm land available, respectively, the rest being forests.

There are high variations in the level of use of single- and tandem-axle tractors on farms not only across municipalities but also across villages within their borders. Average power and tandem-axle tractors are 36.84 kW.

Of the total number 183 of tractors, single-axle tractors were represented with only 8.93%. Total energy equipment, as expressed through the total nominal engine power per hectare of agricultural land was in average 4 kW / ha

The farms surveyed have insufficient machinery; therefore, this problem hinders the improvement of agricultural production. Only 78% of the farms surveyed own two-axle tractors that have a cultivation rate of 9 ha and 2.6 attachment machines.

Key words: *farm size, number of tractors, energy equipment, number of attachable units*

41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

WATER DROPLET BALLISTICS IN A SPRINKLER SPRAY FLOW: THE CLASSIC AND QUANTUM DYNAMIC FRAMEWORKS FOR A SINGLE AND MANY-PARTICLE SYSTEMS

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ABSTRACT

One of the most challenging modelling problems in modern engineering is that of a particle crossing a continuous phase (air). In sprinkler irrigation practice this may refer to a water droplet travelling in air from the nozzle to the ground. The challenge mainly refers to the difficulty in designing and solving the system of governing equations for that very complicate process, where many non-linearity occur when describing the relations and dependences among the parameters that rule the phenomenon. The problem becomes even more complicated when not just a single droplet alone is assessed but a multi-droplet system is accounted for. In addition to the inter-parameter dependencies, it is also observed an inter-droplet reciprocal connection, mainly due to electrical interactions between the hydrogen and the oxygen atoms of the different water molecules. An alternative to traditional classic approaches to analyse water droplet dynamics in sprinkler irrigation have been recently proposed in the form of a quantum approach, but the whole classic-quantum and single-droplet versus multi-droplet alternatives need to be discussed and pinpointed and these are among the main aims of the present paper which focuses on the theoretical part of the issue, thus highlighting the new perspectives of a deeper comprehension in the spray flow related phenomena.

Key words: *spray particles kinematics, single- and multi-droplet systems, classic and quantum mechanics, sprinkler water droplets, mathematical modelling*

INTRODUCTION

Albeit the process of a liquid particle moving within a gaseous phase may describe many different technical applications, broadly investigated in many scientific sectors and from many different points of view, a complete, clear and generally applicable mathematical modelling is still far from having been achieved. Very recently Molle et al. (2012) gave an extremely useful experimental contribution in the field of irrigation, which will be of substantial usefulness for future investigations and modelling attempts. The results of the present paper were mainly reached by featuring the sprinkler irrigation context. The outcomes, if suitably adapted, may also apply to other fields and aims, such as pesticides distribution, heat removal or fire suppression, to name but a few. The fundamental problem is not just that of solving the equations ruling the development of the system and of the phenomenon but, upstream of that, it lies in the characterization of such equations. According to the Authors of this paper such hurdle can be attributed to a not complete understanding of the system-process evolution. This of course should not be taken as a form of underestimation of the analytical difficulties due to the mutual interrelationships between the parameters that govern the process, on the one hand, and the characteristics of the particles involved, on the other. In fact the main thematic scientific literature (Edling, 1985; Keller & Bliesner, 1990; Kincaid & Longley, 1989; Kinzer & Gunn, 1951; Thompson et al., 1993) tries to overcome such computational complication binding the solutions achieved to the specific case studies faced. In general, however, the kinematic analysis of sprinkler water droplets during their aerial path is devised adopting a Newtonian approach and considering a single-droplet system. A ballistic form of the same viewpoint, based on a Newtonian approach for a single-droplet system, was also proposed by the Authors (De Wrachien & Lorenzini, 2006; Lorenzini, 2004; Lorenzini, 2006). This approach will be described in the paper as a classic/single-droplet model. Coming again to the "not complete understanding of the system-process evolutions" quoted above, the issue has very recently led the Authors of the present work to the belief that to fully comprehend and describe the phenomenon another viewpoint could be considered: the quantum one (Dirac, 1931). The results which were arrived at (De Wrachien et al., 2012) were in the form of the time-dependent Schroedinger's equation and of the Scale Relativity Theory (Nottale, 1992) written as a Riccati equation. The former, in particular, was written for single-droplet systems, seen as waves and material particles (Goldstein et al., 2011) and considering a Lagrangian or Eulerian description for both steady and transient states. The present paper, therefore, will treat further possibilities to study the kinematic behaviour of both single- and multi-droplet systems during their aerial path in according to both the classic (i.e. Newtonian) and quantum approach.

THE CLASSIC MECHANICAL PICTURE

We do not wish to review the whole classic approach, as reported in the literature, but to explore the modelling possibilities in relation to the topic of the present paper. Anyway to further deepen the state-of-the-art one could refer to other publications by De Wrachien and Lorenzini (Lorenzini, 2004; De Wrachien & Lorenzini, 2006; Lorenzini, 2006). Some more information on spray kinematics modelling (mainly Lagrangian) both in sprinkler irrigation and in chemical sprays contexts are also available (Keller et al.,1990; Teske et al., 1998a,b;

Teske & Ice, 2002), while spray drift Lagrangian modelling is treated in Hewitt et al. (2002), and in Bird et al. (2002). Recently the Authors_(Lorenzini, 2004; De Wrachien & Lorenzini, 2006; Lorenzini, 2006) defined and validated (see also: Edling, 1985, and Thompson et al., 1993) the following simplified analytical model feasible to solve water droplets kinematics, based on the Second Principle of Dynamics:

$$\begin{cases} m\ddot{x} = -k\dot{x}^2 \\ m\ddot{y} = -k\dot{y}^2 - ng \end{cases} \tag{1}$$

developed in terms of parametric equations:

$$x(t) = \frac{m}{k}\ln\left(\frac{v_{0x}k}{m}t + 1\right)$$

$$\dot{x}(t) = \frac{mv_{0x}}{m + kv_{0x}t}$$

$$y(t) = h - \frac{m}{k}\ln\frac{\cos\left(\arctan\frac{\sqrt{\frac{k}{m}}v_{0y}}{\sqrt{\frac{n}{m}g}}\right)}{\cos\left(\arctan\frac{\sqrt{\frac{k}{m}}v_{0y}}{\sqrt{\frac{n}{m}g}} - t\frac{\sqrt{kng}}{m}\right)}$$

$$\dot{y}(t) = -\sqrt{\frac{ng}{k}}\tan\left[-\frac{\sqrt{ngk}}{m}t + \arctan\left(\sqrt{\frac{k}{ng}}v_{0y}\right)\right] \tag{2}$$

being: f the friction factor according to Fanning (Bird et al., 1960); g gravity; h [m] the initial y co-ordinate; $k = \frac{f\rho A}{2}$ the friction coefficient; m the particle mass; n the droplet actual mass (buoyancy); t time; v_{0x} and v_{0y} initial horizontal and vertical velocity components; x, y, $\dot{x}$, $\dot{y}$, $\ddot{x}$, $\ddot{y}$ co-ordinates, velocities and accelerations along the horizontal and vertical axes. Being the model analytical, albeit simplified, it is applicable to a variety of problems but the more reliable results were obtained for high Reynolds numbers. Obviously, as mentioned above, the model presented is one of the possible ones which can describe a single-droplet system from a classic viewpoint: the choice was mainly due to the fact that such model is tightly related to the second law of dynamics ,as previously mentioned. To complete the topic, anyway, one may in general face the kinematic analysis of a multi-droplet system (i.e. composed of N droplets) from a classic viewpoint by means of the following analytical expression (Lopreore and Wyatt, 1999):

$$m_k \frac{d^2 Q_k(t)}{dt^2} = -\nabla_k V \cdot Q(t) \tag{3}$$

where m_k ($1 \leq k \leq N$) is the k-th particle mass, Q is the classic trajectory, V is a potential function accounting for time dependence (Lopreore and Wyatt, 1999) and ∇_k is the 3-D gradient operator referred to the k-th particle.

Validation of the dynamic model

The validation of the classical 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 data set are reported in table 1

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 (dm3/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

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).

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.

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

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)	Thomps n 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

THE QUANTUM MECHANICAL PICTURE

Quantum mechanics for a single particle

The discrepancies between a classic *Vs.* quantum description, on the one hand, and between a single-droplet *Vs.* multi-droplet one, on the other, may be highlighted examining the following expressions for single- and multi-droplet systems (respectively) as compared to those in the previous section of this paper (Lopreore and Wyatt, 1999; De Wrachien et al., 2012):

$$m\frac{d^2Q(t)}{dt^2} = F(t) \tag{4}$$

$$m_k\frac{d^2Q_k(t)}{dt^2} = \nabla_k\left(V \;|\; V_{qu}^{\psi_t}\right)Q(t) \tag{5}$$

where: F is force, m particle mass, $V_{qu}^{\psi_t} = -\sum_{j=1}^{N}\frac{\hbar^2}{2m_j}\frac{\nabla_j^2|\psi|}{|\psi|}$ $(1 \le j < k \le N)$ the quantum potential, $\hbar$ the Dirac constant. Comparing equation (5) with equation (3), the first useful consideration is that, if the quantum potential assumes a value which is in the vicinity of zero, then the quantum and classic kinematic pictures tend to coincide. But as a quantum viewpoint presumes that the "object" evaluated is not just a material particle but also a wave, then for each element of a multi-droplet system one may write the time-dependent Schroedinger's equation as:

$$D^2\nabla^2\psi(\vec{x},t) - \frac{1}{2}\cdot m\cdot V(\vec{x},t)\cdot\psi(\vec{x},t) = -i\cdot D\cdot\left(\frac{\partial}{\partial t}\right)\cdot\psi(\vec{x},t) \tag{6}$$

where D is the diffusion coefficient, $\psi(\vec{x},t) = R(\vec{x},t) \cdot exp[S(\vec{x},t)]$, R is the wave amplitude, S is the wave phase. Equation (6) can be re-written in the form of continuity and Euler-type "quantum fluid-dynamic equations", respectively (Wyatt, 2005; Ghosh, 2011; De Wrachien et al., 2012):

$$\frac{\partial}{\partial t}\rho(\vec{x},t) + \nabla[\rho(\vec{x},t) \cdot \vec{v}(\vec{x},t)] = 0 \tag{7}$$

$$\frac{d}{dt}\vec{v}(\vec{x},t) \equiv \left[\frac{\partial}{\partial t} + \vec{v}(\vec{x},t) \cdot \nabla\right] \vec{v}(\vec{x},t) = -\frac{1}{m} \cdot \nabla[V(\vec{x},t) + Q(\vec{x},t)] \tag{8}$$

(ρ is density, $\vec{v}$ is velocity, V is the classic potential, Q is the quantum potential). Equation (6) can be re-worked by means of Nottale's Scale Relativity theory (Nottale, 1992) using a probability density function for a semi-infinite domain (Hermann, 1997) for writing the second law of dynamics in the complex field (u is a scalar potential, W is a complex velocity):

$$-\nabla u = m \cdot \frac{ð}{dt}\boldsymbol{W} \tag{9}$$

Dividing the real and imaginary parts in equation (9) (U is the imaginary part of W) one gets:

$$\begin{cases} -D \cdot \Delta U - (\mathrm{U} \cdot \nabla)U = -\nabla u \\ \frac{\partial}{dt}U = 0 \end{cases} \tag{10}$$

which (first equation) may be re-written for a 1-D path as a Riccati equation (Al-Rashid et al., 2011), being c a constant and $y(x)$ an arbitrary function of x:

$$\frac{d}{dx}U(x) = -\frac{m}{\hbar} \cdot U^2(x) + \frac{2}{\hbar} \cdot (u(x) - c \cdot m) \tag{11}$$

$$\frac{d^2}{dx^2}y(x) - \frac{2 \cdot m}{\hbar^2} \cdot (u(x) - c \cdot m) \cdot y(x) = 0 \tag{12}$$

Both are very powerful tools as they allow for quantum particles computations avoiding the time-dependent Schroedinger's equation, even if just for 1-D domains, which is useful in particular cases as for instance a droplet vertical downfall.

Quantum mechanics for many-particle systems

Considering multi-droplet systems the time-dependent Schroedinger's equation needs to be suitably re-written, provided that water has a V-shaped molecule resulting in a magnetic field due to the electric potential between oxygen and hydrogen. This results in (Gosh, 2011):

$$\left[\frac{1}{2}\sum_j\left(-2iD\nabla_j-\vec{K}(\vec{x_j},t)\right)^2+\frac{1}{m}V\left(\overrightarrow{x^N},t\right)\right]\psi\left(\overrightarrow{x^N},t\right)=2iD\frac{\partial\psi\left(\overrightarrow{x^N},t\right)}{\partial t} \tag{13}$$

being $V\left(\overrightarrow{x^N},t\right)$ the electric potential, $\phi(\vec{x_j},t)$ the external time-dependent scalar potential, $\overrightarrow{x^N}$ the *N*-particle coordinates. This may be transformed similarly to single-droplet systems as:

$$\psi\left(\overrightarrow{x^N},t\right)=R\left(\overrightarrow{x^N},t\right)exp\left[S\left(\overrightarrow{x^N},t\right)\right] \tag{14}$$

then giving the continuity equation:

$$\frac{\partial\rho^N\left(\overrightarrow{x^N},t\right)}{\partial t}+\sum_{k=1}^N\nabla_k\vec{J_k}\left(\overrightarrow{x^N},t\right)=0 \tag{15}$$

and the Euler-type equation:

$$\frac{\partial\vec{v_k}\left(\overrightarrow{x^N},t\right)}{\partial t}+\sum_j\left(\vec{v_j}\left(\overrightarrow{x^N},t\right)\nabla_k\right)\vec{v_j}\left(\overrightarrow{x^N},t\right)+\sum_j(1-\delta_{jk})\vec{v_j}\left(\overrightarrow{x^N},t\right)\times(\nabla_k\times)\vec{v_j}\left(\overrightarrow{x^N},t\right)=$$
$$=-\left(e\vec{E}(\vec{x_k},t)+\frac{e}{c}\vec{v_k}\left(\overrightarrow{x^N},t\right)\times\vec{B}(\vec{x_k},t)\right)-\frac{1}{m}\nabla\left[V_0\left(\overrightarrow{x^N},t\right)+U\left(\overrightarrow{x^N},t\right)+Q\left(\overrightarrow{x^N},t\right)\right] \tag{16}$$

∇_k is the gradient operator related to the coordinate $\vec{x_k}$ of the *k*-th particle; $\rho^N\left(\overrightarrow{x^N},t\right)=$ $=R^2\left(\overrightarrow{x^N},t\right)$ the *N*-particle density; $\vec{J_k}\left(\overrightarrow{x^N},t\right)=\rho^N\left(\overrightarrow{x^N},t\right)\cdot\vec{v_k}\left(\overrightarrow{x^N},t\right)$ the fluid current density; $\vec{v_k}\left(\overrightarrow{x^N},t\right)=\frac{\hbar}{m}\cdot\nabla_k S\left(\overrightarrow{x^N},t\right)-\frac{e}{mc}\cdot\vec{A}\left(\overrightarrow{x^N},t\right)$ the velocity field of the *h*-th particle; $\vec{E}(\vec{x_k},t)=-\nabla\phi(\vec{x_j},t)-\frac{1}{c}\cdot\frac{\partial\vec{A}\left(\overrightarrow{x^N},t\right)}{\partial t}$ the external electric field; $\vec{B}(\vec{x_k},t)=curl\,\vec{A}\left(\overrightarrow{x^N},t\right)$ the external magnetic field. The first integrations of equations (15) and (16) were carried out by Madelung (Madelung, 1926), and the work was successively extended by Bohm (Bohm, 1952a; 1952b).

THE DYNAMICAL AND NUMERICAL APPROXIMATIONS

In any case an analytical “closed form” solution of the equations describing the quantum kinematics of particles is obviously extremely difficult and even the most advanced techniques often fail to achieve such purpose, albeit in the years to come this attempt will not be abandoned. This is why, recently, different forms of approximation have been introduced to treat the “quantum fluid-dynamic equations”: among those, literature reports numerical and dynamical approximations (Kendrick, 2011), which are both currently being developed. The formers may rely on Eulerian, Lagrangian or Arbitrary Lagrangian-Eulerian descriptions, all characterised by advantages and disadvantages. Lagrangian descriptions are easier in the form through which they write down the equations, as the grid moves with the particle and follow its evolution; but they become difficult to handle as, step after step, the grid becomes non-uniform with problems in the accuracy of the flow solution. Eulerian descriptions are complicate at the beginning of the simulation, due to an increased analytical complication, but prove to be more practical afterwards as the grid does not change with time. A uniform grid following the flow evolution is instead met in the Arbitrary Lagrangian-Eulerian descriptions, also adopted in some computational fluid dynamics codes. The dynamical approximations do not rely in a mathematically-simplified description of the problem but in a physically-simplified one by superimposing some particular conditions (e.g. incompressible flow) or neglecting some other characteristics considered not so relevant to the whole picture. Obviously it would not be inconceivable to imagine a mixed numerical-dynamical approximation approach and we feel that on this aspect research will invest a part of its future resources: in relation to this challenge one should highlight that quantum trajectories can be treated quite similarly to the classic ones when considering, for the particles treated, the suitable relations among the dynamic and the potential part of the problem.

CONCLUSIONS

Describing in an analytically and physically correct way the phenomenon of a water droplet travelling from the exit of a sprinkle nozzle down to the ground is an extremely difficult task, as many studies performed in the last decades have broadly demonstrated, trying to find a solution via different means and approaches. The present investigation starts from a recent hypothesis made by the same Authors of this paper: a water droplet could be treated as a quantum object, characterised both by material particle and by wave properties. Thus the time-dependent Schroedinger's equation may be employed to study the process and a parallel classic-quantum description may be achieved, both for single-droplet and for multi-droplet systems. The latter systems are not only affected by the usual fluid-dynamic parameters but the mutual repulsions and attractions between particles are to be accounted for, in the form of electric-magnetic potentials bound to the molecular structure of water: this allows one to re-write the time-dependent Schroedinger's equation and the so-called “quantum fluid-dynamic equations” in a novel and more complete form. In addition the paper provides a general overview of the numerical and dynamical approximations currently available to treat the systems of equations arrived at. Future studies will deepen the novel modelling approach suggested to make it more and more suitable for practical applications.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Prethodno priopćenje
Preliminary communication

CLIMATIC RISKS DETERMINED BY THE PLUVIOMETRIC REGIME REGISTERED IN THE BANAT AREA DURING 1961-2010

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SUMMARY

Most papers describe the Banat area as the historical and geographic region from the south-west of Romania encompassing the Timis county, the Caras-Severin county, part of the Arad county south from the Mures river and the western part of the Hunedoara county.

The Banat area has warm mild continental climate, a moderate humidity during the entire year, without an excessively dry season and relatively moderate summers. The cold and the warm seasons are well delimited from a thermal point of view. The plain areas in Banat are characterized by a wide opening for all wind directions with advections of the various air-masses.

Atmospheric precipitations are one of the most important climatic characteristics and of the main links of the water circuit in nature. The term atmospheric precipitations is used for all condensation and crystallization products of the atmospheric water, which usually fall from clouds and land on the earth surface in liquid form (rain, drizzle), solid form (snow), or in both forms at the same time (slush).

The main pluviometric maximum is achieved during the month of June. In the Banat plains the average precipitation quantities are less than 100 mm, in the highlands they are over 100 mm and in the mountains they vary between 80 mm and 178 mm.

The main pluviometric minimum is registered in February and March. Atmospheric precipitations fall under the natural risk category, and, according to their origin, under the subtype of natural climatic risks, which, on hydrologic level, *result in floodings with catastrophic effects. Droghts which appear due to the lack of atmospheric precipitations also fall under natural climatic risks. Here we can mention the drought of the 1998 summer in the southern part of the country or the one in 2000.*

For the Banat region, the main pluviometric risks are humidity excess, as well as droughts. Here we can also add pouring rain and hail storms [9]. One of the rainiest years was 1970, when there were 844.2 mm registered in Timisoara and 821.5 mm in Arad.

The decrease of the multiannual average precipitation value by 15-20% in some years labels those years as excessively droughty. If the negative deviation is higher than 25% the year is labeled as exceptionally droughty, situation registered in 1961, 1962, 1983, 1992, 1993 and 2000.Very low precipitation quantities were registered in 1967, 1971, 1973, 1976 and 1994.

The droughtiest year was 2000. The summer of 2000 was the droughtiest summer in the last 100 years and the spring of the same year was placed among the first 7 droughtiest springs from the same period. The negative effects of this scarce pluviometric regime were accentuated by the simultaneous registering of an abnormally high thermal regime during the entire spring-summer interval in 2000.

Key words: *atmospheric precipitations, meteorological stations, droughtiest year, climatic risks*

INTRODUCTION

Banat is a historical entity that includes geographical areas belonging to three countries: Romania, Serbia, Hungary. In Romania, in most works, Banat is a historical and geographical region in southwestern Romania including Timis, Caras-Severin, Arad County south of Mures, west of Hunedoara County (Sălciva and Pojoga places), southwestern area of the Mehedinti county.

Any divergence related to the territorial extension does not affect essential, Banat area.Northern limit of Romanian Banat is the river Mures, in north-west the state border with Hungary, in west and south the state border with Serbia (part of it being the Danube River). To the east limit consists of Poiana Rusca Mountains, Tarcu-Godeanu, Cerna and Mehedinti Mountains.

Banat Plain has an area of 9800 km^2, laing about half of the Banat surface. Altitudes ranging from 75 m where Timis river is out of the country , up to 200 m below Pogănişului Hills. G. Posea delimits four major types of fields, namely: an alluvial plain created by the river Mures in North, a low plain-of Timis and Bega river, the Lugoj plain and a Glacis type plain under Dognecei Hills.

METHODS

Climate is defined by the OMM as a summary weather conditions in a particular area characterized by long strings of atmospheric variables data in the area for at least 30 reference years. Climate elements include temperature, precipitation, humidity, sunshine, wind speed, atmospheric phenomena such as storms, frost, fog and other weather features.

The climate of a region is determined by radiative, dynamic and physical geographycal factors.They directly influence spatio-temporal variations of climatic elements in a given territory.

Natural climate variability, often determine meteorological extreme weather phenomena. A meteorological phenomenon is considered highly when he determines the system passage much different from climatic norm.

General atmospheric circulation represents the main genetic factor of rainfall and storm risks. Forms and types of precipitation, also the duration and intensity depend on the different types of atmospheric circulation and air masses involved.

In order to highlight the precipitation variation in the last 50 years, we analyzed the annual precipitation quantities registered at the Arad and Timisoara meteorological stations for the period 1961-2010, and from some pluviometric posts in Banat as well.

RESULTS AND DISCUSSION

Banat region has a warm temperate continental climate with moderate humidity throughout the year without a summer dry season with relatively mild summers, hot and cold season being well defined.

The Banat plain areas are characterised through a wide opening to all the wind directions, with advections of the various air masses. Rainy periods are generally determined by the baric cyclone formations.

In the West and south-west of the country, atmospheric fronts have a higher frequency, due to the position of their trajectories and the Carpathians orografic dam, which is why the frontal precipitation will prevail. Atmospheric precipitation is one of the most important features of the climate and one of the main links of the water cycle.

Rainfall term refers to all products of condensation and crystallization of water vapor in the atmosphere, which usually fall from the clouds and reach the surface in liquid form (rain, drizzle), in solid form (snow), or both forms at the same time (freezing rain).

Meteorological stations in the network perform two types of observations on rainfall Weather stations in the network shall be carried out on two types of observations of atmospheric precipitation

General circulation characteristics of the atmosphere and surface structure are the fundamental causes of land assets that determine the territorial distribution of rainfalls. Rainfall show a high variability, both in time and space.

Annual rainfall regime shows the distribution of rainfall over different periods of the year. Annual pluviometric regime is a typical temperate-continental climate, with a maximum in June and a minimum in February and March. The analysis of monthly average quantities found a decrease in values from January to March inclusive, after which it increases reaching a maximum in June (table 1). Then precipitation will decrease until November, when they grow again until January. Maximum rainfall occurs mainly in June.

Table 1 Average monthly amounts of precipitation in Banat (1961-2010)

Station/months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Sannicolau	31,6	26,9	30,5	45,5	51,1	73,7	56,7	48,7	40,2	34,7	41,5	46,1
Jimbolia	37,8	36,9	33,2	46,2	58,2	70,8	52,7	50,6	41,5	36,8	46,2	47,2
Arad	34,6	32,6	33,9	48,7	61,7	85,8	60,9	52,9	45,0	38,4	45,0	49,8
Timisoara	39,6	37,3	36,9	48,1	64,7	81,1	58,2	51,3	43,6	51,2	49,3	49,1

At Beba Veche, the most western point of Romania, recorded the lowest value, 521 mm, then the quantities increase to the East and South, because of higher altitude and submeditareneene influences, reaching 691 mm in Lugoj.n the hot half of the year, months of April to September, the quantities of precipitation sums, in the Romanian Banat, 60-70% of the average annual quantity. The average quantity of this season is less than 400 mm in the plain regions, unlike the Romanian Plain, where the values are generally under 350 mm.

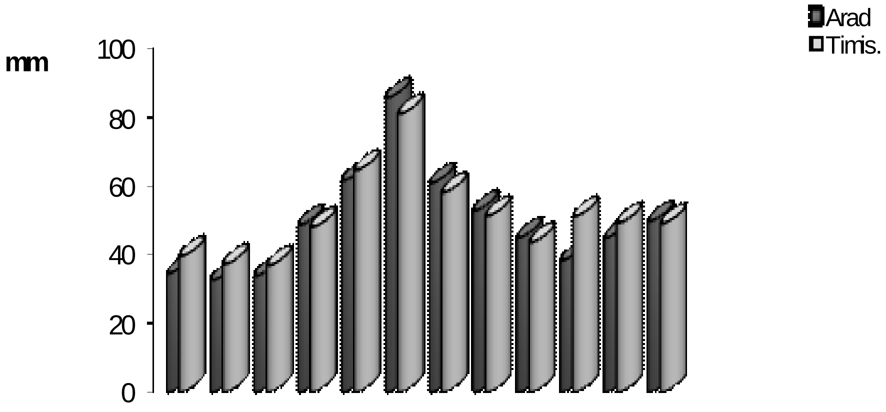

Figure 1 Multiannual average monthly precipitation amounts in Arad and Timisoara

Percentage values increase from 31 to 34% in the plains, to 40-41% in the mountains. Higher percentage in the mountains is explained by orographic rainfall, along with the front. Quantities of water falling in the summer in the lowlands varies between130 mm at Sânnicolau Mare, 215 mm in Lugoj and 243 mm from Bocşa. In hilly regions quantities varies much reaching over 320 mm in Borlova. In mountain areas quantities exceeding 400 mm.

Autumn average quantities of precipitation is about 22% of the total annual and winter rate is 20-22%. Quantities of water are slightly lower than those that fall in the spring. They have an important role for autumn crops. Quantities of water varies from 110 mm in the plains and over 230 mm in the mountains. Quantities of water falling in winter are the most reduced. They exceed the minimum 110 mm in the plains and reach 170 mm in Cuntu. Mixed precipitation is rain, snow and sleet.

Climate hazard represents a random climatic phenomenon, or the probability of occurrence in a region in a given period of a natural phenomenon with great destructive potential, such as hurricanes or tropical cyclones. Risk is defined as "the potential number of casualties, injuries, property damage of any kind, produced during a reference period in a given region, where there is a particular natural phenomenon"

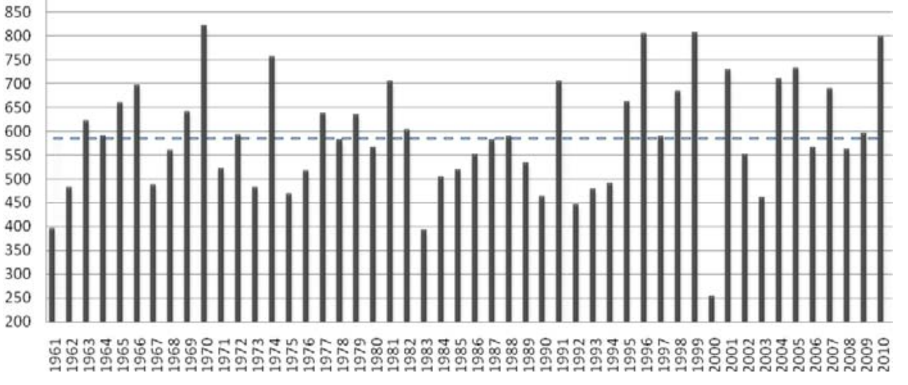

Figure 2 Annual amounts of precipitation in Arad (1961-2010) and yearly averages

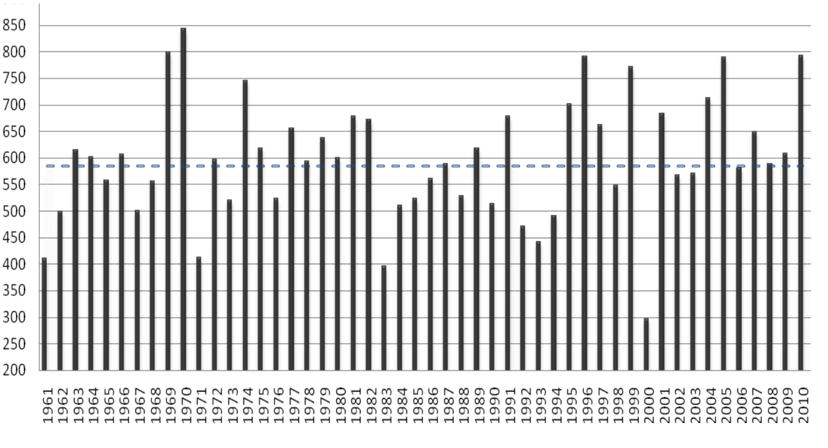

Figure 3 Annual amounts of precipitation in Timişoara (1961-2010) and yearly averages

Climate risks, and in particular the rainfall, may give rise to other risks: hydrological, geomorphological, ecological or environmental conditions. For Banat, the most important risks are humidity excess and dryness and drought phenomena. To these are added the heavy rains and thunderstorms accompanied by hail.

To point rainfall fluctuations in the last 50 years [9] have examined the annual amounts of precipitation from Arad weather stations (Figure 2) and Timisoara (Figure 3) between 1961-2010, but also some rainfall stations in Banat.

In Banat excess humidity is determined by rainfall generated by the Icelandic Basin activity or Mediterranean cyclones with normal or retrograde evolution. When cyclonic activity persists accumulates large amounts of precipitation.

When these surplus amounts of precipitation occur in a very short space of time talking about torrential rain. Annual average quantities increase by 15-20% over the average multi-annual award years respectively classified as excessive rain.

The years with positive deviations more than 30% shall be allocated the qualifier exceptionally rainy years.

Excessive rainy years proved to be 1966, 1970, 1999 and 2010[9]. In Timișoara meteorological station the 1969-1970, 1974, 1981, 1982, 1991, 1995-1996-1997, 1999, 2001, 2004, 2005, and 2010 have been years with rainfall in excess, years of floods have occurred more or less severe.

In Arad meteorological station surplus precipitation years were the 1970s, 1974, 1981, 1991, 1999, 2001, 2004, 2005, 2007 and 2010.

Table 2 Exceptionally rainy years in Banat, with the percentage deviation more than 30%

Years	Meteorological station	Precipitations	The deviation from the average %
1966	Berzasca	976,3	54%
	Buzias	922,1	44%
	Caransebes	1055,1	39%
1970	Bucova	1513,3	67%
	Timisoara	844,2	43%
	Recas	854,1	39%
	Arad	821,5	39%
1999	Ortisoara	980,9	80%
	Tirol	1129,7	64%
	Resita	1108,8	46%
	Arad	806,1	37%
	Timișoara	772,3	31%
2010	Arad	799,2	36%
	Timișoara	793,2	35%

One of the most rainy year was 1970. In Timișoara were registered in that year, 844,2 (table 2) mm while in Arad.821,5 mm. At the pluviometric station Coșteiu de sus was measured 1692 mm in 1970, with more 119% compared to the multi-annual average. The decrease of the average quantities of rainfall with 15-20% from the multi-annual average assigned to the respective years the qualifier of excessively droughty. If the negative deviation is higher than 25% the year is qualified as exceptionally droughty, situation registered in 1961, 1962, 1983, 1992, 1993 and 2000[9].

Table 3 Exceptionally droughty years in Banat, with the percentage deviation more than 25%

Years	Meteorological station	Precipitations	The deviation from the average %
1961	Periam	355,0 mm	-66%
	Lugoj	415,7 mm	-40%
1983	Giarmata	343,2 mm	-42%
	Jimbolia	338,2 mm	-40%
	Timișoara	407,2 mm	-32%
1993	Cenei	330,9 mm	-39%
	Buziaș	398,5 mm	-38%
	Recas	432,6 mm	-29%
2000	Jimbolia	218,5 mm	-56%
	Arad	254,2 mm	-55%
	Timișoara	296,3 mm	-49%
	Sânnicolau Mare	267,7 mm	-49%

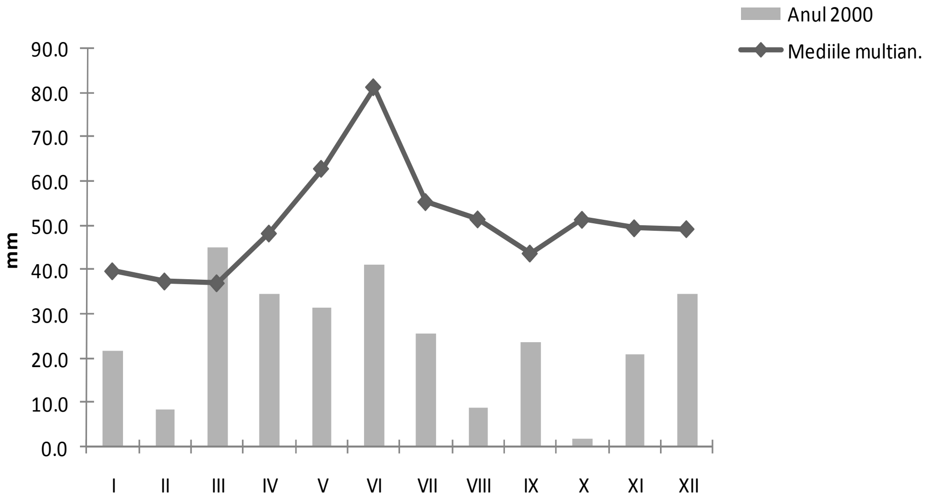

Figure 4 Monthly rainfall amounts in Timișoara 2000, compared with the multiannual monthly average

Very low precipitation quantities were registered in 1967, 1971, 1973, 1976 and 1994. The doughtiest year was 2000 (figure 6). The summer of 2000[8] was the doughtiest summer in the last 100 years and the spring of the same year was placed among the first 7 doughtiest springs from the same period. The negative effects of this scarce pluviometer regime were accentuated by the simultaneous registering of an abnormally high thermal regime during the entire spring-summer interval in 2000.

CONCLUSIONS

Excessive rainy years proved to be 1966, 1970, 1999 and 2010. In Timişoara meteorological station the 1969-1970, 1974, 1981, 1982, 1991, 1995-1996-1997, 1999, 2001, 2004, 2005[9], and 2010 have been years with rainfall in excess, years of floods have occurred more or less severe.

In Arad meteorological station surplus precipitation years were the 1970s, 1974, 1981, 1991, 1999, 2001, 2004, 2005, 2007 and 2010.

The month of April 2005 has been characterized by a very high humidity generated by large quantities of precipitation. Appreciable quantities of rain fallen in the periods that have succeeded at intervals of a few days also the amount of water added, mainly in the snow at altitudes above 1200-1300 m have led to record successive flash floods on the rivers Timiş and Barzava.

Monthly rainfall amounts recorded in April 2005 were particularly large at many stations representing the highest value in the whole range of observations.

Drought represents 15-20% of the total days of the year. The dryness phenomenon has a frequency of 25-27%. Together, the two phenomena have a average annual frequency between 40.5% in the North and 48.2% in the South. Therefore, the two phenomena sums half of the year in the southern part of the plain and somewhat less on the rest of the territory.

The number of drought days highlights during the year, the presence of an autumn droughts and also spring or winter, the autumn droughts being much more intense. The drought phenomenon may occur, across the plain in any month of the year with the highest frequency in the July-October period.

In the winter months, and beginning of spring on the analyzed territory have become more driest in recent years while the beginning and middle of autumn and the middle of the summer the wettest.

To decrease the effects of drought in agriculture is used irrigation, cultivated plant species resistant to dryness and we use different agricultural systems that reduce the loss of water from the soil.

The summer of 2000 was the doughtiest summer in the last 100 years and the spring of the same year was placed among the first 7 doughtiest springs from the same period. The negative effects of this scarce pluviometer regime were accentuated by the simultaneous registering of an abnormally high thermal regime during the entire spring-summer interval in 2000.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.16:631.51:633.16:635.655
Prethodno priopćenje
Preliminary communication

EKONOMIČNOST PROIZVODNJE SOJE I JEČMA NEKONVENCIONALNIM SUSTAVIMA OBRADE TLA

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SAŽETAK

Istraživanje nekonvencionalnih sustava obrade tla provedeno je na pokusnom polju u blizini Starog Petrovog Sela (45° 10' N, 17° 30' E) u uvjetima semi-humidne klime na tlu teksturne oznake praškasta ilovača. Pokus s pet različitih varijanti obrade tla postavljen je na površini 15,5 ha, a sustavi obrade tla i primijenjena oruđa bili su: CT – plug, tanjurača, sjetvo-spremač, sijačica; RT 1 – rovilo, tanjurača, sjetvospremač, sijačica; RT 2 – rovilo, integrirani agregat zvrk drljača + sijačica; RT 3 – plug, integrirani agregat zvrk drljača + sijačica; RT 4 – rovilo, plug, integrirani agregat zvrk drljača + sijačica. Na proizvodnju soje i jarog ječma značajan su utjecaj imala klimatska obilježja, te su pojave sušnih razdoblja tokom vegetacijskih sezona mogle utjecati na redukciju prinosa. U uzgoju soje najveći prosječni urod od 3,78 t ha^{-1} ostvaren je na varijanti pokusa s reduciranom obradom RT 1, dok je najviši prosječni urod ječma od 3,20 t ha^{-1} zabilježen je na varijanti RT 2. Najveće uštede energije i radnog vremena u obradi tla, uz najniže ukupne troškove proizvodnje, ostvarene su na varijanti pokusa s reduciranom obradom RT 2, no zbog značajno nižih uroda ovaj sustav nije se pokazao primjerenim u proizvodnji soje. Najvišu ekonomičnost proizvodnje soje pokazala je varijanta s reduciranim sustavom obrade RT 1 (koeficijent 2,16), dok je u proizvodnji ječma najekonomičniji bio sustav RT 2 (koeficijent 1,81). Kod izbora sustava obrade tla, uz pretpostavku ujednačenih razina prinosa, prednost bi trebalo dati sustavu s nizom razinom agrotehnike, ne samo radi snižavanja troškova, već i zbog mogućnosti jednostavnije organizacije proizvodnje obzirom na manji utrošak radnog vremena ljudi i strojeva.

Ključne riječi: *obrada tla, utrošak energije, troškovi proizvodnje, dobit*

UVOD

U ratarskoj proizvodnji obrada tla dominira kao najveći potrošač energije. Od izravno utrošene energije za radove u polju više od polovice otpada na obradu tla ukoliko se primjenjuje konvencionalni sustav obrade. Baziran na oranju lemešnim plugom u osnovnoj obradi, te dopunskoj obradi tanjuračama i raznim kombiniranim oruđima konvencionalni sustav obrade tla je skup i spor stoga što iziskuje veliki utrošak energije i radnog vremena. Dugogodišnja primjena konvencionalne obrade u ratarstvu iskazala je značajne ekonomske i ekološke nedostatke. S ekonomskog stajališta nedostaci konvencionalnog sustava obrade tla su: izrazito veliki utrošak energije i ljudsko-strojnog rada, veliki investicijski troškovi i troškovi održavanja mehanizacije, te u konačnici veći troškovi proizvodnje ratarskih usjeva (*Košutić i sur. 2006*). Prema europskim istraživanjima (*Tebrügge i Düring, 1999*) konvencionalni sustav obrade tla iziskuje 434 kWh ha^{-1} energije i 4,1 h ha^{-1} ljudsko-strojnog rada. Nasuprot tome, reduciranim sustavima obrade moguće je realizirati uštedu oko 30%-50% energije i ljudskog-strojnog rada, a izravnom sjetvom čak i do 70%, u usporedbi s konvencionalnim sustavom obrade tla. S ekološkog stajališta nedostaci konvencionalnog sustava obrade su: povećanje zbijenosti tla izazvano prekomjernim gaženjem oranice strojevima, sustavno smanjenje sadržaja organske tvari u tlu (humusa) kao posljedica intenzivnog i učestalog djelovanja oruđa na tlo, veća podložnost konvencionalno obrađenih tala eroziji (*Birkás 2008*). Također ekološki problem predstavlja i značajna emisija CO_2 kao posljedica izgaranja velikih količina goriva utrošenih u intenzivnoj obradi tla (*Filipović et al. 2006*).

U supstituciji konvencionalnog sustava obrade tla različitim varijantama reducirane obrade i izravnom sjetvom u svijetu prednjače SAD i Kanada na sjevernoameričkom kontinentu te Brazil, Argentina, Urugvaj, Paragvaj na južnoameričkom gdje se konzervirajuća obrada i no-tilll sustav primjenjuju na više od polovine ukupnih ratarskih površina (*Derpsch i Friedrich, 2009*). Udio površina u Europi pod nekim od sustava reducirane obrade nije se do danas bitno povećao, te se procjenjuje da još uvijek iznosi manje od 20 % (*ECAF, 2010*). Unatoč spoznajama o mogućnostima uštede energije i ljudskog rada nekonvencionalnim načinima obrade, u Hrvatskoj je dominantan konvencionalni sustav obrade tla. U glavnim ratarskim regijama u Hrvatskoj, Slavoniji i Baranji, još uvijek se na većini (93,7%) oranica primjenjuje konvencionalni sustav obrade tla (*Zimmer et al. 2002*).

Soja (*Glycine max* L.) i ječam (*Hordeum vulgare* L.) važni su ratarski usjevi uvelike zastupljeni u plodoredu na proizvodnim površinama u Hrvatskoj. Dosadašnja istraživanja ukazuju da je reducirana obrada tla povoljnija za usjeve gustog sklopa poput ozime pšenice, jarog ječma i uljane repice, dok je znatno lošija opcija za jare okopavine kao što su kukuruz i soja (*Vratarić i Sudarić 2000, Pospišil i sur. 2002, Špoljar i sur. 2009, Kisić i sur. 2010*). Iako su neki autori *(Chatskikh i Olesen, 2007)* utvrdili smanjenje prinosa jarog ječma sa stupnjem redukcije obrade tla (14 % niži urod pri reduciranoj obradi i 27 % niži kod izravne sjetve), drugi navode kako nema značajnih razlika u ostvarenim urodima između različitih sustava obrade (*Moret i Arrue, 2007)*. Redukcija troškova proizvodnje primjenom sustava reducirane obrade tla, u uvjetima kada zbog smanjenja razine agrotehnike nisu značajno smanjeni urodi, omogućava snižavanje praga rentabilnosti i osigurava veću razliku prinosa i prihoda za dohodak u proizvodnji (*Stipešević i sur. 2007, Košutić i sur. 2008, Jug i sur. 2010*).

MATERIJAL I METODE

Istraživanje nekonvencionalnih sustava obrade tla provedeno je na pokusnom polju u sastavu proizvodnih površina poljoprivredne tvrtke „PK Nova Gradiška“ u blizini Starog Petrovog Sela (45° 10’ N, 17° 30’ E). Tlo na toj lokaciji je vertično hipoglejno (*Škorić, 1986*), a tekstura u oraničnom sloju je praškasto-glinasta ilovača (tablica 1). Klima na tom području je semihumidna s prosječnim godišnjim padalinama od 775 mm i prosječnom godišnjom temperaturom 10,8 °C (izvor: Državni hidrometeorološki zavod).

Tablica 1 Veličina i distribucija čestica tla
Table 1 Soil particle size distribution

Dubina Depth (cm)	Veličina čestica / Particle size				Teksturna oznaka Texture[1]
	0.2-2 μm (%)	0.05-0.2 μm (%)	0.002-0.05 μm (%)	<0.002 μm (%)	
0-30	16.0	28.0	22.0	34. 0	SCL[2]
30-60	13.0	32.0	26.0	29.0	SCL-SL
60-90	13.0	31.0	28.0	28.0	SCL

[1)] Prema „Soil Survey Staff of the United States Department of Agriculture“
[2)] SCL = Praškasto glinasta ilovača (Silty clay loam), SL = Praškasta ilovača (Silty loam)

Pokus s pet različitih varijanti obrade tla postavljen je na površini 15,5 ha, a polje je podijeljeno na 15 parcela dimenzija 54x185 m postavljenih u slučajni blok raspored s tri ponavljanja za svaki sustav obrade Sustavi obrade tla i oruđa primijenjena kod pojedinog sustava bili su:

1. Konvencionalna obrada – plug, tanjurača, sjetvospremač, sijačica (CT);
2. Reducirana obrada 1 – rovilo, tanjurača, sjetvospremač, sijačica (RT 1);
3. Reducirana obrada 2 – rovilo, integrirani agregat zvrk drljača + sijačica (RT 2);
4. Reducirana obrada 3 – plug, integrirani agregat zvrk drljača + sijačica (RT 3);
5. Kombinirana obrada – rovilo, plug, integrirani agregat zvrk drljača + sijačica (RT 4).

Prilikom obrade tla, sjetve, kao i svih drugih radnih operacija, učinak pojedinog agregata određen je kronografiranjem. Utrošak energije određen je mjerenjem utroška goriva volumetrijskom metodom za svako oruđe u svakom od uspoređivanih sustava obrade, te potom izračunat na osnovi energetskog ekvivalenta diesel goriva od 38,7 MJ l^{-1} (*Cervinka, 1980*). U svim radnim operacijama pri obradi tla korišten je traktor s pogonom na sve kotače i snage motora 136 kW. Radni zahvati pojedinih oruđa odabrani su na osnovi raspoložive vučne snage traktora.

Gnojidba i zaštita usjeva bila je jednaka u svim sustavima obrade tla, određena potrebama istraživanog usjeva. Ukupni urod pojedinog usjeva sa svake obračunske parcele izmjeren vaganjem elektronskim vagama izravno na polju. Vlažnost zrna u vrijeme žetve određivana je naknadno u laboratoriju, te je osnovom toga urod preračunat na površinu od jednog hektara i skladišnu vlagu promatranog usjeva. Raspored radova u polju kao i primijenjene doze gnojiva i zaštitnih sredstava prikazani su u tablici 2.

Tablica 2 Raspored radova i primijenjene doze
Table 2 Date of field operations and application rates

Opis / Description	Soja / Soybean	Jari ječam / Spring barley
	Obrada tla i sjetva / Tillage & Sowing	
Osnovna obrada / Primary tillage	26. kolovoz 2010. August 26th 2010	14. studeni 2011. November 14th 2011
Vlažnost tla (%) na 5; 15; 30 cm Soil moisture (%) at 5; 15; 30 cm	16,2; 44,2; 44,4	31,8; 39,8; 37,4
Dopunska obrada / Secondary till.	21. travanj 2011. April 21st 2011	8. ožujak 2012. March 8th 2012
Vlažnost tla (%) na 5; 15; 30 cm Soil moisture (%) at 5; 15; 30 cm	23,9; 45,9; 43,7	25,5; 46,8; 48,6
Datum sjetve / Sowing date	21. travanj 2011. April 21st 2011	8. ožujak 2012. March 8th 2012
Kultivar (kg ha^{-1}) Cultivar (kg ha^{-1})	Podravka (120)	Scarllet C1 (220)
	Gnojidba / Fertilizing	
Vrijeme primjene / Appl. date	29. ožujak 2011. March 29th 2011	10. studeni 2011. November 10th 2011
Gnojivo, doza (kg ha^{-1}) Fertilizer, rate (kg ha^{-1})	NPK 0:20:30 (400)	NPK 8:26:26 (350)
Vrijeme primjene / Appl. date	20. travanj 2011. April 20th 20011	15. travanj 2012. April 15th 2012
Gnojivo, doza (kg ha^{-1}) Fertilizer, rate (kg ha^{-1})	Urea 46% (100)	KAN / CAN 27% (130)
Vrijeme primjene / Appl. date	7. lipanj 2011. June 7th 2011	20. svibanj 2012. May 20th 2012
Gnojivo, doza (kg ha^{-1}) Fertilizer, rate (kg ha^{-1})	KAN / CAN 27% (100)	KAN / CAN 27% (90)
	Zaštita / Crop protection	
Vrijeme primjene / Appl. date	22. travanj 2011. April 22nd 2011	8. travanj 2012. April 8th 20012
Sredstvo, doza (l ha^{-1}) Chemical, rate (l ha^{-1})	metribuzin (0,70) dimetenamid (1,30)	izoproturon + diflufenikan (1,70)
Vrijeme primjene / Appl. date	10. svibanj 2011. May 10th 2011	7. svibanj 2012. May 7th 2012
Sredstvo, doza (l ha^{-1}) Chemical, rate (l ha^{-1})	fomesafen (0,75) tifensulfuron-metil (0,008)	metaconazole + azoxystrobin (0.80)
Vrijeme primjene / Appl. date	4. lipanj 2011/June 4th 2011	15. svi. 2012. / May 15th 2012
Sredstvo, doza (l ha^{-1}) Chemical, rate (l ha^{-1})	propakizafop (1,00) bentazon (2,5)	aminopiralid + florasulam (0.033 kg ha^{-1})
	Žetva / Harvest	
Datum žetve / Harvesting date	16. rujan 2011. September 16th 2011	13. srpanj 2012. 13th July 2012

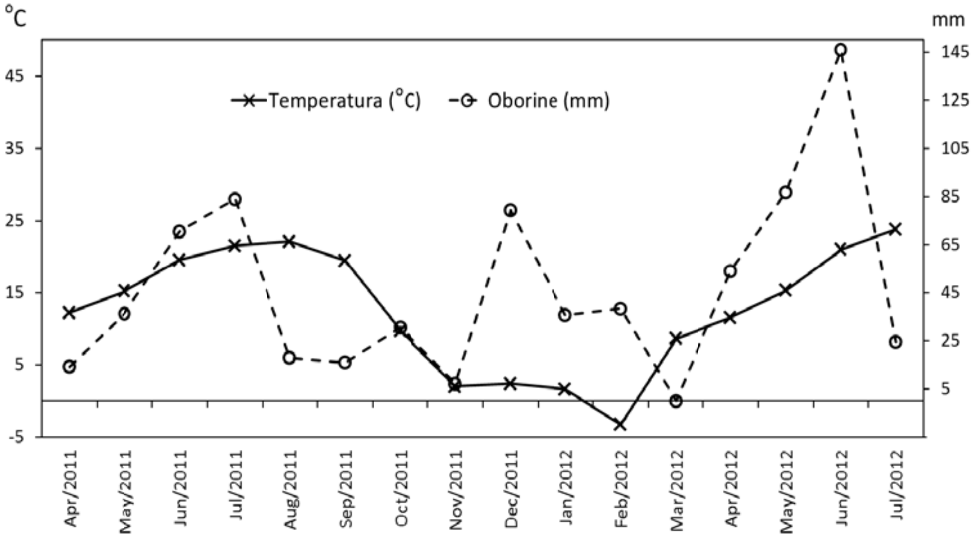
Na temelju naturalnih pokazatelja proizvodnje soje i ječma (utrošci rada, materijala, prinosi), te cijena inputa i outputa proizvodnje napravljene su obračunske kalkulacije ispitivanih sustava obrade tla u proizvodnji, te prema razlikama troškova i cijene koštanja utvrđena razlika ekonomske efikasnosti pojedinih sustava.

Statistička obrada podataka za sve pokazatelje istraživanja učinjena je računalnim programom SAS (SAS Institute, 1990) metodom analize varijance (ANOVA). Značajnost razlika između promatranih pokazatelja utvrđena je F-testom na razini vjerojatnosti p=0.05.

REZULTATI I RASPRAVA

Klimatski uvjeti

Na proizvodnju soje i ječma značajan su utjecaj imala klimatska obilježja. Tokom vegetacijske sezone uzgoja soje srednja mjesečna temperatura zraka bila je za 0,8 °C viša, dok je oborina bilo za 46 % manje od višegodišnjeg prosjeka. Sušna razdoblja uočljiva na klimadijagramu prema Walteru (slika 1) obilježila su vrijeme sjetve i nicanja soje (travanj i svibanj 2011.), te period dozrijevanja usjeva (kolovoz i rujan 2011.). Tokom vegetacijske sezone uzgoja jarog ječma srednja mjesečna temperatura zraka bila je za 1,1 °C viša od prosjeka, a oborina je bilo za 10 % manje. Iako su na klimadijagramu sušni periodi uočljivi samo u vrijeme sjetve i neposredno prije žetve ječma (ožujak i srpanj 2012.), glavninu oborina činili su obilni pljuskovi praćeni velikim vrućinama zbog čega je došlo do isušivanja površinskog sloja tla u kojem se nalazi glavnima relativno plitkog korjenovog sustava ječma. Navedene klimatske prilike mogle su utjecati na redukciju prinosa soje i jarog ječma u promatranim sezonama uzgoja.



Slika 1. Klimadijagram prema Walteru za razdoblje uzgoja soje i ječma
Figure 1 Walter climate diagram for soybean and barley cropping period

Urod

U uzgoju soje najveći prosječni urod od 3,78 t ha^{-1} ostvaren je na varijanti pokusa s reduciranom obradom RT 1 što je za 15 % više od uroda zabilježenog na konvencionalnom sustavu obrade tla (3,28 t ha^{-1}). Najniži prosječni urod soje od 2,76 t ha^{-1}, odnosno 19 % manje od konvencionalnog sustava zabilježen je na varijanti pokusa s reduciranom obradom RT 2. Analizom varijance utvrđene su statistički značajne razlike prosječnih uroda među navedenim varijantama pokusa na razini vjerojatnosti $p<0,05$. Na varijantama pokusa RT 3 i RT 4 urodi su bili nešto niži nego na varijanti s konvencionalnom obradom tla (do 2 %) i te razlike nisu bile statistički značajne.

U uzgoju jarog ječma konvencionalna obrada tla pokazala se kao najlošiji izbor i u toj je varijanti ostvaren prosječni urod od 2,34 t ha^{-1}, što je ujedno bio i najniži urod na svim varijantama pokusa. Najviši prosječni urod ječma od 3,20 t ha^{-1} zabilježen je na varijanti s reduciranom obradom RT 2 što je bilo za 36 % više u odnosu na konvencionalni sustav. Razlike uroda među pojedinim varijantama pokusa bile su statistički značajne na razini vjerojatnosti $p<0,05$. Tako je značajno viši urod u odnosu na konvencionalni sustav zabilježen i na varijanti pokusa s reduciranom obradom tla RT 1 (28 % više), te na RT 4 za 23 % više. Prosječni urod od 2,64 t ha^{-1} ostvaren na varijanti pokusa RT 3 nije se pokazao statistički značajno većim u odnosu na konvencionalni sustav.

Energija i učinak

Konvencionalni sustav obrade tla očekivano se pokazao zahtjevnim s gledišta utroška energije i radnog vremena. Ukupno je u obradi tla i sjetvi soje konvencionalnim sustavom utrošeno 48,23 l ha^{-1} diesel goriva pri čemu se oranje lemešnim plugom ističe kao najznačajniji potrošač s oko 64 % ukupno utrošene energije. Najviše goriva/energije (62,56 l ha^{-1}) u obradi tla je međutim utrošeno u varijanti pokusa RT 4 gdje je zabilježen i najviši specifični utrošak energije od 754,9 MJ t^{-1} po toni prinosa odnosno 32 % više u odnosu na varijantu s konvencionalnim sustavom obrade (568,7 MJ t^{-1}). U varijantama pokusa s reduciranom obradom tla RT 1 i RT 2 utrošeno je za trećinu manje goriva/energije pri čemu se sustav RT 1 zbog značajno višeg uroda ističe s 42,2 % manjim specifičnim utroškom energije (328,7 MJ t^{-1}) u odnosu na konvencionalni sustav. Osim po utrošku energije kombinirani sustav obrade tla RT 4 pokazao se najzahtjevniji i obzirom na utrošak radnog vremena pa je tako za obradu i sjetvu jednog hektara utrošeno 2,51 sat rada strojeva odnosno gledano obzirom na ostvareni prinos zrna soje 0,78 sati po toni prinosa. U varijanti pokusa s konvencionalnim sustavom obrade tla utrošeno je 2,42 h ha^{-1} odnosno 0,74 h t^{-1}. U varijantama pokusa s reduciranom obradom tla ostvarene su znatne uštede radnog vremena: u sustavu RT 1 učinak po jedinici površine bio je za trećinu veći, a u RT 2 čak dvostruko veći u odnosu na konvencionalni sustav, pri čemu su i učinci po jedinici prinosa soje bili za 40 % veći. U varijanti pokusa RT 3 je unatoč neznatno nižem utrošku goriva/energije u odnosu na konvencionalni sustav, učinak bio za 20 % viši.

U proizvodnji jarog ječma najviše je goriva/energije utrošeno u sustavu obrade tla RT 4 (62,69 l ha^{-1}) uz specifični utrošak od 842,1 MJ t^{-1}, dok je za konvencionalnu obradu utrošeno 46,84 l ha^{-1} odnosno 776,3 MJ t^{-1} pri čemu je za oranje utrošeno 63 % ukupnog iznosa (tablica 3).

Tablica 3 Utrošak energije, učinak i produktivnost različitih načina obrade tla
Table 3 Energy and labour requirement of different soil tillage systems

Obrada Tillage system	Soja / Soybean				Jari ječam / Spring barley			
	Gorivo Fuel l ha^{-1}	Energija Energy MJ t^{-1}	Produktivnost Productivity h ha^{-1}	h t^{-1}	Gorivo Fuel l ha^{-1}	Energija Energy MJ t^{-1}	Produktivnost Productivity h ha^{-1}	h t^{-1}
CT	Urod / Average yield = 3,28 t ha^{-1} b[1]				Urod / Average yield = 2,34 t ha^{-1} c			
Plug / Plough	31,12	367,0	1,35	0,41	29,39	487,1	1,30	0,56
Tanjurača Disc harrow	9,67	114,0	0,34	0,10	10,25	169,9	0,31	0,13
Sjetvospremač Seed-bed impl.	4,31	50,8	0,17	0,05	4,26	70,6	0,43	0,18
Sijačica / Drill	3,13	36,9	0,56	0,17	2,94	48,7	0,45	0,19
Ukupno / Total	48,23	568,7	2,42	0,74	46,84	776,3	2,49	1,06
RT 1	Urod / Average yield = 3,78 t ha^{-1} a				Urod / Average yield = 3,01 t ha^{-1} a			
Rovilo / Chisel	15,00	153,6	0,57	0,15	20,84	267,9	0,83	0,28
Tanjurača Disc harrow	9,67	99,0	0,34	0,09	10,25	131,8	0,31	0,10
Sjetvospremač Seed-bed impl.	4,31	44,1	0,17	0,04	4,26	54,8	0,43	0,14
Sijačica / Drill	3,13	32,0	0,56	0,15	2,94	37,8	0,45	0,15
Ukupno / Total	32,11	328,7	1,64	0,43	38,29	492,3	2,02	0,67
RT 2	Urod / Average yield = 2,76 t ha^{-1} c				Urod / Average yield = 3,20 t ha^{-1} a			
Rovilo / Chisel	15,00	209,2	0,57	0,20	20,84	252,0	0,83	0,26
Integra / Rotary harrow + drill	17,04	237,6	0,61	0,22	12,46	150,7	0,61	0,19
Ukupno / Total	32,04	446,8	1,18	0,42	33,30	402,7	1,44	0,45
RT 3	Urod / Average yield = 3,27 t ha^{-1} b				Urod / Average yield = 2,64 t ha^{-1} bc			
Plug / Plough	31,12	368,6	1,35	0,41	29,39	430,5	1,30	0,49
Integra / Rotary harrow + drill	16,44	194,7	0,59	0,18	12,46	182,5	0,61	0,23
Ukupno / Total	47,56	563,4	1,94	0,59	41,85	613,0	1,91	0,72
RT 4	Urod / Average yield = 3,21 t ha^{-1} b				Urod / Average yield = 2,88 t ha^{-1} ab			
Rovilo / Chisel	15,00	181,0	0,57	0,18	20,84	279,9	0,83	0,29
Plug / Plough	31,12	375,5	1,35	0,42	29,39	394,8	1,30	0,45
Integra / Rotary harrow + drill	16,44	198,4	0,59	0,18	12,46	167,4	0,61	0,21
Ukupno / Total	62,56	754,9	2,51	0,78	62,69	842,1	2,74	0,95

[1] Različita slova ukazuju na statistički značajne razlike na razini vjerojatnosti $p \leq 0.05$
Different letters indicate significant ($p \leq 0.05$) differences

Primjenom reduciranih sustava obrade tla ponovo su ostvarene znatne uštede energije, od 21 % u varijanti pokusa RT 3 do 48 % u RT 2 u odnosu na konvencionalni sustav. Također je i utrošak radnog vremena u obradi tla na varijantama pokusa s reduciranom obradom tla bio znatno manji u odnosu na konvencionalnu obradu, a najveća ušteda od 57,8 % ostvarena je u sustavu RT 2 gdje je u obradi ukupno utrošeno 0,45 h t^{-1}. Potrebno je istaknuti da je sustav obrade RT 4 unatoč većem utrošku radnog vremena (2,74 h ha^{-1} naspram 2,49 h ha^{-1} kod konvencionalnog sustava) u konačnici imao veću produktivnost rada (0,95 h t^{-1}) u odnosu na konvencionalni sustav (1,07 h t^{-1}) zahvaljujući značajno većem prosječnom prinosu zrna ječma.

Uspoređujući dobivene rezultate s navodima drugih autora (Pelizzi i sur. 1988; *Hernanz i Ortiz-Cañavate 1999; Kovačev i sur. 2011*) mogu se očekivati veća odstupanja obzirom na tipove tala, trenutne uvjete u polju, dubinu obrade i korištena oruđa, no uočljivo je povećanje produktivnosti rada sa stupnjem redukcije obrade tla.

Ekonomičnost proizvodnje

Ukupni prihodi u proizvodnji soje i ječma izračunati su prema prosječnom prinosu zrna sa svake varijante pokusa i prosječnoj otkupnoj cijeni u vrijeme žetve, te državnim poticajima. Ukupni troškovi uključuju sve troškove mehanizacije od obrade tla do žetve (uključivo transport u polju), repromaterijal (sjeme, gnojiva, zaštitna sredstva), i ljudski rad. Skladištenje uroda i režijski troškovi poljoprivredne tvrtke ovdje nisu uračunati.

U proizvodnji soje najveći prihod ostvaren je na varijanti pokusa s reduciranom obradom tla RT 1, te se upravo taj sustav pokazao najekonomičnijim s najvišim omjerom prihoda i troškova (2,16) među istraživanim sustavima obrade. Iako su na varijanti pokusa RT 2 zabilježeni najniži troškovi, zbog značajno nižeg uroda soje u odnosu na sve ostale varijante, taj se sustav obrade na kraju pokazao najlošijim izborom s najnižim omjerom prihoda i troškova 1,74. Najveće troškove proizvodnje generirao je konvencionalni sustav obrade tla, ponajviše zbog velikog broja operacija i utroška radnog vremena.

Tablica 4 Ekonomski pokazatelji proizvodnje soje i ječma
Table 4 Economic efficiency indicators of soybean and barley production

Obrada Tillage	Soja / Soybean			Jari ječam / Spring Barley		
	Ukupni prihod Gross inc. € ha^{-1}	Ukupni troškovi Total costs € ha^{-1}	Omjer prihodi/troškovi Income/Costs ratio	Ukupni prihod Gross inc. € ha^{-1}	Ukupni troškovi Total costs € ha^{-1}	Omjer prihodi/troškovi Income/Costs ratio
CT	1.394,00	790,00	1,76	744,00	585,00	1,27
RT 1	1.560,00	721,00	2,16	894,00	558,00	1,60
RT 2	1.225,00	703,00	1,74	936,00	518,00	1,81
RT 3	1.389,00	731,00	1,90	812,00	545,00	1,49
RT 4	1.369,00	767,00	1,79	865,00	578,00	1,50

U proizvodnji jarog ječma najviši prihod ostvaren je na varijanti pokusa s reduciranom obradom tla RT 2, a obzirom da su u tom sustavi zabilježeni i najniži troškovi upravo se taj sustav s najvišim omjerom prihoda i troškova 1,81 pokazao kao najekonomičniji. Najveći troškove proizvodnje ponovo su zabilježeni u konvencionalnom sustavu obrade tla u kojem je zbog značajno nižeg uroda u odnosu na ostale varijante pokusa ostvaren i najniži prihod. U konačnici je tako konvencionalni sustav obrade pokazao najnižu ekonomičnost u proizvodnji jarog ječma s omjerom prihoda i troškova od samo 1,27.

ZAKLJUČCI

Temeljem provedenih istraživanja utjecaja nekonvencionalnih sustava obrade tla na ekonomičnost proizvodnje soje i jarog ječma, te prikazanih rezultata, mogu se donijeti slijedeći zaključci:

1. Proizvodnja soje i jarog ječma bila je ekonomična na svim ispitivanim sustavima obrade tla. Najvišu ekonomičnost proizvodnje soje pokazala je varijanta s reduciranim sustavom obrade RT 1 (koeficijent 2,16), dok je u proizvodnji ječma najekonomičniji bio sustav RT 2 (koeficijent 1,81).
2. Redukcija obrade tla ima pozitivan utjecaj na ekonomičnost proizvodnje jedino ako se time prinosi ne smanjuju u značajnoj mjeri kao što je to bio slučaj pri uzgoju soje u sustavu RT 2 koji je unatoč najnižim troškovima imao i najnižu ekonomičnost zbog izrazito niskih uroda.
3. Redukcijom obrade tla moguće je ostvariti znatne uštede energije i radnog vremena ljudi i strojeva. Stoga bi kod izbora sustava obrade tla, uz pretpostavku ujednačenih razina prinosa, prednost trebalo dati sustavu s nižom razinom agrotehnike, ne samo radi snižavanja troškova, već i zbog mogućnosti jednostavnije organizacije proizvodnje.

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ECONOMIC EFFICIENCY OF NON-CONVENTIONAL SOIL TILLAGE SYSTEMS IN SOYBEAN AND BARLEY PRODUCTION

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SUMMARY

Short-term study of non-conventional soil tillage systems was conducted at the experimental field near Staro Petrovo Selo (45° 10' N, 17° 30' E) on hypogley-vertic type of soil and semi humid climate conditions. The tillage systems and implements used were: CT – mouldboard plough, disc harrow, seed-bed implement, drill, RT 1 - chisel plough, disc harrow, seed-bed implement, drill, RT 2 - chisel plough, rotary harrow integrated with seed drill, RT 3 - mouldboard plough, rotary harrow integrated with seed drill, RT 4 - chisel plough, mouldboard plough, rotary harrow integrated with seed drill. The weather conditions had great influence on production of soybean and spring barley, and the occurrence of drought periods during the vegetation season could have affect the yields. The highest average yields were obtained by RT 1 system in soybean (3.78 t ha^{-1}) and RT 2 in barley production (3.20 t ha^{-1}). The greatest energy and labour savings in soil tillage, among the lowest total cost of production, were achieved by RT 2 system, but due to the significantly lower yields this system has not proved adequate for soybean production. The highest economic efficiency of soybean production has shown RT 1 system (coefficient of 2.16), while in barley production the most profitable system was RT 2 (coefficient of 1.81). Regarding the choice of tillage systems, assuming uniform level of yields, the advantage should be given to systems with lower level of tillage intensity, not only to reduce costs but also because of the possibility of simpler production organization due to less machine and labour requirement.

Key words: *soil tillage, energy consumption, production costs, income*

41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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ANALYSIS OF RYE AND BUCKWHEAT YIELD DEPENDENCY ON SOME MECHANICAL SOIL PROPERTIES

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SUMMARY

During the soil tillage, two types of motions of tractors and mobile systems can be evidenced: quasi-linear motion over the inner parts of the parcel, and curvilinear motion (turning) over the headlands. Consequently, the soil is compressed, but with different intensities. On headlands, soil compressing is more intensive due to the lower machine operational speeds while turning. This way, soil is longer exposed to the pressure generated by the machines weight, and gets more compressed. Under that kind of influence of mobile machines and other factors, damaged soil structure causes unfavorable conditions for crops growth and development, which is being manifested by yield decrease, increased expenditures and other negative effects. The aim of this study was to estimate the influence of soil compressing on rye and buckwheat crops. Soil compressing has been measured by Eijkelkamp penetrometer, at depths 0-20cm. Results of three-year experimental work at south Serbia indicate that the soil compression at headlands was in average higher when compared to the inner parts of the parcels: by 43.82% after the germination of rye, and 55.82% before rye harvesting. The average values of incresing the soil compaction at parcel headlands under buckwheat crop were 47.86% and 44.87%, respectively. Because of the higher soil compaction, rye grain yield was lower by 32.71% and buckwheat seeds yield for 33.08% at headlands, in comparison to yields at inner plots.

***Key words**: headland, motion, soil compressing, yield, buckwheat, rye, mechanization*

INTRODUCTION

Agricultural production includes farming operations based on various motions of machine-tractor systems over the parcel. However, increased weights of contemporary mechanization most commonly results in excessive soil compaction, which causes very unfavorable soil condition for plant production and application of complete modern production technology. Consequently, a significant reduction in grain yields and increased production costs may arise. Soil compaction is critical at headlands of the plot due to lower speeds during machine-tractor systems aggregate turning, and the high number of passes.

In the Republic of Serbia in 2010. 3.066.000 ha were seeded, of which the grains were 1.894.000 ha (Statistical yearbook of the Republic of Serbia 2011). Rye was planted on about 5.300 hectares, 5.197 hectares were harvested, giving the average yield of 2.5 t ha^{-1}. There is no precise data on sown areas and the yield of buckwheat.

The importance of buckwheat as a special field crops comes from its speciffical nutrition properties. It is grown for grain that is rich in compounds of iron, potassium, phosphorus, citric, malic and oxalic acid and is rich in content of vitamins B_1, B_2, PP and belongs to a group of good dietary products (Stanišić and Ćetković, 2008). Rye is a farming culture that is important as bread wheat. Contains sufficient amounts of vitamin A, B and E. (Oelke et al., 1990). Rye bread is a delicious, nutritious and stays fresh longer.

So far, many reports focused on problems of arable land compaction and to its effects on damaging the soil structure and the amount of yield, have been published. According to Vučić, (1992) rapid increasing in the mankind population results in deficiency of the arable land and the pursuit of higher yields requires intensive application of mechanization and chemicals which deteriorate soil properties.

Land degradation, caused by natural processes or human activity, reduces the soil ability for growing plants, as a regulator and water regime filter essential to preservation of the environment, Hadžić et al. (1996). The same authors also show that the movement of tractors and other mobile systems leads to permanent soil compaction that is difficult to be removed only by tillage. In addition to the influence of heavy machinery, the soil compaction has also been additionally intensified by the introduction of new technologies in agricultural production and the growing of crops in monoculture.

Ishaq et al. (2000) reported that increased soil compaction significantly reduces yield of wheat, especially during the next three years after compaction measurements. Lynden (2000), indicates that compaction is an important source of land degradation. Friton (2001), points out that soil compaction significantly reduces yields of cultivated crops.

According to Nikolić et al. (2002), excessive soil compaction can result in increasing the production costs for 20-40%, as well as in the yield reductiuon of 10-25%. In addition, they have verified increase in average fuel consumption of about 20-25% and increase investment for fleet, facilities and personnel of 10-25%.

Güclü et al. (2002) were investigating the effect of three processing methods for resist shear, cone resistance, bulk density and soil moisture variation in the production of wheat and corn. Measured values of cone resistance did not exceed the critical value of cone resistance, except at the depth of 20-30 cm, which was 2 MPa. The increase in cone resistance was due to land compaction during combines harvesting.

Nikolić et al. (2003) conclude that the causes and effects of soil compaction are complex and have permanent effects on the land, which rehabilitation demands big investments during a long period. The amounts of average yield losses were increased for more than 20%, while the increase of specific resistance at plowing was about 200-250% during the last 30 years.

Kuht and Reintam (2004), point out that long-term use of heavy equipment has resulted in soil compaction, high damage and permanent degradation, especially in the basic layer. Consequently the yield was reduced for about 40% or more.

Jarak et al. (2005) have studied the effects of compaction on the soil properties and yield of wheat and maize at headlands. They reported that, in the germination phase of crop growing, the elongation of soil under wheat at headland was 25.96% higher with respect to the interior parts of the parcel. In the process of collection, the elongation was higher for even 31.17%. The same authors suggest that microbial activity is lower in the headlands, and the grain yield of wheat was higher at the inner plots for 51.35%, when compared to the headland.

Large number of passages, particularly over headlands, causes intense trampling of the soil, which negatively reflects the changes in the soil structure and all plant species, Nikolić et al. (2006). They reported the following yield losses at the headland: 44.86% for wheat, 54.48% for corn, 19.09% for sunflower, 11.41% for soybean and 52.72% for sugar beet.

After several years of researching, Savin et al. (2007) concluded that headland soil compaction after sowing was 30.56% higher than in the inner part of the plot. Simultaneously, the increase of the soil compaction at headland before harvesting was 37.65%, while the yield reduction was about 31.55%.

Savin et al. (2008), indicated that the average increase in soil compaction at headland, compared to the compaction at the inner parts of the plot was 67.70%. They also reporetd reduction in headland yield of about 19%.

Besides natural compaction, an important role in soil compaction and compression belongs to the influence of contact rubber caterpillar tractors and other agricultural machinery, Biris et al. (2009).

Savin et al. (2009) studied the impact of agricultural practices on soil compaction and found that the resistance of the cone before fertilising the headland was higher (2.73 MPa), than at the inner part (1.51Mpa) – thus giving a compaction increase of 57.27%. According to the same authors, cone resistance is higher in the headland after harvesting (3.82 MPa), while at the inner part it was smaller (2.53 MPa). In the latter case, the cone resistance was higher at the headlands for 50.97% in comparison to the inner part of the plot.

Ramazan et al. (2012), suggest that agricultural mechanization represents a key element in agricultural production, because its application brings many benefits. However, it is very important to be properly applied, because unnecessary and excessive use of heavy machines compacts soil and creates a number of problems that manifest negative impact on the crops growth and yield.

The objectives were to determine influence of soil over-compressing at headland and inner part of land parcel, as a consequence of mechanization moving, on rye and buckwheat yields, as a dominant crops at the investigated area.

MATERIAL AND METHOD

Present study is focused to analysis of the influence of soil compaction on yield of winter rye varieties „Rasa" and autohotonous buckwheat varieties in agroecological conditions of Kosovska Mitrovica. Soil compaction was measured during 2009/12, using a penetrometer *Eijkelkamp 06.01 SA*, the headland and inner part of the depth of 0-20 cm, bearing in mind that the depth of the layer which has been processed lathes. At the same locations where the compaction was measured, soil samples were taken for determination of chemical composition and microbial activity. Measurements were performed on the headland and the inner part. The cone is imprinted in the land with the continuous speed of 2 cm sec^{-1}. In order to address the real headlands plots next to the roads were selected, so that the turning of machine-tractor units was performed only on the land thus forming true headland. Headland width was 10m. Experiments have been conducted on the red-brown dystric cambisol (according to FAO classsification) on flysch. Soil analysis to determine the microbial activities were carried out by the following methods: total number of microorganisms by the method of Poshon and Tardieuix- a, the number of nitrogenbacteria by Anderson, and dehydrogenesis activity by Thalman.

Measurements and soil sampling were performed twice: at the beginning of vegetation after crop emergence and at the end of the season before harvesting. The yields of rye and buckwheat on the inside and on the headland were determined with a $1m^2$ were calculated on the entire experiment. All samples were taken with three repeats. The results are presented in tables and analyzed.

RESULTS AND DISCUSSION

In Table 1 the results of the intensity of soil compaction on headlands and inner part of the rye and buckwheat crops are shown.

The results which are presented in Table 1 indicate that the headland measured soil density is greater than in the inner part of the plot in all the studied variants. The largest eruption phase of compaction in the rye crop was measured at the headland in 2009 at the depth of 0-20 cm and it was 2.40 MPa, while the lowest compaction during crop emergence measured on the inner part of the plot in 2012 was 1.59 MPa.

When it comes to compaction of soil planted with rye before harvest, it is observed that the minimum compaction measured in 2011 The inner part of the plot was 2.25 MPa, and the largest in the headland before harvest in 2012 was 4.12 MPa.

Soil headlands during germination were higher by an average of 43.82% compared to the inner part of the plot. A large number of crossings has led to stronger soil compaction on headlands than in the inner part of the plot before harvesting, so that the increase in soil on headland was an average of 55.82%.

When it comes to crop of buckwheat a similar effect is noticed. Compaction of the largest eruption phase of buckwheat was measured on headland during 2010- 2.69 MPa, and the lowest at the inner part of in 2011-1.45MPa. The minimum compaction before harvesting was measured in the central part of the plot was 2.54 MPa in 2011, and the largest on the headland in 2012 was 3.96 MPa. Average increase in soil at the stage of eruption on the headland buckwheat than in the inner part accounted for 47.86% and 44.87% before harvesting.

Table 1. Intensity of soil compaction at measuring depth of 0–20 cm

Crop	Year	Phase of crop development	Soil moisture (%)	Soil compaction (MPa)		
				Inner part	Headland	Increasing (%)
Rye	2009/10	Germination	23.17	1.70	2.40	41.18
		Harvesting*	14.20	2.49	3.92	57.43
	2010/11	Germination	22.69	1.67	2.38	42.51
		Harvesting*	10.25	2.25	3.59	59.56
	2011/12	Germination	25.84	1.59	2.34	47.17
		Harvesting*	16.57	2.72	4.12	51.47
	Average	*Germination*	*24.27*	*1.65*	*2.37*	*43.82*
		*Harvesting**	*13.41*	*2.49*	*3.88*	*55.82*
Buckwheat	2010	Germination	23.45	1.74	2.69	54.59
		Harvesting*	11.50	2.96	4.19	41.55
	2011	Germination	23.69	1.45	2.15	48.27
		Harvesting*	9.84	2.54	3.89	53.14
	2012	Germination	27.91	1.67	2.35	40.72
		Harvesting	13.87	2.83	3.96	39.92
	Average	*Germination*	*25.80*	*1.62*	*2.40*	*47.86*
		*Harvesting**	*11.86*	*2.78*	*4.01*	*44.87*

*****full crop maturity – fully developed crops, ready for harvesting

The results are consistent with other authors' studies (Ishaq et al 2000; Fritton, 2001; Güclü et al., 2002; Jarak et al., 2005; Savin et al., 2007 and 2009; Biris et al., 2009; Ramazan et al., 2012).

Table 2 presents the data on the yield of rye and buckwheat, depending on the variants.

A large number of passages of machine-tractor units, has led to intensified soil compaction on the headland and the central part of the experimental plots, resulting in the creation of unfavorable conditions for the development of the root system and lower microbial activity, which have been achieved great differences in the amount of return (Table 2).

The highest yield of rye was measured in the central part of the plot 2011 the amount is 2.58 and t ha^{-1}, the lowest on the headland in 2010 was 1.57 t ha^{-1}. Average yield reduction over the three-year examination of rye amounted to 32.71%.

There is a similar effect of soil compaction in the central part of the plot and the headland and the yield of buckwheat. The lowest yield of dried buckwheat grains were measured in 2010 on headland at 0.81 t ha^{-1}, and the largest, in the inner part of a 1.32t ha^{-1} in 2011.

Table 2 Rye and buckwheat grain mass yield on headland and inner part of a field

Crop	Year	Grain mass yield (t ha^{-1})		Yield decrease
		Inner part	Headland	(%)
Rye	2010	2.18	1.57	27.98
	2011	2.58	1.68	35.27
	2012	2.45	1.64	34.88
	Average	*2.40*	*1.63*	*32.71*
Buckwheat	2010	1.28	0.81	36.72
	2011	1.32	0.93	29.55
	2012	1.30	0.88	32.31
	Average	*1.30*	*0.87*	*33.08*

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Average yields of dry buckwheat seeds during the three-year investigation amounted to 33.08%.

Our findings are consistent with the statements of other authors (Ishaq et al 2000.; Nikolic et al., 2002 and 2003; Kuht et al., 2004; Jarak et al., 2005; Savin et al., 2007 and 2008; Ramazan et al., 2012).

As it can be seen in Figure 1, the grain yields of Rye and Buckwheat are correlated with the soil compaction at the germination phase of crop growing. Decreasing the yield is larger for the Rye crop, which is characterized by twice larger value of constant defining slope of trend line (-1.0759) in comparison to the analogue value of slope constant for Buckwheat crop trend line (-0.5011). This means that Rye crop is much more sensitive toward the increase of soil compaction at the germination phase than the Buckwheat plants. The R-square parameters are nearly equal each to other for both crops, having very high values, larger than 0.94. Therefore, the trend lines fit the experimental data very good in these two analyzed cases.

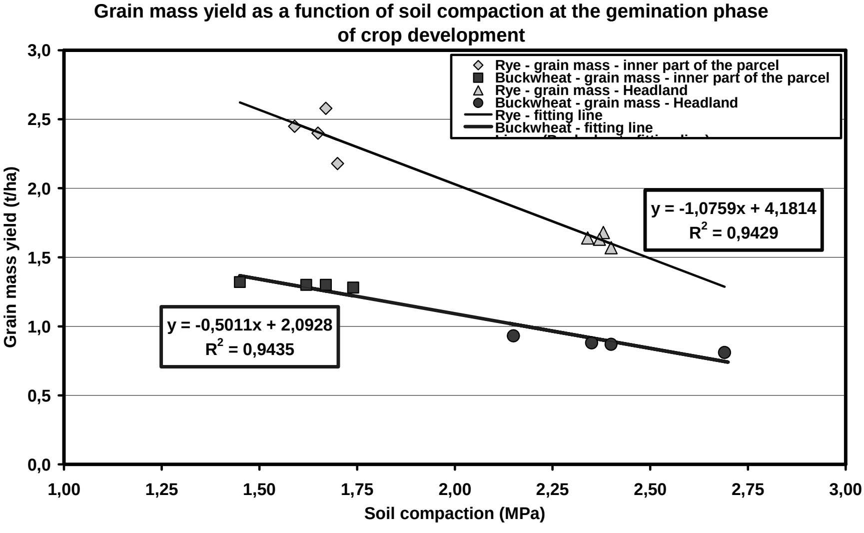

Figure 1 Relationships between the rye and buckwheat yield, expressed by grain mass per hectare of soil area, and the soil compaction at the germination phase of crop development

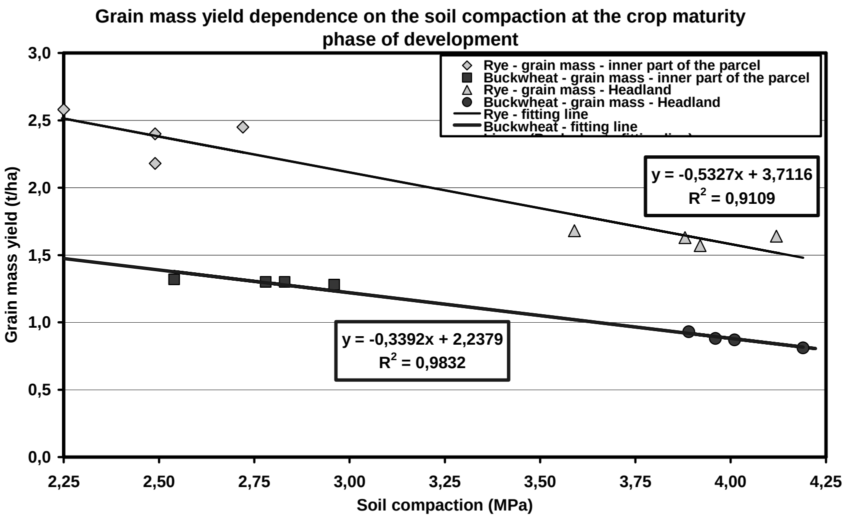

Figure 2 Relationships between the rye and buckwheat yield, expressed by grain mass per hectare of soil area, and the soil compaction at the full maturity (harvesting) phase of crop development

The relationships between the yield of Rye/Buckwheat crops and the soil compaction at the full maturity (harvesting) phase of their growing are quite analogue, figure 2, to those presented in figure 1 for the crops germination phase. However, the slope constants of trend lines (-0.5327 for Rye, and -0.3392 for Buckwheat) are much smaller in this case with respect to those calculated on the base of experimental data presented in figure 1. From the agronomical point of view, it means that yield of Rye/Buckwheat crops is much more sensitive to the influence of soil compaction at the germination phase, and less sensitive according the same parameter measured at the full maturity (harvesting) phase of these two crops growing. Again, following the previous case related to the crops germination phase of crops development, the R-square values are fairly equal each to other for both crops, having very high values. Although their difference is slightly more emphasized: 0.91 for Rye and 0.98 for buckwheat, it can be concluded that trend lines fit the experimental data very good for both crops.

Table 3 Basic microbiological properties of soils in the field experiment

Parameter	Measuring location of the parcel	Sampling depth (cm)	Year					
			2009/10		2010/11		2011/12	
			Sowing	Harvest	Sowing	Harvest	Sowing	Harvest
Total number of Microbial TN (log No)	Headland	0-10	7.72	7.61	7.50	7.45	7.86	7.74
		10-20	7.69	7.56	7.48	7.43	7.83	7.72
	Inner part	0-10	7.89	7.81	7.72	7.76	8.02	7.81
		10-20	7.80	7.67	7.65	7.70	7.89	7.69
Number of nitrogen bacter Azb(log No)	Headland	0-10	2.98	2.74	2.94	2.70	2.96	2.72
		10-20	2.88	2.68	2.82	2.67	2.90	2.70
	Inner part	0-10	3.00	2.79	2.96	2.77	2.99	7.75
		10-20	2.85	2.75	2.80	2.73	2.86	2.74
Activity Dehydrogenase mg TPF/g soil	Headland	0-10	116	97	110	98	125	98
		10-20	104	94	103	95	107	96
	Inner part	0-10	170	104	167	110	168	99
		10-20	166	97	152	105	175	91

Based on the results shown in Table 3, it can be noted that a large number of passages are leading to the intensified soil compaction on headlands than in the inner part of the plot and poor microbiological activity. Therefore, the total number of microorganisms and Nitrogenbacteria was higher in the central part of the plot compared to the headland, which is mainly explained by a weaker structure and disrupted soil aeration on the headland as a result of more intense wear.

Observed a decline in the number of microorganisms and nitrogenbacteria with increasing depth measurements.

CONCLUSIONS

In all investigated variants in headland was measured soil density greater than in the inner part of the plot. The largest eruption phase of compaction in the rye crop was measured on headland 2009 and it was 2.40 MPa, and lowest in the central part of the plot 2011 and it was 1.59 MPa. Biggest compaction before harvesting rye was measured on headland in 2012 the 4.12 MPa, and the lowest 2011 in the central part of the plot 2.25 MPa. Soil headlands during germination of rye was higher by an average of 43.82% compared to the inner part of the plot, whereas before harvesting increase in soil on headland was an average of 55.82%. The emergence of buckwheat biggest stage compaction was measured on headland 2010 and 2.69 MPa, and the lowest in the inner part of the 2011 The 1.45MPa. The minimum compaction before harvesting was measured in the central part of the plot and it is 2.54 MPa in 2011, and the largest on the headland in 2012 -3.96 MPa. Average increase in soil at the stage of eruption on the headland buckwheat than in the inner part accounted for 47.86% and 44.87% before harvesting. Increase in soil on headland at the center of the pitch has led to large differences in terms of return. The highest yield of rye was measured in the central part of the plot 2011 and the amount is 2.58 t ha^{-1}, the lowest on the headland in 2010 and it was 1.57 t ha^{-1}. Average yield reduction over the three-year examination of rye as a result of higher soil compaction accounted for 32.71% of dry grain. The lowest yield of dried buckwheat grains measured in 2010 on headland 0.81 t ha^{-1}, and the largest in the inner part of a 1.32 t ha^{-1} in 2011. Average yields of dry buckwheat seeds during the three-year investigation amounted to 33.08%.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

EFFICIENT MANAGEMENT OF AGRICULTURAL LOWLANDS AFFECTED BY HUMIDITY EXCESS FROM HUNGARY – ROMANIA TRANS-BORDER AREA

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ABSTRACT

In the frame of an collaborating project between Hungary and Romania, two research groups from the mentioned countries were focus on the efficient management of excess water affected lowlands in the Hungarian-Romanian trans-border areas.

The protection of the aquatic environment and the reduction of the negative impacts of excess water on the environment have become a major concern. More attention should be paid to the reduction of its possible negative environmental impacts and risks during the future development of sustainable water management and agriculture development.

In the frame of the project the collaborating research groups focused on the investigation of formation of excess water inundation and assessment of its damages of excess water. The joint research work based on the outstanding results achieved so far by both research groups, which had actively been working in their home countries on the development of water management for years. The collaborating research groups combined their results in order to find common solutions for the effective management of trans-border waters (Aranca River Basin).

This paper will present the results obtained in the frame of this project.

Key words: *efficient management, excess water, lowlands*

INTRODUCTION

The studies and researches developed in the frame in this project were focused on Aranca River Basin, area located in the north-western part of Timis County (Romania), at the border with Hungary. The Aranca belongs to the Danube drainage basin, itself draining 1,470 km² (790 km² in Romania, 680 km² in Serbia). In the lower part it has been channelized, so its navigable for the last 10 km and also very important for the irrigation of the arable land in its valley.

The existence of Aranca channel and the entire hydraulic system (its construction began in 1887 and ended in 1984) had beneficial effects on agriculture in the area. The 75 channels (primary and secondary) and the existence of two pumping stations on the river Mures, have enabled the irrigation of crops, abundant surface water disposal and subdivision of land, favoring the organization and implementation of the latest agro-processing technologies, land and obtain high yields.

The Aranca surface-drainage system is reaching today approximately 85,000 ha. It is situated in the extreme western Romania, being bordered on the north by the Romanian-Hungarian border and the Mureş River's eastern dyke, on the south and south-west, by the Romanian-Yugoslavian border, and on the east and south-east, by Aranca's compartment II. The system overlaps the old course of the Mures River, which used to be flooded during high waters before its damming. Its system drains an area of 1,016 km² on the Romanian territory and its main course has a length of 108 km, up to the Serbian border.

The region Aranca groundwater contributes to excess soil water, but only up to a depth of 2 m; starting from a 2.3 m depth, the groundwater has no influence on soil, but contributes to his water supply during drought. The channel water supply is from precipitation, groundwater springs and fountains of waters.

Soils are related to rock, climate and vegetation and are very different. Soils in the Aranca area are presenting several common features. All soils have the same mother rock at the base, alluvium, and with small exceptions loess on higher sites. A main characteristic of the soil cover is the dynamics differentiated in time and space that results from natural conditions of formation and evolution. As a result of pedo-genetic processes there appeared a cover of mosaic-like soil, which is also seen in the main soil types identified in the area under study. We can find in this area with large surfaces with Chernozems, Fluvisoils, Vertisoils and Pelosoils.

The project was mainly based on exchange of experience as well as on additional research activities.

METHODS

In the first part of our common project we collected some archive information about the problems of water management in both countries. In the second part of project the collaboration research teams visited the partner institutes to study the running research activities related to the joint project.

During the visit to the Romanian partner institute the members of the Hungarian research team participated and gave a presentation (Bozán, Cs., Körösparti, J., Pásztor, L., Pálfai, I.: GIS-based quantifying and mapping of excess water inundation hazard ont he South Great Hungarian Plain) in the International Symposium of 60 Years of Hydrotechnical Engineering Education in Timisoara organized by "Politehnica" University of Timisoara. The presentations of the conference showed the importance of the development of water management in Romania and evaluated its aspects. The member of the Hungarian delegation visited the local institute of the National Administration of Land Reclamation and Improvement, where Dr Blaguescu Constantin (technical director) showed the operational functions of institute and after that we visited the related water work which was belonged to the NALRI. Related with the institution activity we visited the Aranka-Maros multifunctional interconnect channel and its works (weirs, pumping stations etc.). We visited the Banat Water Management Directorate, where we got information about the activities of the institute.

Several different water management works were visited by the delegation of Romanian team in Hungary to show how to solve some kind of water related problems which is caused by excess water inundations.

The first step was to visit the Körös-Berettyó Water Management Association in Békés, where we got information about the main tasks of association in connection with excess water management and defence. After that we visited the most represented water works, i.e. main stabile pumping stations, main drainage, irrigation and double-functioned channels and of course they showed their latest water related investments. After that we visited the most innovative melioration company (Békés-Drén Ltd.) in Hungary. The last step was to visit the Lower Tisza District Environmental and Water Management Directorate in Szeged, where we was informed about the activity of Directorate.

According to our common experience we can discover that there are very similar problems connected with excess water in both countries. In the Research Institute for Fisheries, Aquaculture and Irrigation we have deal with excess water research especially GIS based the excess water hazard mapping. We used limited numbers of affecting environmental factors and information on these factors was collected and arranged in a harmonised manner in the HAKI. According to our GIS-based method the affects of soil, agro-geology, relief, groundwater, land use and hydrometeorology were represented by one parameter. In this way the formation of excess water was defined and quantified.

Each factor was spatially represented by: Soil: soil infiltration capacity based on Kreybig Map Series and Várallyay Maps; Agro-geology: a complex index considering the depth and thickness of the uppermost aquitard; Relief: relief intensity based on 1:25000 Digital Elevation Model; Groundwater: the average of the ten highest groundwater levels within 50 years; Land use: a numeric coefficient of land use based on CORINE Land Cover (CLC100) database and individually attributed to its categories; Hydrometeorology: humidity index (10% possibility of occurrence of root square of sum of monthly weighted precipitation and sum of monthly weighted potential evapotranspiration ratio).

We also compiled the map of relative frequency of excess water events for multiple regression analysis. Its source was the yearly mapping of the areas damaged by maximal inundation from 1951 to 2008.

The serial maps were overlaid providing an independent estimation of the spatial distribution of the most risky areas, as well as the dependent variable of a multiple statistical analysis. Since both its spatial resolution and confidence was weaker than those of the above listed factors, generalized versions of the quantified spatial layers (as independent variables) were jointly analyzed with the relative frequency map in a grid with cell size of 1x1 km^2. Multiple regression analysis was used for the determination of the role of various factors in the formulation of excess water thus providing weights for its stochastic linear estimation by the applied factors. The values coming from the regression equation were multiplied by and added to a constant value which is resulted in the Complex Excess Water Hazard Index and after that the Complex Excess Water Hazard Map (Figure 1.).

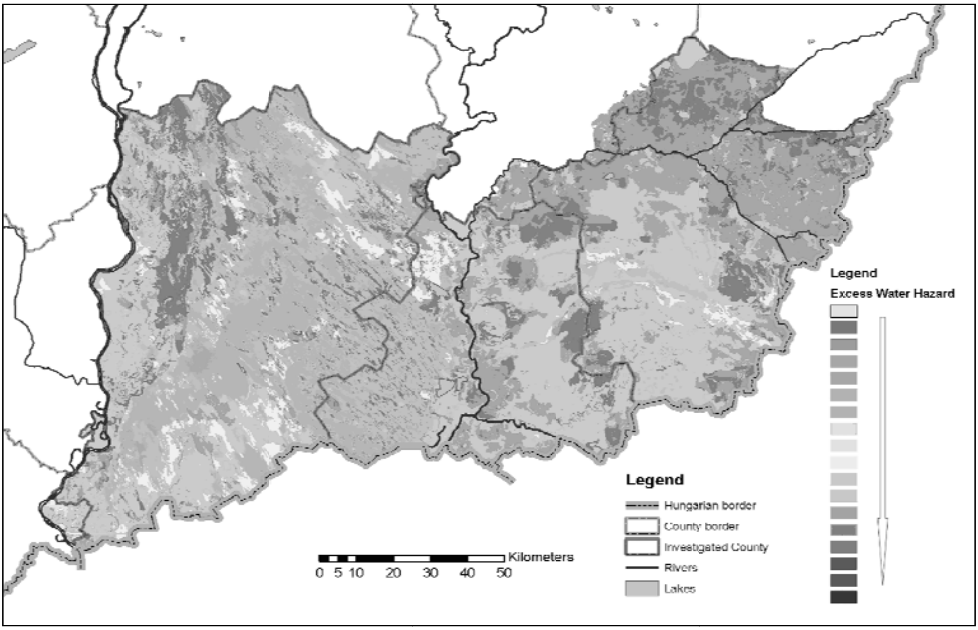

Figure 1 Complex Excess Water Hazard Map [13]

The Romanian part of trans-border areas had also being affected by excess water inundation. The geographical placement of Romania, the climate and relief conditions contribute at Romania's territory obedience to nature hazarded behaviour deployed in time. The existence of three types of hazards: geomorphologic, hydrologic and climatic.

In Romania are 8.62 million hectares agricultural fields affected by humidity excess from which 4.2 million hectares are affected by temporary humidity excess from precipitations, 1.97 million hectares with permanent humidity excess caused by water table and 2.45 million hectares with humidity excess caused by inundations or infiltrations from water courses (Figure 2.). These 3 types of hazards can have individual manifestations but also over positioned manifestations so the generated effects can be very various in a wide domain, from minor damages to disasters. In Hungary there are very similar problems related with formation of excess water inundations. Basically the formation of excess water inundations has two main reasons. On the one hand the constant factors (i.e. geological structure, soil conditions, relief, dead river beds), which create the conditions of development of excess water inundations, and on the other hand the variable factors (i.e. weather and groundwater conditions) and human factors (land use, water management, agricultural techniques, land degradation, over-irrigation and so on), which generate this phenomenon. In hydro-meteorological aspect there is a great importance of the extreme meteorological situations (accumulation of previous precipitation, low air temperature and sunshine duration and low intensity of evaporation periods).

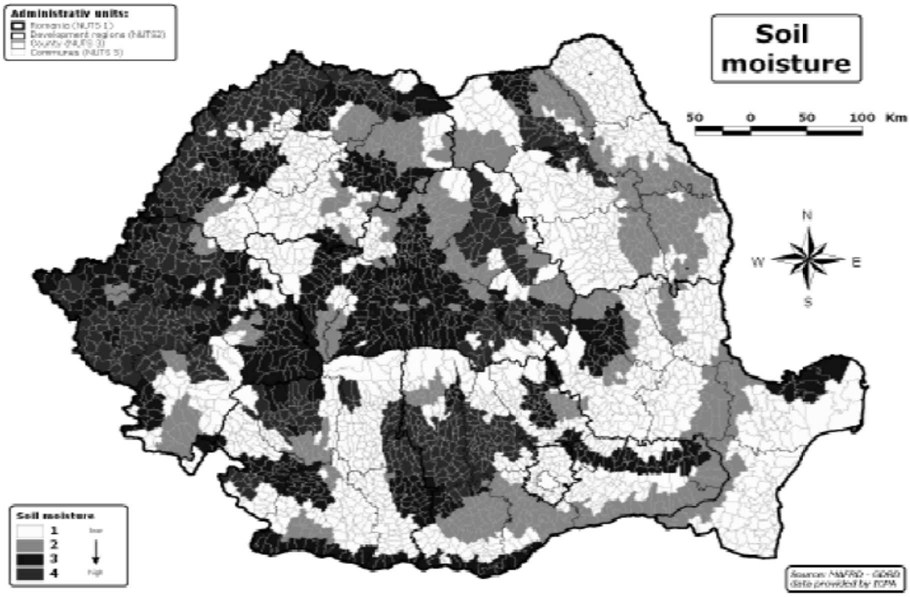

Figure 2 Romania’s situation regarding the soil moisture at NUTS V level (ICPA sourse) [9]

The last years presented in Romania large variations regarding the temperatures and precipitations regimes. The western part of this country (which includes and the Timis County) was affected several times by floods, phenomenons which were followed at very short periods of time by other water hazards. All of these phenomenons can be understand as results of climatic changes.

Specialized studies show that large areas of Timis County were affected by excess water due to overflowing rivers and local rainfall. On the basis of hydrometric observations started in 1813, has resulted in a mean frequency of extraordinary high water every seven years, but after 1989 there is a trend showing bundles dry years (1990, 1992, 1993, 1994) and those with rainy periods and the flood event (1999, 2000, 2005).

When we discuss about humidity excess in Timis County, we must identify and understand the sources and causes of this phenomenon. The most important natural factors are: climatic regime, topography and hydrological regime of the territory. They are associated with geological-lithological conditions, the soil and hydrogeological conditions, which together determine the appearance of flood and water excess stagnation on plains and plane plateaus.

The climate of the studied territory is characterized by great complexity and diversity of atmospheric phenomena that often give rise to periods of high rainfall and long lasting.

Rainfall has a predominant role in the formation and maintenance of excess moisture. The relief is a factor that determines, together with rainfall, flooding and excess water, by its diversity and distribution of natural units according to their average altitude. The phenomena of floods and the excess water occur mainly in low fields and meadows where, because of the plan relief and strong decrease of water flow, they accumulate in large quantities on the surface, flows and stagnate at soil surface.

Hydrologic regime of the territory determines the appearance of flooding, excess water in all fields of our country, but especially in the area studied. Hydrographic network density and especially its ability to transport in the studied fields may be insufficient to discharge naturally the water from rain or melting snow, and those coming from the hilly and mountain and cross plains to the main collectors.

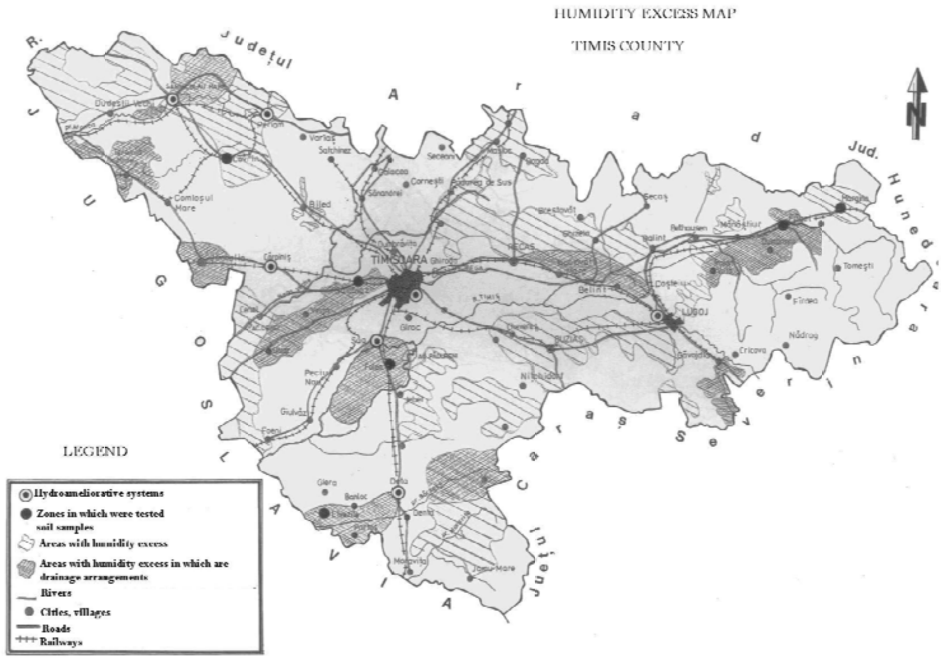

Figure 5 Humidity excess map for Timiş County [12]

In Romania, taking account of soil situation and the opportunity of implementing drainage systems on these soils, have been adopted the following calculation methods:

a. in the case of horizontal drainage, permanent regime, to calculate the distance between drains can be used one of the following methods: Donnan, Dagan, Hooghoudt, Ernst and Toksoz and Don Kirkham;

b. in the case of horizontal drainage, non-permanent regime, checking the distance L between the drains is done using one of the following methods: Glover-Dumm, Dumm, Jenab, Guyon, Kraijenhof van der Ler Maasland.

Calculating the distance between the horizontal drains is made in permanent regime while the distance verification is made in non-permanent regime (the distance between drains determined with permanent regime formula must be able to decrease the watertable level in maximum two days). Even Romanian researchers developed different methods for an efficient water management in agriculture, unfortunately, these methods were not transposed in computer programs and their resolving processes suppose long time and predisposition to errors.

Only in 2007 appeared a new program, DrenVSubIr, with a friendly interface, program which calculate the distance between drains and also verify the possibilities for applying the subirrigation.

The disadvantages of this software are:

- The calculations are realized only for permanent flow regime without verifying the results in nonpermanent situation;
- The results can't be saved on magnetic support and can't be printed;
- The program has only Romanian version.

This program is based on improved Ernst's formula for calculating the drainage with the additional term h_{if}, which represent the head loss of water entering the drainage pipe with filtering material.

Another program used by Romanian researchers for managing humidity water excess was taken from foreign countries (United Kingdom, Netherland, United States, Costa Rica, Brazil etc.). EnDrain does calculations on horizontal subsurface drainage systems in agriculture, hydraulic head, depth and level of water-table in agricultural land, and drain spacing using the energy balance of groundwater flow but also the Darcy and continuity equation. It includes drain entrance resistance and soil anisotropy of hydraulic conductivity. EnDrain is applicable to pipe/tile drains (drain pipes) and open ditches.

Another program used by Romanian researches is Wasim, especially the DrainSpace module. Developed by HR Wallingford and Cranfield University, WaSim is a computer-based training package for the teaching and demonstration of issues involved in irrigation, drainage and salinity management. WaSim is a daily water balance model that simulates the soil water/ salinity relationships in response to different management strategies and environmental scenarios. DrainSpace module, which is included in Wasim program, allows the computation of distances between drains in steady-state approach (Hooghoudt equation) and also to verify the results which were obtained using unsteady-state equations (Glover-Dumm equation).

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

Taking in consideration the increasing phenomenon of climatic change, the drainage role must be review. The costs of irrigation works, which are in a continuous increasing, in the frame of mixed arrangements, can be reduced by practicing the subirrigation with the help of controlled drainage. The areas where the irrigation and drainage works are largely spread constitute the most suitable areas for controlled drainage appliance. Also, we must consider the countries with water scarcity prognosis. This type of drainage can improve the efficiency level of water utilization. It is recommendable to apply this type of drainage in areas with water scarcity periods, with negative effects upon crops development, or in areas where the irrigation appliance supposes high costs.

CONCLUSIONS

The non-uniform distribution of atmospheric precipitation combined with heterogeneous relief and soils with unfavourable physical/hydrophysical properties are the reasons of extreme moisture regime: the simultaneous hazard of waterlogging or over-moistening and drought-sensitivity in extensive areas, sometimes on the same places within a short period. All the above mentioned 3 types of hazards involve directly problems connected with humidity excess in Romania. Geomorphologic hazard can produce on terrain with slopes local inundations, with torrential character. Hydrological hazard has impact through flow regime variation and can produce on plain terrains flooding and soil humidity excess.

Climatic hazard, which has the most variability in time, can produce through the not uniform repartition of temperatures and precipitations humidity excess in soil respectively inundations. In the last decades were done numerous researches which emphasize that to each type of hazard belong about 5 million hectares but are areas which action 2 or 3 types of hazards. Humidity excess is that stage of soil humidity which overcomes soil field capacity and tries to reach or reach almost the saturation capacity. Fields with humidity excess are widely spread in our country in numerous regions (Banat area).

Being given this context, the land reclamation and improvement works, through surface drainage and drainage arrangements for humidity excess elimination, have the role to control and attenuate the effects produced by these hazards.

Timis county lowlands, part of Romania's Western Plain, are considered a characteristic flood zone because of a set of adverse natural conditions, such as poor external drainage, large areas of agricultural land with heavy textured soils, low watertable depths, watercourses torrential regime in the upstream at certain times of the year, lower slopes, water courses, etc.

All drainage arrangements from Timis County are based on classical drainage (surface, subsurface, deep), new technologies and new concepts as controlled drainage, re-use of drainage water, wetlands restoration using drainage control structures, bio-drainage, being unknown or insufficient studied in our country. Taking in consideration the climatic changes and the EU Directives regarding the environment, the problem of humidity excess must be seen as a part of integrated water management, and an area for agriculture with humidity excess must be drained as a part from an agro-ecosystem.

The major conflict between protection of environment and drainage and the necessity of obtaining new lands for agriculture through drainage measures is more than obvious. These conflicts can be mitigated and compensated by developing and applying new technologies with a high efficiency factor. Wastewater treatment should be considered an integrated part of drainage systems. Anyway, the main idea is that the potential negative impact should be reduced at the outset level and not at the end of the drains.

In Timiş County, which presents a special situation with alternative drought and humid periods, and with an intensive fertilizing agriculture, the integrated drainage management is a proper solution taking in consideration its advantages. The climatic conditions (global warming) and the water scarcity requests new measures for an efficient water management including here sustainable irrigation and drainage methods.

The highest attention dedicated to the environment protection in the last time imposes to adopt strategies in a unitary concept which supposes the satisfaction of human needs with minimum impact upon nature. Wetlands must be rehabilitated and protected against anthropic activities or the anthropic activities must be designed to avoid the degradation of these areas or even to help at their conservation.

The economic costs of implementing an integrated drainage management, even they are sufficient high, will be covered by the ability to produce higher value crops and manage salinity and groundwater levels, with positive impacts upon the sustainable development of agriculture and rural space. As a supplementary measure, I must mention the necessity to be created farmers organizations which intend to apply on their lands the principles of integrated drainage management.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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AGRICULTURAL WATER MANAGEMENT IN ARAD COUNTY

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ABSTRACT

The last years presented in Romania large variations regarding the temperatures and precipitations regimes. The western part of this country (which includes and the Arad County) was affected by floods followed at very short periods of time by other climatic hazards as severe droughts. All of these phenomenons can be understand as results of climatic changes.

Arad County is covered by large areas with irrigation arrangements, systems more than necessary for the agricultural systems from this part of Romania. In 2009, only 8.520 ha in Arad were irrigated. From the analysis results that there is no interest in irrigation for other areas, and the surfaces that must be considered for the rehabilitation of the Şag - Fântânele and Şemlac –Pereg systems represent a maximum of 50 % of the facilitated area.

In 2012, even Romania faced the most severe drought period from the last 25 years, the area which was irrigated in Arad County was reduced to zero.

This paper will present some studies concerning the agricultural water management in Arad County, studies which will include drainage studies as well as case studies about irrigation systems.

Key words: *Arad, water management, irrigation, drainage*

INTRODUCTION

Arad County is situated in western Romania and has a total surface of 775,409 ha from which the agricultural surface represents about 65%. 138,520 ha are affected by humidity excess. In Arad County, the land reclamation and improvement arrangements, organized in hydromeliorative systems, include 222,394 ha with surface drainage arrangements, 24,551 ha with irrigation systems and 10,284 ha with arrangements for soil erosion control (Arad County’s Environmental Report, 2005).

The large areas with plains of Arad County, the low plains of Mures and Cris Rivers, the soils with a high fertility, the climate and rich precipitations explain the development of agriculture in this county.

Figure 1 Geographic map of Arad County [6]

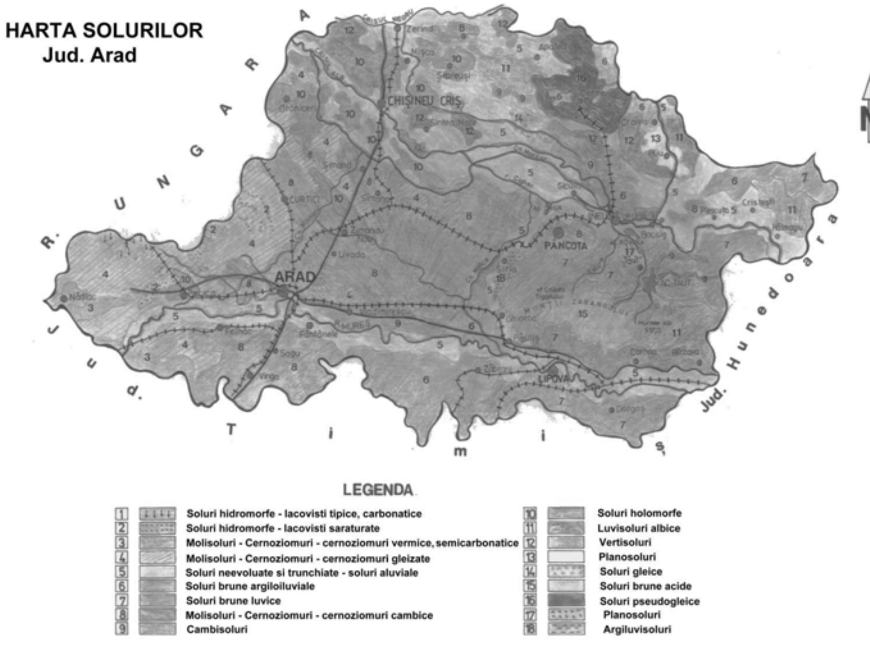

Figure 2 Soils map of Arad County [12]

Table 1 Surfaces covered with land reclamation and improvement works on hydroameliorative systems [8]

No	Name of hydroameliorative system	Surface arranged with:							
		Irrigation		Gravitational surface drainage		Pumping surface drainage		Soil erosion control	
		brut	net	brut	net	brut	net	brut	net
1	Almaş	-	-	-	-	-	-	121	121
2	Aranca	-	-	1920	1836	3897	3670	-	-
3	Bodeşti	-	-	-	-	-	-	900	900
4	Budier	-	-	7400	7077	12916	12165	-	-
5	Cermei	242	240	-	-	-	-	-	-
6	Cermei Taut	-	-	1822	1743	3102	2922	1097	1097
7	Chişer Poganier	-	-	6200	5930	10808	10180		
8	Chisindia	-	-	-	-	-	-	703	703
9	Chisindia Buteni	131		131		-		-	
10	Ghizdia	-	-	-	-	-	-	324	324
11	Cigher	-	-	3705	3543	6197	5837	-	-
12	Colector Oradea	-	-	150	143	267	252	-	-
13	Crac-Nădlac	-	-	3428	3279	8676	8171	-	-
14	Crişul Alb	-	-	-	-	-	-	4420	4420
15	Fântânele-Şagu	7150	6920	-	-	-	-	-	-
16	Gut	-	-	3809	3643	-	-	-	-
17	Hanios-Vărşand	-	-	196	187	24178	22773	-	-
18	Ier-Arad Frontieră	-	-	12200	11668	20718	19514	-	-
19	Ineu Bocsig	-	-	950	909	-	-	-	-
20	Morilor	156	156	6000	5738	10836	10206	-	-
21	Mureş	-	-	-	-	-	-	1987	1987
22	Mureş mal drept	-	-	8800	8416	4810	4530	-	-
23	Mureşel-Ier	3095	3033	-	-	-	-	-	-
24	Musteşti	-	-	-	-	-	-	732	732
25	Neudorf	962	910	-	-	-	-	-	-
26	Păuliş	4193	3962	-	-	-	-	-	-
27	Pil-Vărşand	-	-	1020	976	2382	2244	-	-
28	Pereg	8622	8394	-	-	-	-	-	-
29	Teuz	-	-	25851	24724	29929	28182	-	-
30	Ţiganca	-	-	64	61	-	-	-	-
31	Vinga	-	-	50	48	113	113	-	-
	TOTAL	24551	23746	83565	79921	138829	130759	10284	10284

METHODS

Management of humidity excess

Table 2 Results of drainage studies for Arad County [12]

Location and type of soil	Drain type	Drain diameter (cm)	Hydraulic conductivity (m day^{-1})	Coefficient of resistance to flow at water entrance in drain	Flow (mm day^{-1})	Drain depth (m)	Distance between drains (Ernst formula) (m)
Felnac I gleyied alluvial soil	plastic	5	0.10	0,507	7	1,4	5
		6.5	0.10	0,532	7	1,4	5
		8	0.10	0,607	7	1,4	5
Felnac III gleyied alluvial soil	plastic	5	0.16	0,507	7	1,4	7
		6.5	0.16	0,532	7	1,4	7
		8	0.16	0,607	7	1,4	7

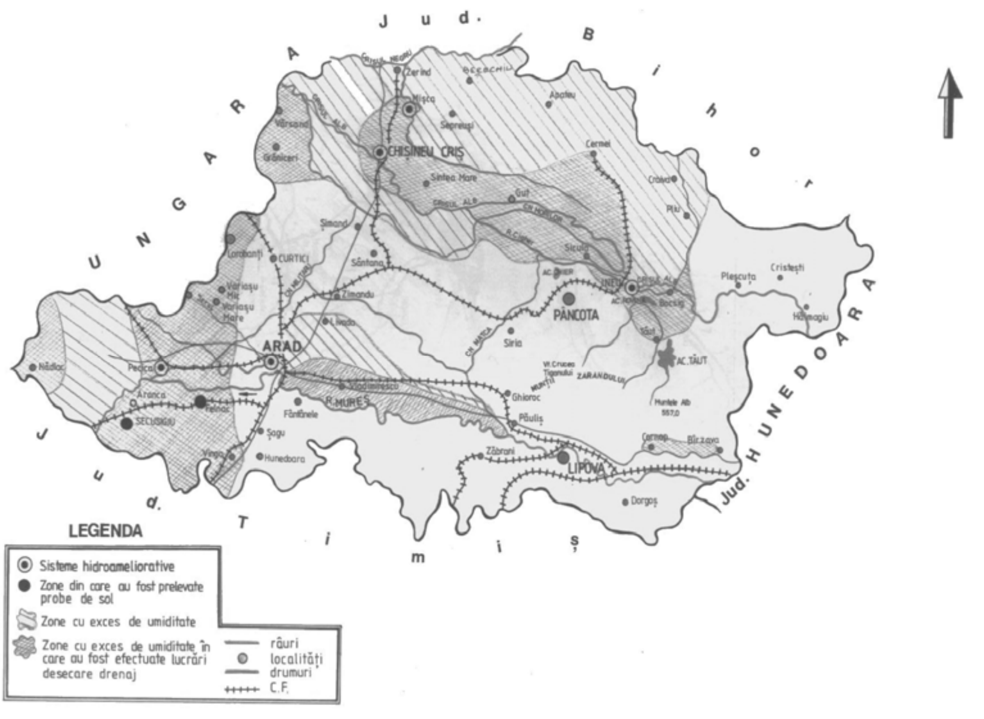

Figure 3 Humidity excess map of Arad County [12]

In Arad County were analyzed two areas: Felnac I and Felnac III. The soil which was tested was a gleyied alluvial soil. For these two areas was determined the permeability coefficient which was 0.10 m day-1 in the first case and 0.16 m day-1 in the second case.

It was determined also the distance between drains for the mentioned areas using three drain diameters (5, 6.5 and 8 cm) and as computation method was used Ernst formula. The soil hydraulic conductivity was determined in the drainage laboratory from 'Politehnica' University of Timisoara, Hydrotechnical Engineering Faculty, Hydrotechnical Constructions and Land Reclamation and Improvement Department.

For Arad County is recommended the cross drainage covered with sand in filtering trenches until above deep loosening. The filtering trench is necessary for all tested samples due to the small soil permeability having the role of gathering the water from loosening area (0.5 – 0.6m) and to conduct it to the drain tubes. Deep loosening must be periodically repeated.

Water scarcity management

Irrigation system Fântânele-Şagu-Arad was designed in 1966, the completing and expansion phase being finalized in 1974 for an area of 9418 ha, 7154 ha being realized and presenting the following scheme of planning hydrotechnical in organizing flow distribution.

The entire territory of this irrigation system is part of Tisa Plain. Plain district Vinga interposed as a relief step that dominates the low plain of 20-40 m and is dominated by piedmont with 40-60 m and forms the high plains with a general plain relief and with an altitude between 110 m and 145 m, low-sloped. This plain have low ripples, numerous valleys of erosion, frequent micro-depressions and light, elongated depressions which accumulate large regular rainfall waters. [2]

From geomorphologic point of view, this area is suitable for sprinkler irrigation and other forms of surface irrigation.

Gravitational water is sometimes present in large pores of the soil and is very mobile, poorly retained in this case, so that is rapidly lost through infiltration or leakage. It is in principle accessible to plants but they cannot benefit only slightly from it. Groundwater level was identified in the area at different depths depending on the type of relief and time. In general groundwater is at depths ranging between 0.50m and 10m, the highest levels being found in valleys of erosion (0,5 m-2m). Most of the groundwater table is at a depth of between 4m and 10m.

The climate of the studied area is characterized by annual average temperature around 10.8^0 C and average annual rainfall of 577 mm. Droughts in the region appear with a higher frequency generally from July to August and especially in September. The most common winds are those from south-easterly direction. Wind speed varies from 2.6 to 4.5 m/s. The performed climate studies indicate a less continental climate and more Mediterranean, with less severe winters and summers not excessively warm. Enough precipitation falls during the summer especially, but they are unevenly distributed on months and critical periods of crop plants growing often causing prejudices. Generally speaking the climate is poor in precipitations, as is shown also in the soil balance calculation resulting a deficit of 206 mm. [2]

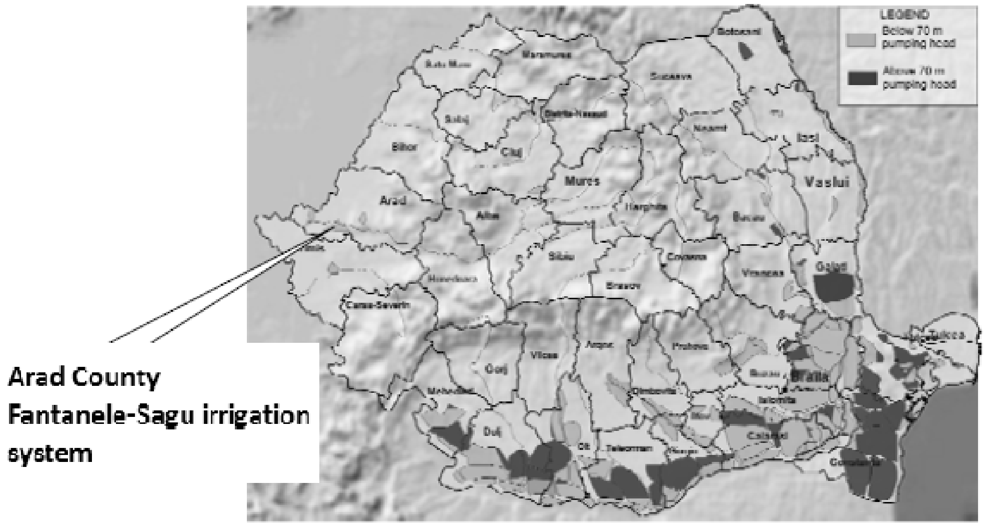

Figure 4 The geographical position of Fantanele-Sagu irrigation system [13]

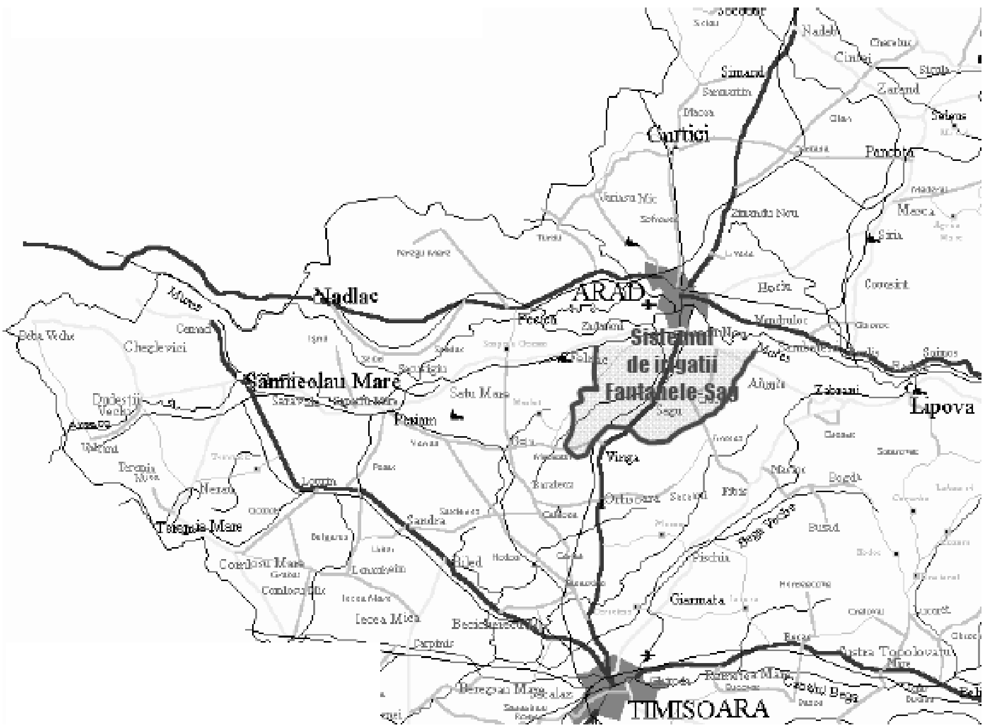

Figure 5 The geographical position of Fantanele-Sagu irrigation system (detailed map) [13]

The system has a lifetime of over 40 years, covers an area of 7154 ha, the whole surface being connected to a single hydrotechnical scheme having the supply at Mures River, being served by two adduction channels (I and II) and two pumping stations. The Floating pumping station (figure 3) consists of two boats, each supporting two pumps SIRET 900 with a total capacity of 7.4 m^3/s.

Considering the over 40 years of operation it is necessary to change the pumps (due to lower yields of operation), the engines and other components of these stations which don't answer to actual requirements. In most pumping stations it is required to change even the electrical panels.

For other parts of the studied irrigation system which are in the custody of the irrigation water users organizations, their rehabilitation and modernization remains the responsibility of these organizations. Thus were prepared several technical expertises for Fantanele pumping station, Sagu 1 Pumping station, Sagu 2 Pumping station as well as for undergro-und piping network.

Fantanele floating pumping station will be removed and replaced with a fixed pumping station, equipped with submersible pumps installed in steel pipe of ϕ1000 mm, located on the left bank of the river Mures, having a slope of 30^0. Station base equipment will consists of 6 submersible pumps that provide a flow of 950 - 1000 l/s each at a height of about 26 meters of water column (MWC). Pumping unit is equipped with an engine of 400 kW, with direct pumps, the supply power being of 400 V. [2]

Figure 6 Ship of Floating Pumping Station on Mures River [2]

The suction pipes are practically nonexistent, each electrical pump being mounted below the minimum water level of river Mures, the pumps being equipped with a vacuum cleaner with proper hydraulic form. Discharge pipes, in number of 6, are placed horizontally at 4.5 m apart, having on the first section of about 20 m a diameter of 1000 mm up to the level of 114 MWC. This level is more than up to 1% insurance flood waters of the river Mures. From this point until the station basin outlet, pipes have a diameter of 800 mm. [2]

All works proposed for rehabilitation of Fantanele Sagu irrigation system Fântânele Şagu fall in "Land improvement arrangements list or parts of land reclamation arrangements declared as public utility improvements, which is administered by the National Administration of Land Reclamation and Improvements provided in Annex 1 of Government Decision 1582 / 2006". [2]

The proposed rehabilitation works cover the area currently occupied by existing works, and therefore are not required to be permanently set aside from agricultural circuit. From a legal perspective, the area occupied by objects of infrastructure which follow to be rehabilitated are in administration of National Administration of Land Reclamation and Improvement.

CONCLUSIONS

The climatic changes, humidity excess, drought, aridity, desertification and water scarcity are interconnected. The permanent water scarcity is connected with aridity and drought as natural phenomenon while a not sustainable use of available resources, the missing of a proper water management can take us to the desertification appearance, effect of a major and negative anthropic pressure.

The changes in the Romania's climate regime can be integrated within the global context and present pessimistic evolutions for the future of agricultural surfaces from western part of Romania, territory which is partially covered by Fantanele-Şagu Arad irrigation system.

Summarised results of the experiment have shown that the soil's humidity excess management is an important and complex problem. The development of new specialized programs for drainage researchers will offer them the necessary tool to create new strategies for an efficient removal of humidity excess.

The highest attention dedicated to the environment protection in the last time imposes to adopt strategies in a unitary concept which supposes the satisfaction of human needs with minimum impact upon nature. Wetlands must be rehabilitated and protected against anthropic activities or the anthropic activities must be designed to avoid the degradation of these areas or even to help at their conservation.

The economic costs of implementing an integrated drainage management, even they are sufficient high, will be covered by the ability to produce higher value crops and manage salinity and groundwater levels, with positive impacts upon the sustainable development of agriculture and rural space. As a supplementary measure, I must mention the necessity to be created farmers organizations which intend to apply on their lands the principles of integrated drainage management.

In Romania, at country level (NUTS 1), the drainage arrangements are under the jurisdiction of National Administration of Land Reclamation and Improvement. In its strategy for the near future, were foreseen in drainage sector as measures the surface drainage channels desilting, the maintenance in activity of 3.1 million hectares with surface drainage and drainage arrangements, stimulus for beneficiaries to form organizations, the rehabilitation of pumping stations, etc.

The adoption and implementation of Water Framework Directive imposes to Romanian Government and its structures to adopt and apply strategies in concordance with European legislation and to have in view the transboundary water management plans. Bringing and implementing in Romania new techniques as integrated drainage management can constitute solutions for the central and local authorities in this domain.

In 2005 in Romania irrigation network covered approx. 2.8 million hectares, of which 1.5 million hectares with irrigation infrastructure recently rehabilitated. This large network of irrigation has been exploited in recent years (1998 - 2003), the percentage of use is between 15.6 to 37.9% of total area recently rehabilitated infrastructure.

Starting with 2010 there are no more irrigation subsidies, under the current legislation, and therefore is urgently required the rehabilitation and modernization of existing systems. In this situation is an urgent need to be prepared new rehabilitation, modernization and equipping projects of these arrangements, to be made proposals to find opportunities of new resources and solutions to support farmers from the fields arranged. These arrangements must be keep on working and provided with new technical solutions that are economically effective and efficient.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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INFLUENCE OF DIFFERENT SOIL PREPARATIONS AND VEHICLE SPEED ON PROCESS PARAMETERS AT SEEDING OF PEAS (*PISUM SATIVUM*) WITH AN TRAILED PNEUMATIC UNIVERSAL SEED DRILL

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SUMMARY

This paper presents the results of an field experiment with an pneumatic universal seed drill (Pöttinger® Terrasem R3; 3 m working width) and four-wheel drive tractor (Steyr 9125; 92 kW DIN), which was carried out at the BOKU-experimental farm Gross Enzersdorf. The analysed data show an increase of the fuel consumption rate (l/h) with operation speed. In contrast the fuel consumption (l/ha) decreases with operation speed. The lowest fuel consumption for seeding was measured in the direct seed drill variant (that is without the pre-tool disc harrow on untilled soil) and the highest in the variant "universal seed drill with disc harrow" on cultivated soil. The emergence and establishment of pea plants were not satisfied in the direct drill-variant because of poor seed/soil contact.

Key words: *pneumatic universal seed drill, fuel consumption, slip, vehicle speed, conservation tillage, direct seeding, plant emergence*

INTRODUCTION

Soil tillage in conventional tillage systems is one of the most energy-consuming processes (Zimmer et al. 2004, Stout 1990, Kalk 1981). The intensity of soil tillage depends on the number of soil tillage operations, power transmission (active by PTO or passive by drawbar power), implement geometry, and depth of operation (McKyes 1985, Loibl 2006, Godwin 2007). Fuel consumption for soil tillage operations is correlated with the intensity of soil tillage. In comparison to conventional tillage systems with a plough for primary tillage, the fuel consumption can be significantly reduced with conservation tillage systems (Mileusnic et al. 2010, Moitzi et al. 2009). The fuel consumption of soil tillage operations varies widely and can be reduced through proper matching of the tractor´s draft and PTO power characteristics and operating parameters to the tillage implement (McLaughlin et al. 2008).The "gear up, throttle down" operating strategy is a suggested method to reduce fuel consumption (Grisso and Pitman, 2001). The idea is to operate tractors in a higher gear when pulling lighter loads, thus achieving a lower engine speed and fuel consumption while maintaining the same ground speed.

Additional soil related parameters, such as soil texture and organic matter content, influence fuel consumption in soil tillage (Moitzi et al. 2009, McLaughlin et al. 2002). Depending on the soil consistency the fuel consumption increases by 0.5 to 1.5 l/ha per centimetre of ploughing depth (Moitzi et al. 2006, Kalk and Hülsbergen 1999, Filipovic et al. 2004). Moreover slippage, which is a measure of the traction efficiency, affects field performance and fuel consumption (Moitzi et al. 2006, Jenane et al. 1996). In general the fuel consumption (l/ha) for a soil tillage operation depends on the fuel consumption rate (l/h) and the theoretical technical field operation time (h/ha). The technical field operation time is a function of the technical working width (m) of the tillage implement and working speed (km/h). Investigations according Filipovic et al. (2004) show that under assumption of the constant field capacity (ha/h) the increase of working width is more fuel efficient than the increase of working speed.

The objective of this paper is to present the results of the influence on different working speed and soil preparation on technical process parameter (field performance, fuel consumption, slip, etc.) and working quality (emergence of seeded peas).

MATERIALS AND METHODS

On 4th July 2012 an field experiment with an pneumatic universal seed drill (*Pöttinger® Terrasem R3*; 3 m working width, figure 1) and four-wheel drive tractor (Steyr 9125; 92 kW DIN) was carried out at the BOKU-experimental farm Gross Enzersdorf (Lower Austria; 48° 15′ N/ 16° 37′ E; semi-arid region with an average precipitation of 546 mm and average temperature of 9.8 °C). The silty loam soil belongs to the soil type Chernozem. The average air temperature from 27th June 2012 to 4th July 2012 was 21.2° C and the precipitation was 7.4 mm.

The used pneumatic universal seed drill (figure 1) is equipped with an electrical dosage-system that enables continuously seed amount adjustment from 0.6 to 350 kg/ha. For the experiment the adjusted seed amount for pea (*Pisum sativum*) was 140 kg/ha.

For the measurement of the fuel consumption, a high-performance flow meter (PLU 116H, AVL® List, Graz, Austria) with a proportional–integral (PI) controller was installed in the fuel system of the tractor. All signals of measured parameters in Table 1 were recorded with a multi-channel datalogger (Squirrel® Datenlogger 2020) at a scan rate of 1 Hz.

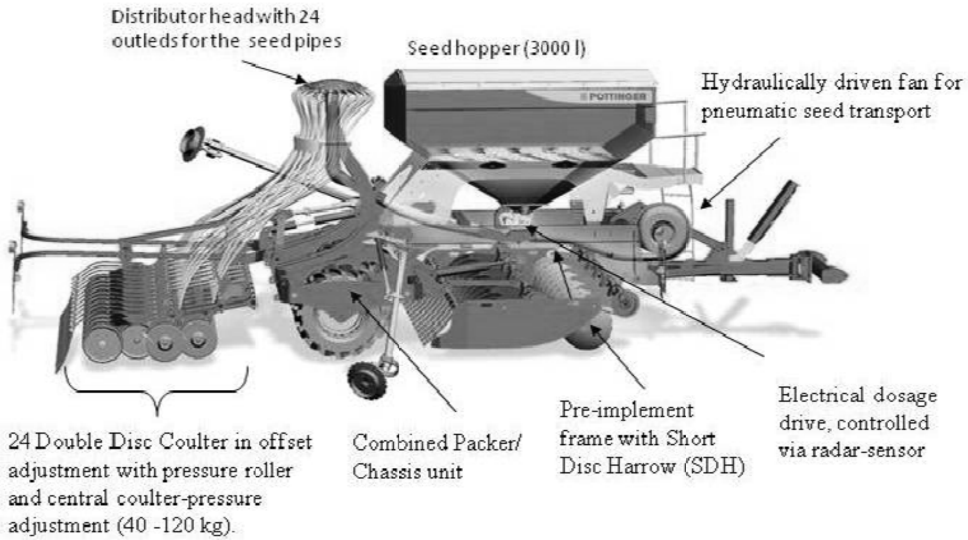

Figure 1 Components of the pneumatic universal drill machine (*Pöttinger® Terrasem R3*)

Table 1 Process parameters and their measurement

Process parameter	Measurement engineering
Vehicle speed (v)	Radar sensor generates a rectangular signal (130 pulses m^{-1} = 27.8 Hz/(km/h)
Wheel speed (v_0)	Transmission sensor (inductive transducer), generates a 0.4 - 3.8 V AC signal
Engine speed (n_E)	Inductive sensor generates a rectangular signal between 0 - 12 V AC signal
Fuel consumption (B)	Flow meter (PLU 116 H), generates a digital rectangular signal between 22 - 2800 Hz

The experimental design (Table 2) consists of the factor soil preparation (untilled barley stubbles, cultivated, ploughed) and seeding speed (8, 10, 11 km/h). The 65 m broad field was divided in three plots: "untilled", "cultivated" and "ploughed". Within each plot there are two operation variants of the universal seed drill: once with usage of the pre-implement Short Disc Harrow (SDH) and once without usage the pre-implement SDH.

The flat field was 450 m long. Within the 450 m field length three speeding speeds (8, 10, 11 km/h) were tested. The used tractor (Steyr 9125) is equipped with a full synchron multistep powershift transmission with 4x6 gears. The first 150 m was the section, where working speed of 8 km/h was realised with the 2nd gear and 3rd powershift. Then the gear was changed to 3rd gear and 3rd powershift for the next 150 m with an working speed of 10 km/h. In the last 150 m of the field, the working speed of 11 km/h was realized with the gear adjustment of 3rd gear and 4th powershift.

Table 2 Overview of the investigation variants

Soil preparation	Universal seed drill without short disc harrow	Universal seed drill with short disc harrow
Untilled	8, 10, 11 km/h; each 4 replicates	8, 10, 11 km/h; each 3 replicates
Cultivated (15 cm)	8, 10, 11 km/h; each 4 replicates	8, 10, 11 km/h; each 3 replicates
Ploughed (20 cm)	8, 10, 11 km/h; each 3 replicates	8, 10, 11 km/h; each 4 replicates

The variant specific engine speed data (not presented in this paper) ranged between 1400 rpm and 1800 rpm. For each factor combination (Table 2), 150 to 270 values of the process parameter (Table 1) were measured. The whole data were analysed with the statistical software SPSS Version 18.

Besides the measured process parameter (Table 1) the emergence of the seeded peas were detected by counting the plants in an square meter frame on 28th August 2012. The vegetation period between seeding (4th July 2012) and counting of established plants (28th August 2012) was characterized with an average air temperature of 21.2° C and precipitation of 106 mm.

RESULTS AND DISCUSSION

Process parameter

The mean process parameter for the three speeds (8, 10 and 11 km/h) are presented independently of the soil preparation in Table 3.

The analysed data in Table 3 and Figure 2 show an increase of the **hourly fuel consumption (l/h)** with operation speed. According to investigations by Kichler et al. (2011), operating at fast speeds in deep tillage increased: draft, fuel consumption, axle torque and field performance. With regards to energy efficiency, the optimal vehicle speed depends on matching the implement to a tractor, and a good match can achieve substantial energy savings (McLaughlin et al. 2008). An indicator for fuel-efficient engine operation is the engine speed, which is for most engines at 70 - 80 % of the nominal engine speed. The "gear up, throttle down" strategy by Grisso and Pitman (2001) is a practical approach for saving fuel in field operations. It is more fuel efficient to operate an implement with a smaller tractor at a "good load" than with a larger tractor at a "bad load" for a certain vehicle speed.

Table 3 Mean process parameter with subgrouping according Student-Newman-Keuls test

Wheel speed (km/h)	N	Subgroup for α = 0.05		
		1	2	3
8 km/h	1767	8.13		
10 km/h	1189		9.79	
11km/h	1051			10.98
Vehicle speed (km/h)				
8 km/h	1438	8.24		
10 km/h	987		9.89	
11km/h	898			11.08
Slip (%)				
10 km/h	987	1.13		
11 km/h	897	1.20		
8 km/h	1430		1.42	
Engine speed (1/min)				
8 km/h	1767	1662		
10 km/h	1188		1709	
11km/h	1051			1799
Fuel consumption (l/h)				
8 km/h	1767	16.88		
10 km/h	1188		18.72	
11km/h	1051			20.23
Theoretical field performance (ha/h)				
8 km/h	1767	2.44		
10 km/h	1188		2.94	
11km/h	1051			3.29
Fuel consumption (l/ha)				
11 km/h	1051	6.15		
10 km/h	1188		6.38	
8 km/h	1767			6.92

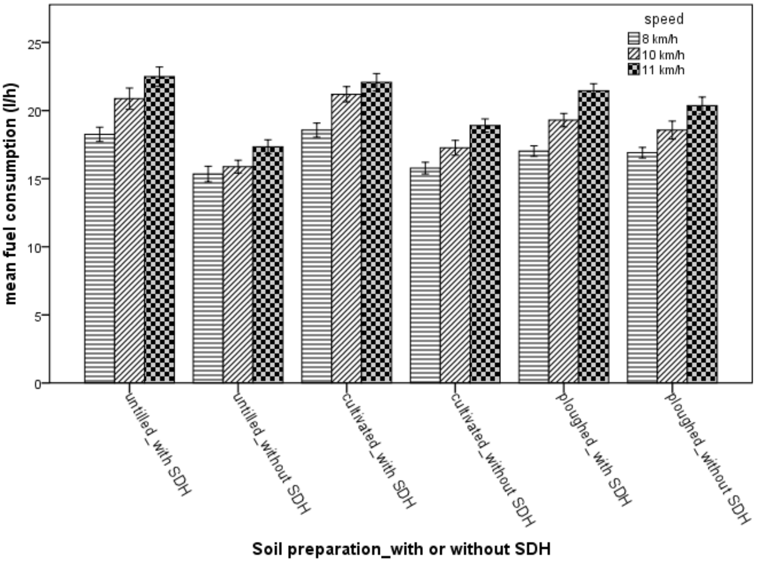

Figure 2 Mean hourly fuel consumption (l/h) with standard deviation at drilling on untilled, cultivated and ploughed soil with and without pre-implement Short Disc Harrow (SDH)

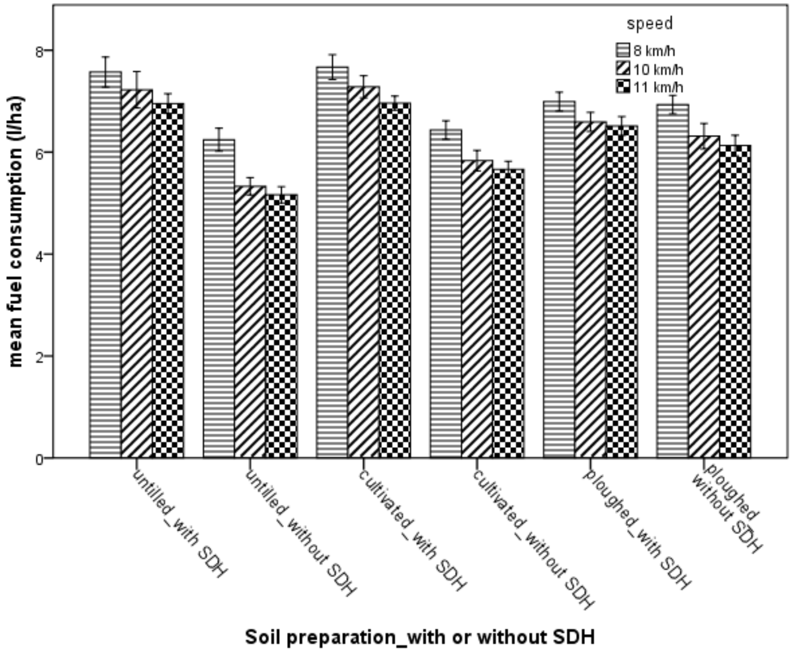

Figure 3 Mean area fuel consumption (l/ha) with standard deviation at drilling on untilled, cultivated and ploughed soil with and without pre-implement Short Disc Harrow (SDH)

In contrast to previous, the **area fuel consumption (l/ha)** decreases with operation speed (Table 3 and Figure 3). The lowest fuel consumption for seeding was measured in the direct seed drill variant (that is the usage of the pre-implement short disc harrow on untilled soil) and the highest in the variant "universal seed drill with short disc harrow" on cultivated soil. The application of the pre-implement short disc harrow (SDH) results in an average additional consumption for untilled soil of +1.64 l/ha (=+29 %) for cultivated soil of 1.03 l/ha (=+18 %) and for the ploughed soil of +0,21 l/ha (=+3 %) in comparison without SDH.

Pea plants per square meter

The emergence and establishment of pea plants were not satisfied in the untilled and cultivated variant because of the poor seed/soil contact. Especially the direct seeding variant (untilled_without SDH) shows a poor field emergence and establishment of pea plants. The unsatisfactory seed embedding was caused by hard dry soil at untilled plots and limited coulter pressure of 130 kg. The universal seeding machine was not designed for direct seeding. The combination of the short disc harrow and seeding coulter are normally used for seeding after cultivating or ploughing.

Table 4 Mean number of pea plants in a square meter after 55 days of seeding for different seeding variants

Plants per m^2	N	Subgroup for α = 0.05[1)]		
		1	2	3
Untilled_without SDH[2)]	62	9.2		
Untilled_with SDH	53	10.4		
Cultivated_with SDH	52	10.8		
Cultivated_without SDH	72	11.2		
Ploughed with SDH	72		14.0	
Ploughed without SDH	54			16.0

[1)] Student-Newman-Keuls procedure with the statistic programme SPSS 18.
[2)] Short Disc Harrow

Table 5 Mean number of pea plants in a square meter after 55 days of seeding in dependence of the seeding speed

Plants per m^2	N	Subgroup for α = 0.05[1)]		
		1	2	3
11 km/h	120	10,1		
8 km/h	125		12,2	
10 km/h	120			13,5

[1)] Student-Newman-Keuls procedure with the statistic programme SPSS 18.

There was no consistent explanation for the significant influence of the seeding speed on the pea plants per square meter (table 5), because the systematic effect of the seeding variants and randomly effects are included.

CONCLUSIONS AND OUTLOOK

The carried out experiment realized the highest speed (v=11.0 km/h), which was at the performance limit of the used tractor engine (P_e= 92 kW). Experiences from the farmers show, that seeding with an universal pneumatic seed drill are usually in the speed range between v=13.0 - 15.0 km/h because they use a more powerful tractor. With increased speed the hourly fuel consumption (l/h) increased while the area fuel consumption (l/ha) decreases because of the increase of the theoretical field performance. The effect of seeding speed on the soil disturbance caused by the interaction between soil/disc coulter or soil/tines should be investigated, because there rare data for tillage erosion by seeding.

Future research should be focused on embedding of different kind of seeds with the vertical and horizontal distribution under firm soil conditions. Also the comparison of the whole cropping system with the different seeding strategies of the universal pneumatic seed drill at different site conditions (climate and soil) is necessary.

ACKNOWLEDGEMENT

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

THE STUDY OF HEAVY METALS LEVEL FROM AMBIENT AIR: CASE STUDY – CLUJ COUNTY

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SUMMARY

Air pollution by heavy metals is a dangerous component of general pollution, affecting environment and human health. In this paper we present the study of heavy metals pollution level in Cluj County between 2009 and 2011, identifying polluter and proposing measures to reduce pollution. Using existing equipment at Regional Environmental Agency Cluj we have measured the levels of cadmium, chromium, copper, mercury, nickel and zinc on each type of pollutant. We have found that the main type of heavy metals pollution is the burning of fuels in manufacturing processes and in energy transformation processes and also in road transport. Since 2011, the heavy metals are catalogued by the last directive of IPPC, COV and Seveso. The collected data shows a decreasing trend for heavy metals pollution, primarily due to reduced industrial activities but also to reduced pollution from transport. We also propose some measures to improve environmental management in order to reduce pollution.

Key words: *heavy metals, lead, pollution level, polluters, pollution reduction*

INTRODUCTION

Air pollution is one of the great challenges of the last decades. This is due to the aggressiveness of pollutants on human health and their impact on the environment: air, water, soil and vegetation.

Dust that you respire is made up of a number of components, and of these heavy metals are of particular importance because of the impact on human health. Heavy metals can’t be degraded naturally, because it has a long residence time in the environment. In the long term they are dangerous because they can accumulate in the food chain.

Thus, in this paper we presented experimental data regarding to concentrations of heavy metals in the air in Cluj. Data were collected in 2008-2011 from automatic monitoring stations for air quality, located in Cluj-Napoca (Aurel Vlaicu Street - traffic) and the Dej City (Dej - urban).

METHODS

The amount of metals in ambient air can be theoretically determined from Inventory Emission. Further, they can be experimental by processing filters that PM10 sampling was performed, followed by mineralization and determination of heavy metals concentration through Atomic Absorption Spectrometry (AAS).

Samples, after conditioning process, are undergoing a process of mineralization. During mineralisation process was used an Microwave decomposition system - ETHOS D. The system consists of a microwave generator with programmable power and with inside lined with multiple layers of Teflon to resist acid vapours HCl, H_2SO_4, HNO_3. Mineralization is performed under pressure up to 100 bar.

The second stage of processing is to determine the concentration of metals samples by atomic absorption spectrometry (AAS). Atomic Absorption Spectrometer equipped with a graphite furnace, Thermo SOLAAR Model was used. In this stage was used an Atomic Absorption Spectrometer equipped with a graphite furnace rather than an Atomic Absorption Spectrometer with flame. That because the used model have the conversion efficiency of the sample, in an free atoms population, lower then the other spectrometer which has the conversion efficiency of the sample in graphite furnace where the entire sample is converted in free atoms. In analytical terms, the measurements in useful absorbance field can be achieved with less concentrations of the sample. In spectral terms the sensibility of the graphite furnace is 100 greater then the flame.

Particulate mass collected on a filter membrane is put on acid solution. The heavy metals present are solubilised and solution is analyzed by atomic absorption spectrometry. Absorbance is measured at specific wavelengths to each metals analyzed.

RESULTS AND DISCUSSIONS

Industrial pollution and road traffic are major sources of air pollution in Cluj-Napoca. Industrial platforms of Cluj-Napoca and urban traffic arteries are the most affected areas, in terms of air pollution with heavy metals.

In the present paper are analysed the data achieved regarding to heavy metals concentrations (Cu, Cr, Ni, Zn) and their evolution in 2009 – 2011. The data was achieved in collaboration with Environmental Protection Regional Agency Cluj. Data was divided on economical activities which at the end it was cumulated.

The data achieved on 2009 are showed in table 1.

Table 1 The heavy metals emissions according the major activities in Cluj Region, in 2009.

SNAP Activity Classification		The heavy metals emissions in 2009, [kg/year]					
No.	Activity Name	Cd	Cr	Cu	Hg	Ni	Zn
01	Energy conversion and conversion industry	1,354	1,895	1,083	0,271	2,707	37,905
02	Non-Industrial Heating Plant	0,253	0,531	0,350	0,112	4,089	6,946
03	Heating in Manufacturing Industry	4,265	10,520	10,213	1,558	24,476	260,521
04	Manufacturing Process	0,176	0,246	0,140	0,070	0,351	4,916
05	Solvents and other products use	0,001	0,002	0,001	0,0005	0,003	0,035
06	Road traffic	0,105	0,496	16,873	-	0,695	9,913
07	Other mobile sources and equipments	0,109	0,547	18,599	-	0,766	10,818
08	Storage and Treatment Waste	1,131	0,177	1,175	0,0005	0,302	2,867
Totally in Cluj Area		7,395	14,414	48,435	7,833	33,390	333,920

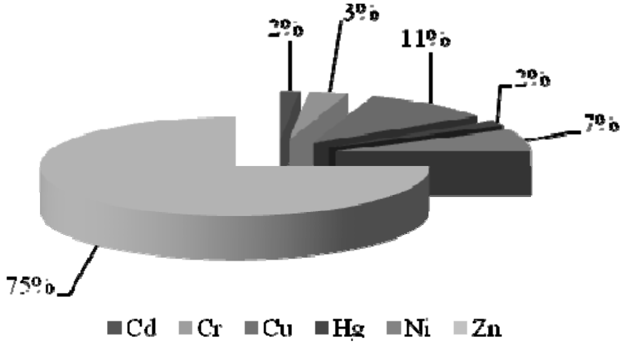

Figure 1 Heavy metal emissions in Cluj Area, in 2009

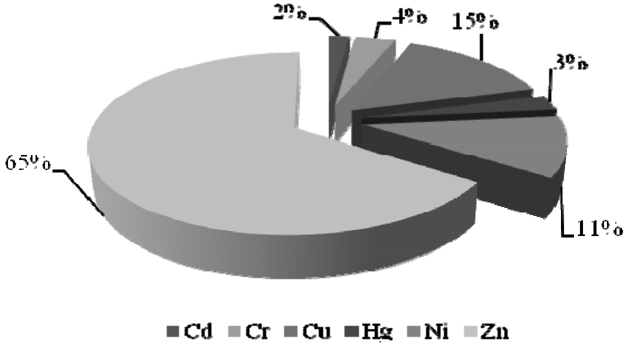

Figure 2 The heavy metals emissions in Cluj Area, in 2010

The partitioning of particular heavy metals in total quantity of metals assessed and monitored in Cluj Area in 2009 is showed in figure 1.

The data from the Table 1 showed the heavy metals quantity resulted from the main activity made in Cluj Region in 2009, respectively 450,2723 kg heavy metals total amount (As, Cd, Cr, Cu, Hg, Ni, Se, Zn). The data, shown in Table 1, do not include the quantity of Pb, As and Se. Data analysis shows that the largest quantities of heavy metal emissions are from manufacturing industry and energy production activities.

The data regarding to heavy metal amounts in 2010 are showed in Table 2, and their structure divided by the main activities made from Cluj Area in 2010 are showed on Figure 2.

From the emission inventory, in 2010 a heavy metals amount about 172 kg came from industrial activity. The data showed a decrease of heavy metal amounts emitted in 2010 comparing to 2009 (Table 3 and Fig. 2). There is a significant reduction in emissions of heavy metals in all kinds of activities inventoried and the categories of pollutant activities remained constant.

Since 2011, the amount of heavy metals resulting from businesses inventory has been subjected to the IPPC, COV and SEVESO Directives. Thus, in 2010 the storage data methodology was changed. Using the new methodology in table no.3 is showed the data cumulated on the activity in 2011.

Data analysis showed that in 2011, were recorded the lowest value of heavy metals concentrations. The data show the same downward trend as in 2009 and 2010. Thus, in 2011 was emitted in atmosphere a heavy metals amount about 110,78 kg, made from industrial activity. In 2011, an important attention was paid to cadmium and nickel.

Table 2 The heavy metals emissions divided on the major activities made in Cluj Region, in 2010

SNAP Activity Classification		The heavy metals emissions in 2010, [kg/year]					
No.	Activity Name	Cd	Cr	Cu	Hg	Ni	Zn
01	Energy conversion and conversion industry	1,258	1,761	1,006	0,252	2,515	35,213
02	Non-Industrial Heating Plant	0,268	0,532	0,334	0,119	3,910	7,101
03	Heating in Manufacturing Industry	2,226	6,256	4,159	0,843	19,753	101,412
04	Manufacturing Process	0,244	0,342	0,195	0,098	0,488	6,836
05	Solvents and other products use	0,001	0,001	0,0008	0,0004	0,002	0,003
06	Road traffic	0,096	0,438	14,886	-	0,613	8,742
07	Other mobile sources and equipments	0,099	0,496	16,856	-	0,694	9,631
08	Storage and Treatment Waste	1,206	0,185	1,250	5,983	0,309	3,296
Totally in Cluj Area		5,398	10,011	38,688	7,294	28,286	172,260

For cadmium indicator values were recorded monthly average concentrations in the range of minimum (0,200 ng/mc in Dej) and maximum concentrations (1,916 ng/mc in Cluj-Napoca, Aurel Vlaicu Street).

Average annual values for cadmium determined in particulate matter at two automatic stations for air quality monitoring are showed in table 4.

Table 3 The heavy metals emissions in 2010, [kg/year]

Cd	Hg	As	Cr	Cu	Ni	Se	Zn
1,046	0,418	0,193	1,354	0,781	2,04	0,236	104,68

Table 4 The annual average concentration of Cadmium, in 2011, in Cluj Area

Monitoring Station Name	Average annual values for cadmium ng/mc
CJ1- Aurel Vlaicu Street - traffic	1,169
CJ5- Dej - urban	0,459
Annual target value	5

Table 5 The annual average concentration of Nickel, in 2011, in Cluj Area

Monitoring Station Name	Average annual values for nickel ng/mc
CJ1- str. Aurel Vlaicu - traffic	1,499
CJ5- Dej - urban	0,849
Annual target value	20

For nickel indicator values were recorded monthly average concentrations, in 2011, in the range of minimum (0,530 ng/mc in in Cluj-Napoca, Aurel Vlaicu Street) and maximum concentrations (2,514 ng/mc in Cluj-Napoca, Aurel Vlaicu Street). The highest value was recorded in February 2011, in Cluj Napoca, CJ1 Monitoring Station located on Aurel Vlaicu Street (2,514 ng/mc).

Average annual values for nickel determined in particulate matter at two automatic stations for air quality monitoring are showed in table 5.

Thus, the average annual nickel value recorded in 2011 was below the annual target value (20 ng/mc). The annual target value for nickel concentration was imposed by the Ministerial Order no. 448/2007 approving the Norms on the assessment for arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air.

CONCLUSIONS

The emission inventory from Cluj Area, made from Regional Agency for Environmental Protection Cluj-Napoca, showed that the amount of heavy metals (As, Cd, Cr, Cu, Hg, Ni, Se, Zn), in 2010, was 265,26 kg while in 2009, was 450,27 kg. Thus, in 2010, the heavy metal emissions decreased by 41,09% compared to the previous year. Downward trend in 2011 was held, the calculated amount of heavy metals was 110,78 kg.

Increasing businesses inventory has achieved an image closer to reality in terms of quantities of pollutants emitted into the atmosphere.

It was found that in recent years the share of heavy metal emissions from industry declined, but there was an increase in heavy metal emissions from mobile sources.

Quantities of heavy metals emissions reported by businesses are declining, mainly due to retrofitting and upgrading their business.

Cluj Area was included in the national air quality monitoring network, which allowed a more rigorous monitoring of heavy metals.

Monitoring sensitive locations in Cluj was the basis for measures in reducing polluting emissions (particulate matter and heavy metals).

The quality of ambient air is one of the more important factors in relation between the comfort and population health and the quality of the air in residential areas. So, this factor is very important for the quality of environment.

The respiratory tract is the first affected by the air pollution. Thus, the environmental factors can be considerate a source of evolutionary bursts. It should be noted that the incidence of respiratory diseases in children raises a number of issues currently private epidemiology with important consequences.

Child population is at risk category due to illness higher biological features (body growing, underdeveloped immune system). To track the impact of environmental pollution on health is necessary to follow certain health indicators, approved and proposed by the European Community. They can highlight the degree to which human health can be affected after short or long term exposure.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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MAGNETORHEOLOGICAL BRAKE AS POTENTIAL APPLICATION FOR SEAT SUSPENSION SYSTEMS

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ABSTRACT

Potentially negative effects on human health caused by vehicle operating are numerous. Vibrations generated by off-road machinery exploitation are such kind of influence that has negative, long-lasting effect on driver's body. Great deal of efforts has been made in the past several years to reduce this kind of influence. Active and passive systems for vibration intensity reduction are in the focus of development. Application of intelligent materials such as magnetorheological fluids, gives excellent results. Magnetorheological fluid application in this field has so far been concentrated at shock absorbers as damping elements for driver's seat system.

Investigation results for magnetorheological brake application potential as a damping element at driver's seat suspension system have been presented in this paper. For this purpose a test rig was designed and manufactured with the aim to determine control current – torque relationship. The results show that there is a great potential for this kind of magnetorheological's brake application.

***Key words**: Vibrations, test rig, agricultural tractor, amplification factor..*

INTRODUCTION

One way to lessen the adverse effects of vehicle vibration to the operator's body is with a seat suspension system. During operation, vehicles are subjected to significant energy and conventional seats tend to amplify vertical vibration [9]. Adaptive seat suspension system is one of the keys in reducing vibration transfer from vehicle to the operator. This is achievable with usage of controllable damper devices that utilize intelligent materials such as magnetorheological – MR fluids.

MR fluids represent a group of intelligent materials that react to external magnetic field influence. By varying the intensity of magnetic field, rheological properties of MR fluids can be precisely altered. Change generated by external magnetic field is often referred as MR effect. The MR effect directly influences mechanical properties of the MR fluid, mainly its viscosity. The change is rapid, reversible and controllable with the magnetic field intensity. Numerous devices, such as brakes, clutches, engine mounts, shock absorbers, dampers etc. utilize MR fluid in order to have adaptable control/response.

Convectional MR seat suspension systems use MR shock absorbers as damping elements [5], [7]. Research accent of this paper was on determining Overall Braking Torque – OBT, control current – OBT relationship and the MR`s brake potential as a damping element for operator`s seat suspension system. This paper represents experimental MR brake characteristic research.

STATE OF THE ART

Agricultural tractors operators are exposed to a numerous negative working surrounding effects, mechanical vibrations especially. It is proven that certain illnesses are more common at tractor operators and its source can be reduced to mechanical vibrations exposure [3].

To lessen these kinds of risks, it is essential to reduce operator’s exposure to mechanical vibrations as much as possible. On the other hand, agricultural tractors ride on rough terrains, i.e. terrains that are characterized with considerable amplitudes and small wave lengths. These sorts of terrains can exert significant vibration excitation, even at small speeds. Situation deteriorates by the fact that most of the agricultural tractors are characterized by the absence of elastic suspension system. Here, tires are the only element that serve for road loads cushioning. Tire oscillatory characteristics are however, determined by their constructive parameters. These parameters must meet the requirements related to payload capacity, propulsion, soil conservation etc. Based on these requirements, it is difficult to optimize rigid suspension vehicles vibration characteristics. In addition, compared to commonly used suspension systems tire has very low damping.

All aforementioned facts leads to the conclusion that the agricultural tractor vibrations that are affecting operator can be reduced only by the means of elastically suspended seat and/or cabin.

With usage of passively suspended seat, in higher frequency domain, dynamic vibration attenuation occurs in relation to excitation. At lower frequency range, however, driven vibration amplitude amplification occurs. This behavior is the consequence of the nature of the transfer function of elastic system exposed to driven vibrations, such as passively suspended seat.

This shortcoming of passive suspended seat can be eliminated or at least mitigated by using system that can actively adjust damping of the seat suspension to the frequency content of excitation signal, so that response amplitude is minimized under broad spectrum of working conditions.

This is achievable by means of semi-active suspension systems that are characterized by variable damping in relation to external excitation.

In order to obtain semi-active seat suspension, with usage of conventional seats, a new type of actuators is needed - MR fluid based actuators. With quick response, variable torque and adaptability MR shock absorbers have great application potential. Newer the less, MR brakes show considerable damping potential as well

MR brake experimental results for damping application potential are presented in this paper's sequel. Response time, overall braking torque and amplification factors have been presented.

MAGNETORHEOLOGICAL ACTUATOR MECHANICAL MODEL

The most common non-Newtonian fluids mechanical model founded in literature is Bingham`s model, [2], [11], [13]. This model was used in this research. Aside Bingham`s model there are a few more, [1], [4], [6], [9], but of higher level of complexity. Depending on type of application and MR fluid's mode of operation, some models can produce better approximation results then the Bingham's model.

Applications, such as MR brake do not require excessive precession in modeling process, so the use of complex models is not justified. This is the main reason for Bingham's model large literature presence.

In the absence of an external magnetic field, OFF state, an MR fluid behaves as Newtonian fluid (1). When an external magnetic field is applied, ON state, the rheological properties of MR fluid change. The change is instantaneous, fast and reversible and it leads to change in MR's fluid rheology. When magnetic field is applied, the MR fluid is represented as a non-Newtonian fluid (2).

$$\tau = \eta \dot{\gamma} \tag{1}$$

$$\tau = \tau_B + \eta \dot{\gamma} \tag{2}$$

where η is plastic viscosity, $\dot{\gamma}$ is share rate; τ_B is yield stress - field dependent. Equation (2) consists out of two parts: i) the field-induced part - τ_B and ii) the viscous part; $-\eta\dot{\gamma}$. The overall braking torque - OBT in MR fluid brake comprises out of two aforementioned parts and the third – friction part. The third part, the friction part is generated from bearings and seals. In this study, the friction part was measured on the test rig.

Based on Equation (2) and brake's specific geometrical configuration, it applies:

$$dT = 2\pi N \tau r^2 dr \tag{3}$$

where T is the brake torque, N is the number of surfaces of the rotor, perpendicular to magnetic flux lines and in contact with MR fluid and r is rotor`s radius.

The sum of torque parts i.e. the field induced part and viscous part, form a braking torque that can be obtained by the following integral:

$$T_B + T_{vis} = 2\pi N \int_{R_i}^{R_o} \tau r^2 dr \tag{4}$$

where R_o and R_i are outer and inner radii of the rotor, respectively. Adding the friction part to braking torque equation, Equation (4), the OBT, for MR disk brake design, can be expressed as:

$$OBT = T_B + T_{vis.} + T_{fric.} = \frac{4}{3}\pi\tau_B\left(R_i^3 - R_o^3\right) + \pi\eta\frac{\omega}{g}\left(R_i^4 - R_o^4\right) + T_{fric.} \tag{5}$$

EXPERIMENT SETUP

For performance evaluating of MR disk brake, a test rig was set up. With its parts, the test rig is depict in Figure 1 and Figure 2, and was described in more details in [10]. The system composes of four main parts:

- drive and support frame,
- power supply,
- MR brake and
- measuring and data acquisition equipment.

An 8-pole AC motor with 0.75 kW and maximum of 750 rpm, model 5 AZ 100 LA – 8 (Koncar) was placed at one end of the support-frame. The inverter - Micro Master (Siemens), Figure 2, position 2, controls the AC motor`s direction and sets speed. Speed range was 150 rpm to 750 rpm with 50 rpm step. Two, aforementioned elements, form a drive part of the test rig. The flexible coupling connects AC motor and the MR brake’s shaft. MR brake rests on two self-aligning ball bearings, P203 (FK). To avoid leakage of MR fluid, Nitrile Rubber lip seals, that were suitable for MR type application, have been used.

Torque transfer from the MR brake to a measurement device was indirectly. A load arm connected to the MR brake housing at one end rests on top of the load cell on the other end, Figure 1, position 7. Thus, by measuring the force on the load cell, we could estimate the exact value of reactive torque. The capacity of the load cell, 1030 (Tedea), was 15 kg. The signals were processed by universal amplifier, KWS 673.A2 (HBM), Figure 2, position 3.

The optical encoder, model AMT102-V-REV-C (CUI Inc.), was connected to the MR brake’s shaft, at the opposite side of the AC motor. The DC power supply, EA PS 2016-100 (Elektro-automatik), was connected to the leads of the coil and provides flux generation.

This was the control current, with range of 0 A to 2 A and 0.2 A increment. The coil had 840 windings of copper wire with diameter of 1 mm (18 gauge). The wire has been coiled on a 57.85 mm outer radius of the MR brake's housing - stator.

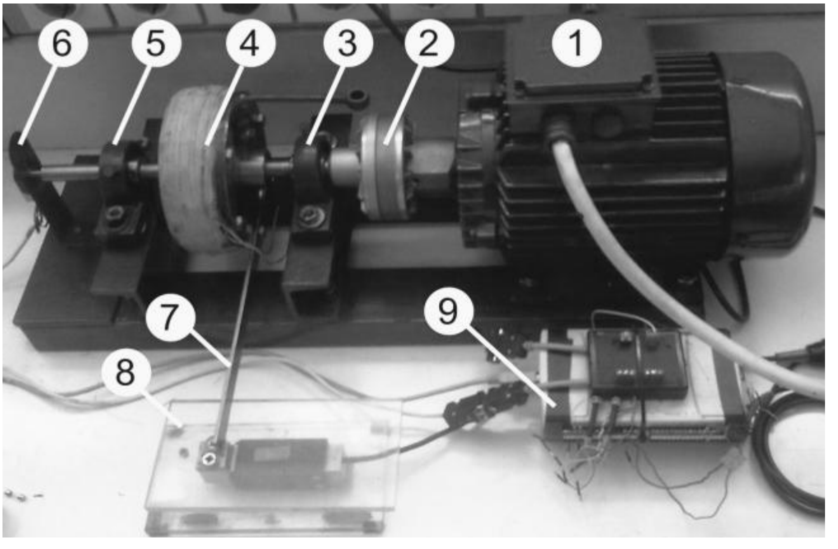


Figure 1. Test rig for MR brake performance evaluating
1. drive, 2. coupling, 3. self-aligning ball bearing, 4. MR fluid brake, 5. self-aligning ball bearing, 6. optical encoder, 7. load arm, 8. load cell, 9. data acquisition card

The MR fluid used in this experiment was Basonetic® 5030, from BASF® [14]. It is a carbonyl iron powder based MR fluid.

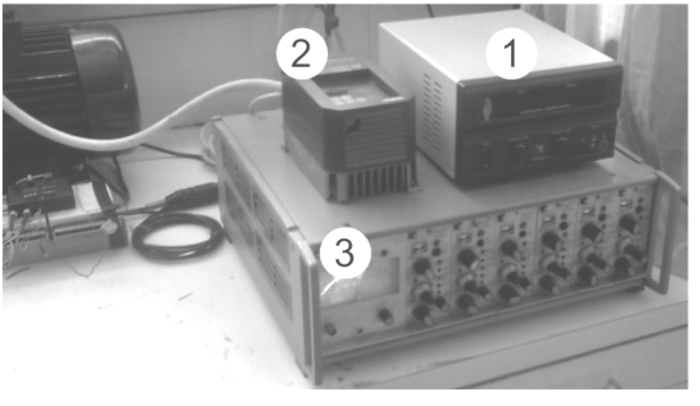


Figure 2. Measurement and data acquisition equipment,
1. stabilized power supply, 2. inverter, 3. universal amplifier

A typical testing procedure was as follows. First, the MR brakes shaft was set to a certain speed for 1 min as an initial condition, which stirred the MR fluid in the brake to distribute it uniformly. The desired magnetic field was then applied by setting the coil current i.e. control current and waiting for 1 min. This ensured MR fluid's stable structure forming. The load cell detected transmitted torque. Finally, the signal from the load cell was processed and recorded.

EXPERIMENTAL RESULTS

The first part of experiment was to determine the influence of the supporting ball bearings and seals, without MR fluid inside the brake. This was a friction braking torque component. After this step, the brake was filled with MR fluid. Second part was to determine the summary influence of friction and viscous component. In this way, the information on viscous torque level was be obtained, assuming that bearings and seals did not change their friction characteristics in time.

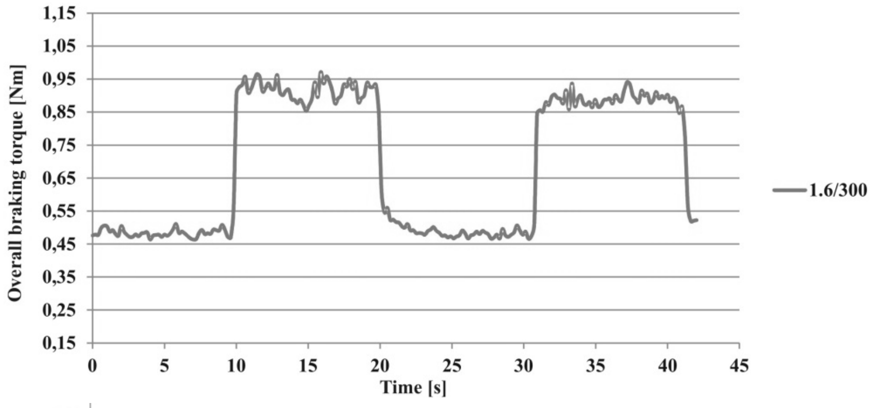
Aforementioned recordings were needed in order to get clear and precise information about field induced component. Now the control current could be applied in coil, for the same speed sets as for the friction and viscous torque components measurements. For each speed set, two control current turn on and turn off sequences were made which generated four OBT changes. Two OBT result samples are depicted in Figure 3, a) and b). Magnetic field influence on OBT is apparent.

Because of the large number of data obtained in the experiment, authors decided to used amplification factor in order to get a clearer picture of the effect produced by magnetic field. Amplification factor represents relation between OBT and sum of friction and viscous torque, i.e. relation between the MR fluid's ON and OFF state.

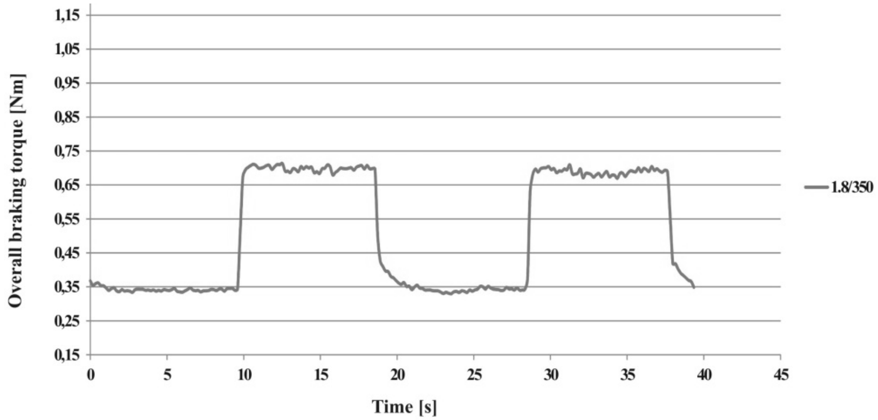
$$\text{Amplification factor} = \frac{T_{\text{Overall}} \text{ at current I}}{T_{\text{Overall}} \text{ at zero current}} \tag{6}$$

Amplification factor curves for all 13 speeds sets are plotted in Figure 4. This figure shows that the amplification factor increases with increase in control current. This was expected, since the higher the current, the higher field induced torque should be. Results are presented with rotational speed variation as well.

Figure 4 indicates that the amplification factors for speeds 150 - 350 rpm were much larger than the ones for 450 - 750 rpm. Transition rpm value for this MR brake was 400 rpm. This was somewhat opposite to the torque predicted by equation (5). As per Equation (5), OBT should increase with angular speed. This was not the case here. However, other authors have also reported the same trend - reduction of amplification factor with increment of speed: [8], [12]. This may be due to the possible shear thinning of the MR fluid at high shear rates. This reduces the effectiveness of MR brake at higher speeds. Therefore, to make MR brake effective at higher speed operation, one needs to think of „Shear stable MR fluid".



a)



b)

Fig. 3 Samples of overall braking torque results, a) 1.6 A at 300 rpm, b) 1.8 A at 350 rpm

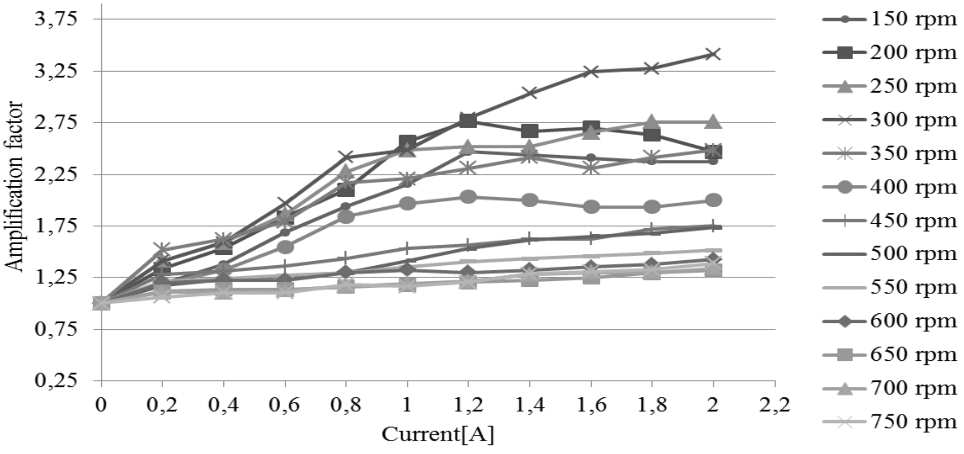


Figure 4 Variation in amplification factor with control current

CONCLUSION

Magnetorheological - MR brake test rig and experimental procedure were presented in this paper. Basic MR brake design was used. The goal of the experiment was to determine the overall braking torque – OBT characteristic. Based on acquired results, an amplification factor for each control current – speed set was presented. Further analysis showed, the MR brake's application potential as a vibration damper.

Measurement system inertia was not taken into account for time delay assessment. Although designed for different purpose, MR brake presented in this paper, shows great potential for seat suspension damping. Real application demands are still out of the range for tested MR brake. Optimization of the magnetic circuit in MR brake for higher torque capacity is needed.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

TIRE ENVELOPING BEHAVIOR ON 3D SURFACES AS BASIS FOR EXCITATION OF SIMPLE VERTICAL DYNAMICS TIRE MODEL

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ABSTRACT

Using simple tire model with single point contact interface to describe tire behavior on the rough roads requires tire excitation from the ground to be given by effective road profile instead of the real road shape. This is obtained on the basis of tire enveloping behavior. In this paper, simulations of the tire rolling over rough surface have been carried out based on effective road profile obtained in previous research. Due to the fact that the tire can envelope road irregularities in both longitudinal and lateral directions, road profile is defined in 3 dimensions. Experimental measurements have also been made in order to make comparison with simulation results. In general, good agreement between simulation and experimental results was observed. In some cases large dissipation of the results was present. It was concluded that obstacles of larger dimensions should be used in order to obtain results of the magnitude that is sufficiently higher than that of the noise present in the signal, caused by tire lugs and non-uniformity.

Key words: *tractor tire, tire dynamic behavior, effective road profile, single point contact interface*

INTRODUCTION

Typically, tractors use mostly off-road terrain, on which impact obstacles, potholes and short-wavelength undulations are present. Wavelength of these undulations is often roughly equal or less than tire contact patch length. In such circumstances tire deforms locally enveloping short-wavelength undulations and smoothening sharp edges. It therefore acts as a geometric low-pass filter, so that excitation transmitted from tire to vehicle differs from the road profile shape. Response of the tire in such conditions is determined by its enveloping behavior. Excitation transmitted to the vehicle is defined by effective road profile. Its shape is represented by the wheel center motion path obtained when tire rolls quasistatically over the road.

When rough road profile is used directly as computer simulations input for vehicle dynamics investigations, tire model capable of correct representation of tire enveloping behavior is required. One-point contact tire models, used for smooth, long-wavelength road profiles, are not valid for description of the tire that envelopes rough irregularities. Appropriate models are, on the other hand, often too complex to be used economically in vehicle dynamics simulation programs [1]. From the point of view of such programs, a simple tire model is required in order to keep computational effort and therefore time within acceptable limits. A solution to avoid a trade-off between model simplicity and accuracy is to use effective road profile as input instead of the real road geometry. Then a contact point model of interface between tire and road can also be used for the rough roads, as it is possible to do for the smooth ones. The idea behind this concept is that the quasi-static responses of a tire model with a single-point tire-road interface on an effective road surface are similar to the quasi-static responses of the real tire on the real road [14].

In this paper usage of effective road profile as excitation for simple Voigt-Kelvin-model based tire representation was investigated. Investigations were based on the measurements of real tire behavior on short-wavelength test ground.

Due to low internal pressure and relatively large width of tire contact patch, tire can envelope small road irregularities not only in longitudinal but also in lateral direction. It was shown that such properties impact overall enveloping behavior and should hence be taken into account [11]. Therefore different spatial configurations of the road profile were used for investigations in order to be able to further assess impact of lateral profile variation on effective road profile and tire dynamic response.

EXPERIMENTAL SETUP

Test facility

Experimental measurements were carried out using experimental facility shown in the Figure 1. Facility was described in more details in [10, 13]. It is based on rail-track-guided cart, which holds wheel with tested tire. Wheel driveshaft is mounted within the frame, which can freely move vertically up and down with regard to the cart. Additionally, vertical load is transferred from this frame to the tire. Facility is equipped with elements i.e. systems for driving and braking torque application to the tire, in which way the motion of entire facility is controlled.

Road profile shapes

Due to relatively large width of tire contact patch, road profile shape in lateral direction impacts tire enveloping behavior as well as that in longitudinal direction. Therefore, basic road profile was considered in three dimensions, i.e. profile shape in lateral direction was also taken into account.

Figure 1 Tractor tire test facility

Criteria that apply for the road profile shape choice were discussed in [10]. Aim of the excitation was to produce output that gives a broadest possible description of system behavior. It is common to use harmonic, periodic or stochastic excitation whose frequency content satisfies certain conditions. From practical point of view, it is important to maintain production costs as well as complexity of use and manipulation within the limits. In the present case, it is important to have a possibility to produce different profile configurations on the facility ground and to easily switch between them during experimental investigations.

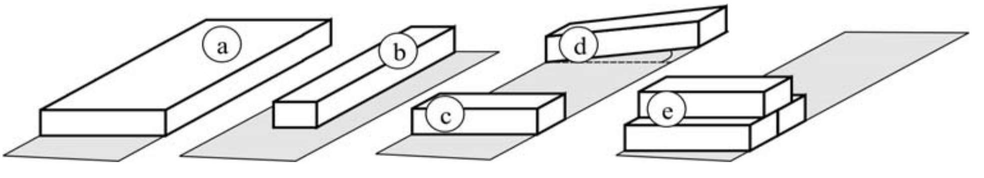


Figure 2 Road profile shapes: a - step, b - narrow step, c - basic bump, d - oblique bump, e - large bump

For the experimental study, different road profile shapes were created using wooden blocks with cross section of 80×50 mm placed in different spatial orientations, as shown in Figure 2. Profile shapes used for these investigations included:

- Step
- Narrow step
- Basic bump
- Oblique bump
- Large bump.

Details of geometry for different road profiles i.e. obstacles can be found in [11]. All profiles shown here cover the whole width of the tire contact patch, except narrow step obstacle, which covers approximately ⅓ of the width located centrally. Narrow step and oblique bump were used to investigate impact of profile change in lateral direction on tire enveloping behavior. In previous investigations [11], bump obstacle covering only left half of the contact patch width, was also used. Results obtained therewith, however, exhibited too large dissipation so that their further processing was not considered purposeful.

Experimental conditions

Experimental investigations were conducted with following parameter values:

- Tire size: 12.4 R 28
- Tire pressure: 1.5 bar
- Tire vertical load: 940 daN
- Test facility speed: 1.2 m/s

For the pressure of 1.5 bar, following elastic properties were obtained for the given tire [12]:

- c = 443 kN/m – stiffness
- k = 2.7 kNs/m – damping coefficient

Goal of the measurements

Goal of the measurements was to obtain tire dynamic response when rolling over given obstacles under given conditions, in order to compare results with the results of appropriate computer simulation.

EFFECTIVE ROAD PROFILE SHAPES FOR IMPACT OBSTACLES

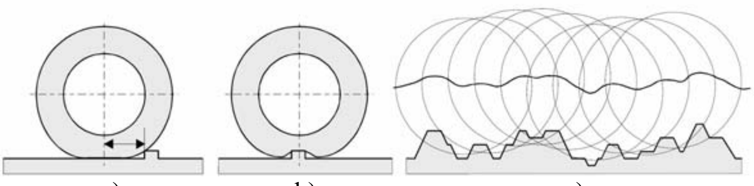
Basic phenomena of the tire rolling over rough road

Effective road profile is generated on the basis of tire enveloping behavior. More detailed explanation of accompanying phenomena can be found in the literature, e.g. [14]. The tire, acting as geometric filter due to its shape and compliance, smoothens the sharp edges of rough road unevenness. If the tire rolls over discrete obstacle, it will always hit the obstacle before the wheel center is above the obstacle (Fig. 3, a). This makes the influence of the discrete obstacle longer than the length of the obstacle. Furthermore, the tire partially or wholly envelopes small irregularities (Fig. 3, b). Both effects result in a filtering of the irregularities: the response at the wheel center is much smoother than the shape of the actual road surface (Fig. 3, c). Low-pass geometric filtering behavior of the tire is hence exhibited through the following effects:

- Length of the short obstacle impact is longer than the obstacle itself;
- Vertical displacement of the wheel center is less than the height of the short obstacle;

- Sharp edges of the discrete obstacle produce smooth segments of the effective road profile.

Issue of tire enveloping behavior investigations and modelling was previously discussed by a number of researchers. Some approaches use separate threatment of enveloping curves in order to use effective road profile as input for a tire model with simple, one-point tire/road contact interface. This approach can be thereafter combined with more sophisticated representation of tire internal structure and dynamic behavior [2, 8, 9, 14]. Other group of modeling techniques uses more comprehensive consideration of tire structure, leading to models that are capable of standalone applications in wide spectrum of operational conditions such as e.g. [1, 4, 5, 7] and various FEM models. Such models can also be used for „pure" analysis of tire enveloping propoerties.



a) b) c)

Figure 3 The phenomena of the tire rolling on the rough road: a) lengthening of response; b) enveloping discrete road irregularity; c) filtering of the road unevenness [14]

In papers mentioned, analysis was carried out in time and / or spatial domain. There are, also, some papers in which effects of tire enveloping properties were taken into account through changes in power spectral density of tire dynamic response, i.e. in frequency domain [3, 6].

In the present study, enveloping curves were obtained directly by measurements for obstacles shown in Figure 2 and used as input for simulations carried out withVoigt-Kelvin tire model with one point contact interface. Results of those simulations are shown and discussed subsequently.

Experimental study of the tire enveloping properties

The enveloping properties of the tire rolling over obstacles were studied experimentally on the test facility described above. Results were published and discussed in [11]. Main results and conclusions will be summarized in the following:

- Experiment results unambiguously shown that the profile shape in lateral direction influences tire enveloping behavior, which justifies considering road as 3D surface;
- Characteristic two-sectional curve was obtained as can be seen from Chart 1;
- Significant results dissipation can occur in some cases, most probably caused by the tire non-uniformity and the impact of the tire lugs.

Enveloping curves obtained by measurements for different obstacles are depicted in Chart 1. There, one typical realization for each of the measurements for obstacles a, b, c and d

(Figure 2) is shown. Although one example curve for each case is shown, measurements were carried out 5 times for each case. Final enveloping curve for each of the obstacles was obtained by fitting the polynomial through the points by appropriate regression technique. The degree of the polynomial and appropriate coefficients were determined semi-automatically by using appropriate data processing software. Wheel center height in Chart 1 is given in relation to position of the wheel center when the wheel rolls or rests on the level ground (without obstacles and / or undulations).

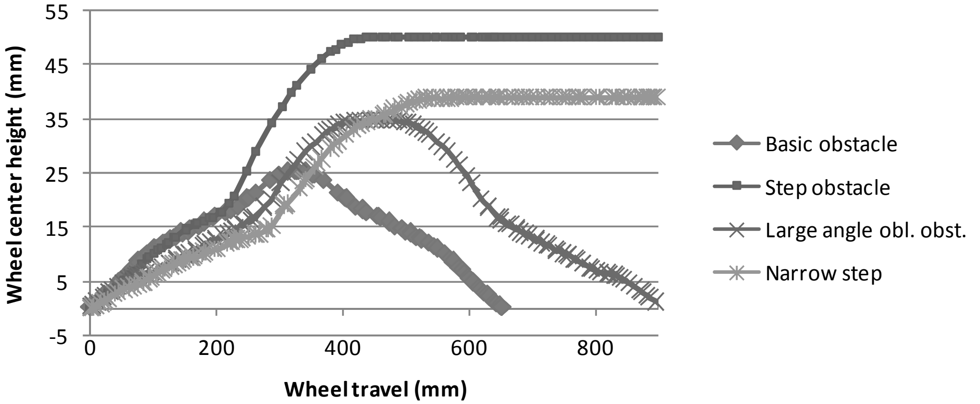


Chart 1 Effective road profile for different obstacles

SIMULATION OF TIRE DYNAMIC RESPONSE BY USING SIMPLE TIRE MODEL AND EFFECTIVE ROAD PROFILE

Simple tire model for vertical dynamics and its use

In fundamental vehicle vertical dynamics, it is enough to treat a tire purely as an element that transfers vertical forces from the ground to the vehicle. Due to its nature, tire develops elastic deflection when loaded, which is taken into account through modeling. The simplest tire model is Voigt-Kelvin element, i.e. massless spring and damper connected in parallel, Fig. 4. In most basic approach, both spring and damper are considered to exhibit linear behavior. Despite the contrast between complexity of the real tire and simplicity of this model, it is very wide used to describe tire behavior in a variety of applications. It uses a point contact interface and is hence primarily provided for simulation of motion on the smooth, long-wavelength road surface. For short obstacles, effective road profile has to be used as model input instead of the real one, as explained in previous sections.

In this work, simulation of the motion on the rough surface was carried out using enveloping curves shown in the previous chapter, and compared with measurement results.

Simulation and measurements results

Simulation was carried out on the basis of simple 1-DOF linear vibration system, Fig. 4, which represents a tire carrying a load. Vibration excitation come from the road profile as system moves along. This model structure corresponds to the test facility with a tire that carries vertical load as shown in Figure 1. For constant velocity in longitudinal direction, expressing road profile in time domain, differential equation of motion in vertical direction reads:

$$m\ddot{z} + k\dot{z} + cz = k\dot{h} + ch \tag{1}$$

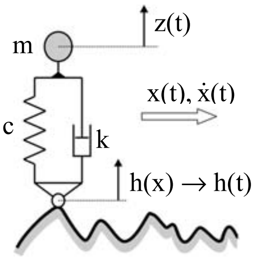


Figure 4 Vibration model

All numeric data necessary for carrying out of the simulation are presented in the chapter about experimental setup and experimental conditions.

Solution of the non-homogenous part of equation (1) is straightforward, provided that harmonic function is used as input. In such case, it would be most purposeful to obtain direct analytical solution for motion. Herein, however, input was a single obstacle transformed to the enveloping curve. This curve, moreover, was described by approximating polynomial of very high order (up to 10^{th}), which would lead to difficulties if solved analytically. Therefore excitation was introduced as array of discrete values of effective profile height as function of time, taking into account spatial shape and velocity. This approach required numerical solution of equation (1), which was obtained using appropriate computer program.

Solutions are depicted in Chart 2, a – e and compared with measurement results. Generally, simulation results show good agreement with experiment results. Certain shortcomings are though present. Most noticeable amongst them were measurement result variations that caused by tire non-uniformity, impact of lugs and presence of noise in signal caused mostly by electric drive system. Experiment results for basic obstacle (Chart 2a) show that order of magnitude of tire response is not much greater than that of signal noise content which makes results interpretation more difficult. Results of simulations and experiments mostly show the same order of magnitude, but in some cases phase shift is present. This can be caused, amongst all, by filtering of the results, which had to be carried out due to high noise content in the signal. Most pronounced disagreement between simulation and measurements can be noticed in the case of oblique obstacle (Chart 2e). Shape of the experimental results curve is most probably caused by velocity fluctuations while negotiating the obstacle. These fluctuations, which are caused by system elasticity and drive system power and regulation characteristics, were more pronounced in this case than in the others. This was most probably caused by the duration of the transient period of obstacle negotiation (period from the first contact between tire and obstacle until the full axle height is reached). This period was longer in this case than in the others, because of the obstacle shape, which could cause greater negative and positive values of longitudinal acceleration in different phases of obstacle negotiation.

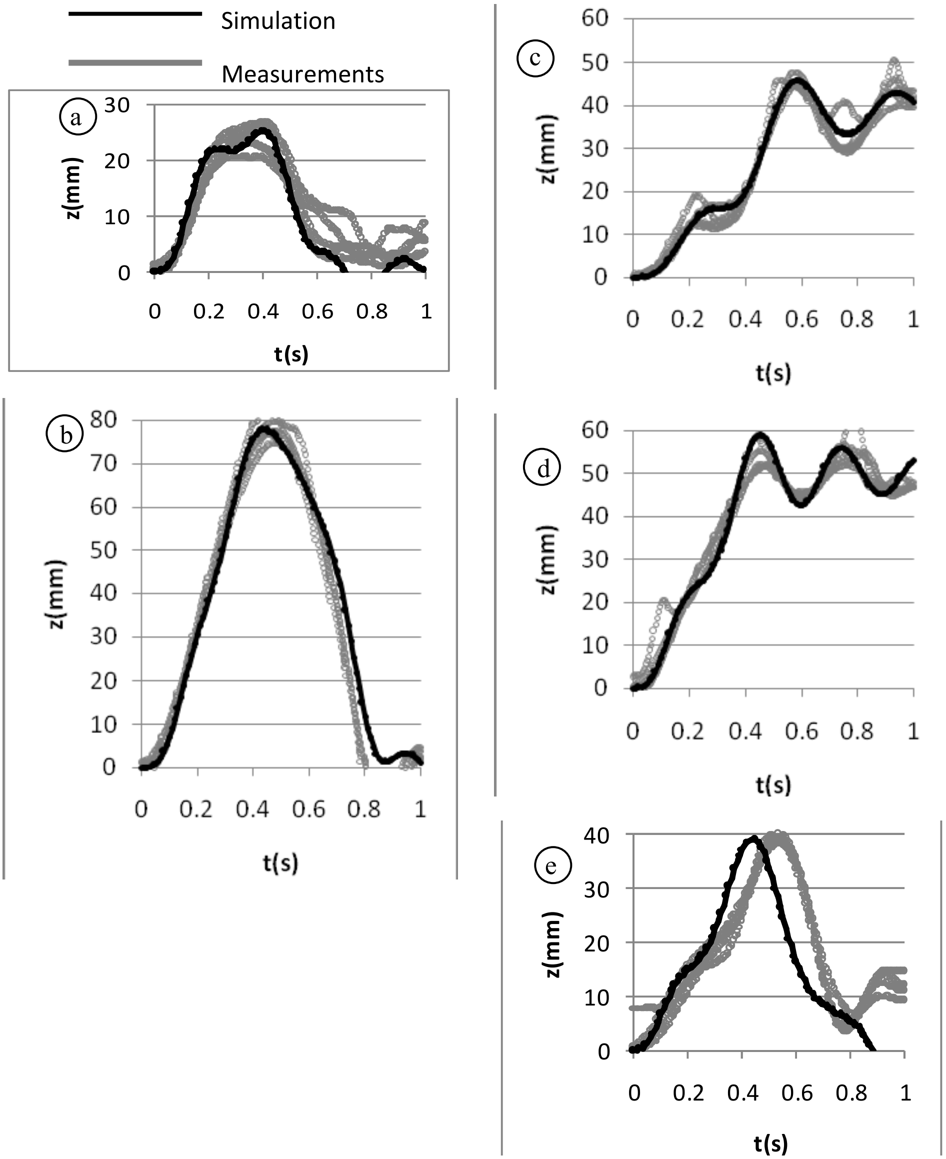


Chart 2 Comparison of simulation and experimental results for obstacles: a – basic, b – large, c – narrow step, d – step, e – oblique

CONCLUSIONS

In this paper simulation of tractor tire dynamic response on the rough surface using simple tire model was examined. Use of such model was justified by introducing effective instead of the real road profile as tire excitation from the ground. Effective road profile was obtained in previous research on the basis of enveloping properties of the quasistatically rolling tire.

In general, good agreement between simulation and experimental measurements was observed. Assumption that the quasi-static responses of a tire model with a single-point tire-road interface on an effective road surface are similar to the quasi-static responses of the real tire on the real road is hence confirmed.

Experimental measurement of tire dynamic behavior has shown significant results dissipation. Main reasons for this are presence of the tire lugs and tire non-uniformity. This requires increased number of measurements in order to obtain plausible results. Further, it is concluded that a certain minimum dimensions of obstacle for testing has to be used. Otherwise, tire response would be of the similar order of magnitude as a noise present in the signal. It is therefore advisable to use larger obstacles in order to obtain tire response that is sufficiently higher in magnitude than the signal noise.

Influence of road profile spatial shape on tire response was confirmed. In future investigations attention will be focused on the development of the model approach that can be used to describe tire enveloping behavior on the 3-dimensional road surface.

ACKNOWLEDGMENT

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 621.95
Stručni rad
Expert paper

WORK PERFORMANCE OF STIHL BT 121 MOTOR DRILL IN PLANTING

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ABSTRACT

The present research displays the results obtained after the digging of holes for planting saplings in a previously unprepared soil, following the steps to carry them out according to some physical-mechanical properties of the soil.

The research was carried out on a horizontal ground in the Forest District Iuliu Moldovan, in two forest compartments 31 C and 32 A, in a previously unprepared ground, on two types of soil: gley-soil (the muddy subtype) and alluvial soil (the vertical-gleyed subtype), and in Forest District Radna, forest compartment 74, on a brown typically luvic soil, using the Stihl BT 121 motto-borer with a 150 mm drill.

The objectives of the research were to make a comparative determination, on different types of soil, of the qualitative parameters, among which the most important ones are: degree of loosening of the soil taken and left in the hole, resistance to penetration, resistance to shearing, timing of drilling holes, degree of scattering of the soil taken out from the hole, degree of evacuation of the soil from the hole, gas consumption for the drilling of the hole, using the Stihl BT 121 motto-borer in order to establish its technical efficiency.

In order to observe the influence which the drilling of holes has on its walls, we measured the resistance to penetration and resistance to shearing every 10 cm at a 30 cm depth, the proper depth for planting small-sized saplings, on two opposing sides, so that we could get the most probable values of these physical-mechanical properties of the soil.

After taking the measures in order to establish the compaction degree of the wall and of the bottom of the hole by the borer in that interval, it was judged that *in conditions of normal humidity, if the borers have sharp knives and are well conceived and executed from a technical point of view, there are no big values of the resistance to penetration which could affect the subsequent development of the saplings.*

The usefulness of the present paper stays in the research data collected, processed, analyzed and valorized in order to offer a pertinent study material, which could indeed be used by specialists in designing the process for obtaining, through a mechanized means, the holes for planting small-sized saplings on a horizontal ground, using the Stihl BT 121 motto-borer.

Key words: *motto-borer, resistance to penetration, average time of drilling, degree of scattering, degree of evacuation*

INTRODUCTION

There is a general concern for introducing and extending the motto-borers for drilling holes in the sylvan field even in other countries. In our country, people tried several types of motto-borers without being extended in the production. [10]

The objectives of the research carried out were to comparatively determine on different types of soil, the qualitative parameters, among which the most important ones are: degree of loosening of the soil taken and left in the hole, resistance to penetration, resistance to shearing, time of drilling holes, degree of scattering of the soil taken out from the hole, degree of evacuation of the soil from the hole, gas consumption for the drilling of the hole, using the Stihl BT 121 motto-borer in order to establish its technical efficiency.

In order to obtain pertinent results, the research was done according to a complex methodology, with a novelty character in this domain, which gave the possibility to study different technical aspects of usage of the motto-borer.

Because of the compaction, while digging holes for planting saplings, there are several phenomena of friction occurring which increase the resistance to penetration through the walls of the hole. For the same reason, the soil offers resistance to some mechanical, exterior forces, presenting resistance to compression, shearing and penetration. [7]

During the drilling of the holes with a motto-borer, there are two categories of friction forces. The first category is represented by the friction forces which occur among the soil particles, which come in contact with them, and the second one by the shearing forces given by the soil particles with the metallic part (the drill). [2]

At the mechanized execution of holes for planting saplings, one needs to act to reduce the friction forces between the soil and the active organs, because, if on the contrary, there is registered a supplementary consumption of energy. [5]

METHODS

The research was carried out on a horizontal ground in the O.S. Iuliu Moldovan, in two arranged unities (parcels) 31 C and 32 A, in a previously unprepared ground, on two types of soil: gley-soil (the muddy subtype) and alluvial soil (the vertical-gleyed subtype), and in

O.S. Radna, arranged unitie 74, on a brown typically luvic soil, using the Stihl BT 121 motto-borer with a 150 mm drill.

The technical characteristics of the motto-borer used in our research are given in Table 1, and its photography appears in Figure 1.

Figure 1 Stihl BT 121 motto-borer Motoburghiul Stihl BT 121, [11]

Table 1 Technical data of the Stihl BT 121 motto-borer

Cylindrical capacity	30,8 cm³
Weight	9,4 kg
Power	1,3/1,8 kW/CP
Level of vibrations left/right	2,2/2,5 m/s²
Speed of rotation	190 1/min
Level of acoustic pressure	103,0 dB(A)
Level of acoustic pressure	109,0 dB(A)

The present research displays the results obtained after the digging of holes for planting saplings in a previously unprepared soil, taking into consideration the following aspects: time needed to dig holes according to some physical-mechanical properties of the soil, degree of aeration of the soil taken out and left in the hole, the degree of scattering of the soil taken from the hole, the degree of evacuation of the soil in the hole, the gas consumption for digging holes.

The physical-mechanical properties were determined by using the method of cylinders with a constant volume of 100 cm^3, carrying out five repetitions at different depth, from 10 to 10 cm until the depth of 30 cm. The determination of the resistance to penetration was made with the aid of a penetrometer and that of the resistance to shearing was made with the aid of the equipment for shearing through rotation.

The methods of analysis and interpretation of the results as well as the work procedure for the determination of the physical – mechanical properties are those indicated in the specialized literature. [1]

In order to observe the influences which the digging of holes have on their walls, we measured the resistance to penetration and the resistance to shearing on the holes' walls from 10 to 10 cm until the depth of 30 cm, on two opposing sides, so as to get the most probable values for these physical-mechanical properties of the soil, depth sufficient enough for the planting of small-sized saplings. The placement of samples for the resistance to penetration and shearing on the walls of the holes is given in Figure 2.

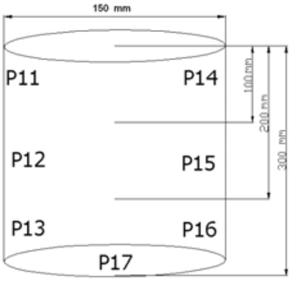

Figure 2 Placement of samples for the resistance to penetration and shearing on the walls of the holes

The degree of scattering of the evacuated soil from the hole was expressed by the ratio of the maximum diameter of scattering or of the diameter at which is deposited most of the quantity of soil, at the diameter of the hole. The degree of evacuation of the soil from the hole was expressed by the ratio between the volume of the soil evacuated from the hole and the volume of the soil left in the hole at a 30 cm- depth. The elements measured for the determination of these qualitative indexes are given in Figure 3.

In order to accomplish the objectives we have dug 50 holes for each type of soil chosen for the experiment, placed on a horizontal ground, previously unprepared, using the Stihl BT 121 motto-borer with a 150 mm drill.

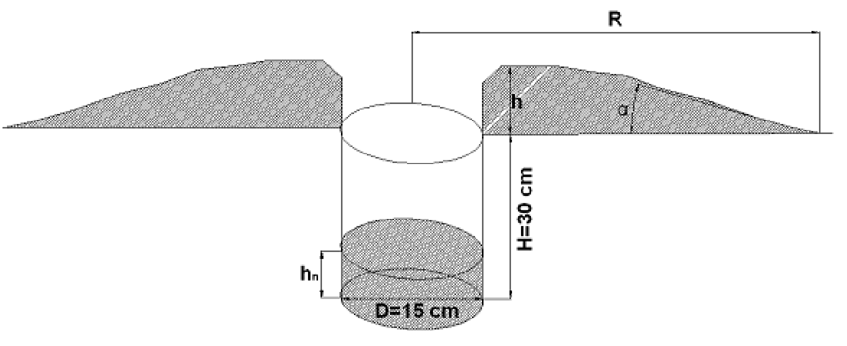

Figure 3 Determination of the degree of scattering and degree of evacuation of the soil in the hole (H – depth of digging, h_n – height of the un-evacuated soil, h – height of the soil bed evacuated, D – diameter of the hole, α - angle of setting of the evacuated soil, R – radius of scattering of the evacuated soil.

RESULTS AND DISCUSSIONS

To establish the quality of the work carried out with the Stihl BT 121 motto-borer with a 150 mm drill, we made the following measurements:

a) Degree of aeration of the soil taken and left in the hole,
b) Resistance to penetration and shearing of the walls and of the bottom of the hole,
c) Average time for the digging of a hole,
d) Degree of scattering of the soil taken out from the hole,
e) Degree of evacuation of the soil from the hole,
f) Gas consumption for the execution of a hole.

Physical properties

The state of aeration of the processed soil and in the natural setting can be expressed through specific issues: apparent density and total porosity. [8]

The three types of soil on which the research was carried out are: gley-soil (the muddy subtype), alluvial soil (the vertical-gleyed subtype), and a brown typically luvic soil. The physical properties determined during the execution of the holes like the granulometry of the soil are presented with average values in Table 2 and 3.

Table 2 Average values of the physical properties of the soil analyzed

Depth of prelevation of the sample, cm	Natural humidity, %	Apparent density, g/cm^3	Total porosity, %
SOIL 1: GLEYSOIL – MUDDY (u.a. 31 C, O.S. IULIU MOLDOVAN)			
0-10	24.11	1.62	37.89
10-20	22.73	1.69	37.43
20-30	20.09	1.72	36.45
SOIL 2: ALLUVIALSOIL– VERTICAL GLEYED (u.a. 32 A, , O.S. I. MOLDOVAN)			
0-10	20.75	1.70	36.97
10-20	19.46	1.75	35.73
20-30	17.38	1.73	35.19
SOIL 3: BROWN TYPICALLY LUVIC (u.a. 74, , O.S. RADNA)			
0-10	22.43	1.69	37.43
10-20	21.10	1.71	36.31
20-30	18.74	1.73	36.09

Table 3 Average values of the granulometric analysis at different depths of prelevation

Depth of prelevation of the sample	Sand		Dust		Clay
	Coarse	Fine	I	II	
SOIL 1: GLEYSOIL – MUDDY (u.a. 31 C, , O.S. IULIU MOLDOVAN)					
0-10	0.74	36.04	16.94	16.94	29.54
10-20	2.34	45.44	12.54	12.54	27.34
20-30	1.84	39.34	16.54	13.84	28.64
SOIL 2: ALLUVIALSOIL– VERTICAL GLEYED (u.a. 32 A, O.S. I. MOLDOVAN)					
0-10	1.74	39.04	14.54	24.24	20.64
10-20	1.84	37.54	14.14	23.04	23.84
20-30	2.44	39.54	14.54	18.54	25.24
SOIL 3: BROWN TYPICALLY LUVIC (u.a. 74, , O.S.RADNA)					
0-10	1.24	37.54	15.74	20.59	25.09
10-20	2.09	41.49	13.34	17.79	25.59
20-30	2.14	39.44	15.54	16.19	26.94

Resistance

The results of the research carried out, [4] demonstrate that the resistance to compression and cutting of the soil increase while the humidity of the soil is reduced to under 14% and goes even lower while its humidity increases to values over 28%.

In the situations in which the humidity is reduced under the minimum threshold shown, the active organs of the equipment take out clods and the aggregates are being highly stressed, which leads to the increase of specific consumption for materials (gas and metal). If humidity goes above the threshold of 28%, the soil begins to lose its organs. Consequently, it is recommended that the mechanic execution of the holes for planting to be done when its humidity is found in an optimal state (18-24%). [6]

Another important aspect is related to the resistance to penetration in connection with the study of the development and penetration in the soil of the root system of the saplings. The experimental research shows that at values under 10-15 kgf/cm^2 the resistance to penetration does not influence negatively the penetration in the soil of the roots, while at values over 35-50 kgf/cm^2 it is almost null. [9]

The values obtained are given in a graphic in Figure 4 to 6.

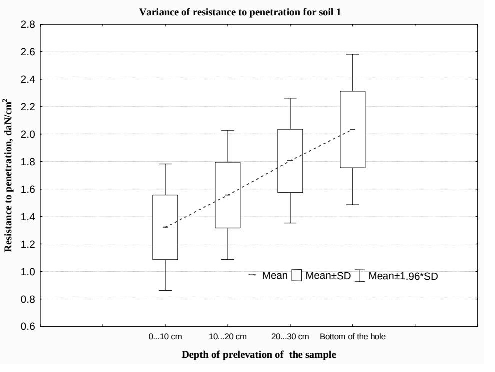

Figure 4 Variance of resistance to penetration for soil 1

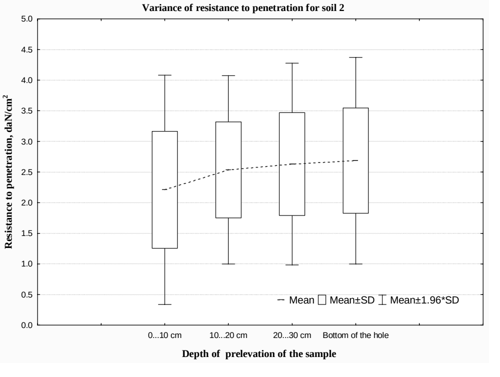

Figure 5 Variance of resistance to penetration for soil 2

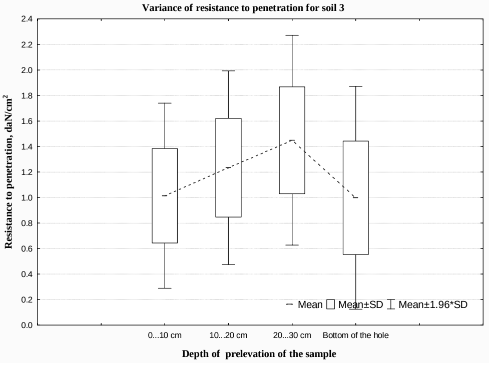

Figure 6 Variance of resistance to penetration for soil 3

The problem of determining the resistance to cutting of the grounds represents a very special practical importance, because the excessive deformation and the breaking of the crop of land are produced because of the overcoming of this resistance by the effective and tangential efforts which appear inside the ground.[3] The representation of these values under a graphical form is given in Fig.7 to 9.

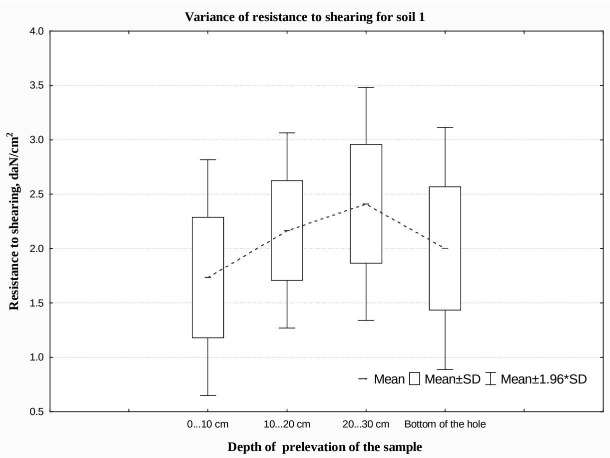

Figure 7 Variance of resistance to shearing for soil 1

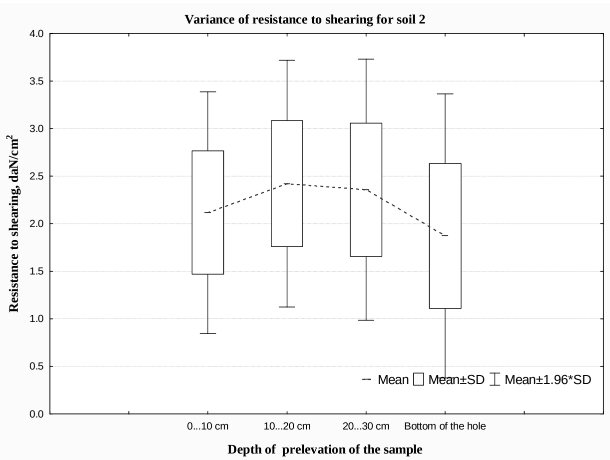

Figure 8 Variance of resistance to shearing for soil 2

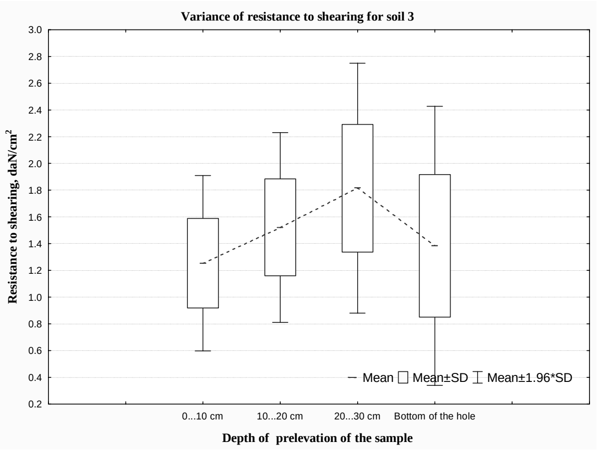

Figure 9 Variance of resistance to shearing for soil 3

Duration of drilling

In order to establish the economic efficiency of the Stihl BT 121 motto-borer, at the boring of the holes for planting, we registered the number of drilled holes for each variant of work and established the average time of execution of a hole for every type of soil included in the experiment.

We can notice the enormous periods of execution for the holes in the 2nd soil, this fact being easily explainable because in this case we observed a more frequent presence of the roots, but also of the parental material and, in addition, bigger values of the resistance to penetration in comparison with the other types of soil which were included in the experiment.

The allure of the connection is that of the polynom of II degree and the equations are given in Figures 10 to 12.

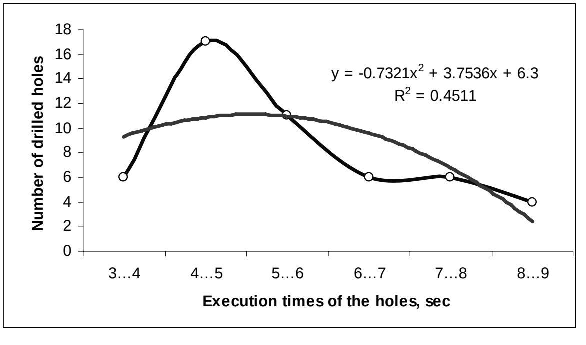

Figure 10 Variance of the periods of execution of the holes drill for the 1st soil

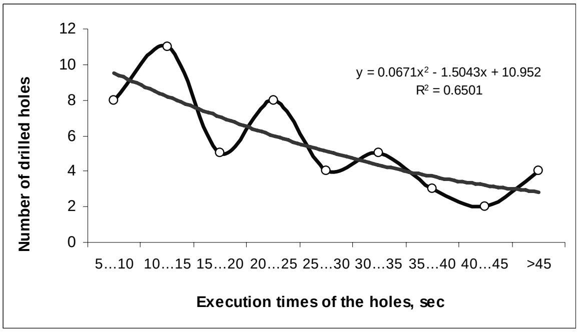

Figure 11 Variance of the periods of execution of the holes drill for the 2nd soil

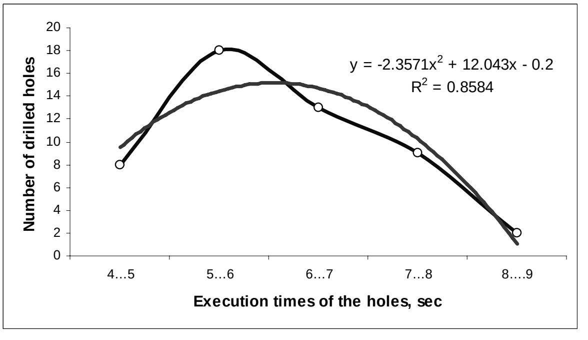

Figure 12 Variance of the periods of execution of the holes drill for the 3rd soil

Degree of scattering of the soil taken from the hole

The degree of scattering of the soil taken out from the hole can be expressed through the ratio between the maximum diameter of scattering (or the diameter at which point most of the quantity of evacuated soil is scattered) and the diameter of the hole. The registered values for the determination of those qualitative indexes are given in Table 4.

Degree of evacuation of the earth from the hole

The degree of evacuation of the soil from the hole is expressed in the ratio between the quantity (volume) of soil evacuated from the hole and the quantity of soil left in the hole at a 30 cm-depth.

Gas consumption for the digging of a hole

The measurements regarding the gas consumption were taken in conditions of ground previously unprepared, on a plain country where the study took place and the results are presented in Table 4.

Table 4 Data regarding the quality of work with the Stihl BT 121 motto-borer on a horizontal ground

Type of soil	Ratio between the diameter at which point most of the quantity of evacuated soil is scattered and the diameter of the hole	Ratio between the maximum diameter of scattering of the soil and the diameter of the hole	Ratio between the quantity of soil evacuated and the quantity of soil left in the hole	Average gas consumption, ml
Soil 1	1.14	1.21	2.46	4.72
Soil 2	2.29	2.43	3.54	5.56
Soil 3	1.25	1.38	2.85	4.55

The gas consumption was determined by introducing in the tank a known quantity of gas (0,5 l), with which there were made 106/90/110 holes, according to the type of soil. Relating the quantity of gas introduced in the tank to the number of holes dug we obtained the average quantity of gas for the digging of a hole, until the depth of 30 cm, which has the following values: 4.72 ml for the 1st type of soil, 1, 5.56 ml for the 2nd type of soil and 4.55 for the 3rd type of soil.

CONCLUSIONS

From all of the above, we can infer the following conclusions regarding the qualities and the behavior of the Stihl BT 121 motto-borer with a 150 mm drill in the sylvan field of activity, on a horizontal ground:

- The small values of the resistance to penetration and shearing were obtained also because of the optimal values of the soil humidity during the drilling of the holes, these values oscillating between 19.20 % and 22.31 %.
- In the pedological conditions of these three parcels included in the experiment the average time of execution of the holes are: 5.41 sec. for the 1st type of soil (gley-soil- the muddy subtype), for the 2nd type of soil (alluvial soil - the vertical-gleyed subtype) the average time was 23.42 sec, while for the 3rd soil (brown typically luvic soil) the average time was 6.08 sec for the 150 mm drill.
- The ratio between the diameter at which one can find scattered the biggest amount of soil evacuated and the diameter of the hole varies according to the type of soil as it follows: 1.14 for the 1st soil, 2.29 for the 2nd soil and 1.25 for the 3rd soil.
- The average gas consumption necessary for digging a hole until the 30cm-depth is 4.72 ml for the 1st type of soil, 1, 5.56 ml for the 2nd type of soil and 4.55 for the 3rd type of soil.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.352/354
Pregledni rad
Review paper

TRENDOVI RAZVOJA KOSILICA

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SAŽETAK

Potreba za profitabilnijim spremanjem krme i korištenje energetskih kultura u proizvodnji biogoriva usmjerava razvoj kosilica prema povećanju učinka i dobivanju visokokvalitetne krme. Kombinacijom triju nošenih kosilica mogu se postići radni zahvati do 10,00 m; za veće radne zahvate potrebna je kombinacija s vučenim kosilicama ili samokretna kosilica. Ovisno o uvjetima mogu se ostvariti visoki radni učinci u košnji, od 10 do 20 ha/h. Intenzivnijim kondicioniranjem se ubrzava proces sušenja krme i smanjuje opseg radnih operacija nakon košnje. Oblikovanjem samo jednog otkosa za radni zahvat veći od 9,00 m može se značajno smanjiti broj prohoda s rotacijskim grabljama s četiri rotora ili sa strojevima sa sakupljačkim (pick-up) uređajem velikog radnog zahvata te tako povećati učinak, smanjiti onečišćenje krme i oštećenje travnjaka. Za povećanje radnih brzina poboljšavaju se sustavi za smanjenje pritiska kosilice na tlo i prilagođavanje neravninama terena. Ušteda u potrošnji goriva se postiže smanjenjem broja prohoda, korištenjem sustava za automatsko vođenje traktora i priključka, te izmjenom istrošenih noževa na kosilicama.

Ključne riječi: *kosilica, kombinacija kosilica, samokretna kosilica, spajanje otkosa*

UVOD

Za spremanje krme uz što veću dobit potrebna je visokoučinkovita mehanizacija i proizvodnja visokokvalitetne krme na što većim površinama. Cilj je postići visoki učinak uz što manje onečišćenje krme tlom i što manje mehaničke gubitke hranjivih tvari uzrokovanih rastresanjem, okretanjem, prikupljanjem i transportom krme. Standardna pitanja bitna za spremanje krme su: pravovremeni početak košnje, koliko je vremena na raspolaganju za punjenje silosa ili baliranje, te koliki može biti učinak, odnosno koja se količina krme može dnevno ili po satu pokositi, rastresti, skupiti u zboj, pokupiti, te prešati i/ili transportirati. Za poljoprivredna gospodarstva su različite potrebe u opremanju mehanizacijom ovisno o njihovoj veličini, opremljenosti, topografskom položaju, klimatskim uvjetima, tipu tla, regionalnoj strukturi, zatim u kojoj mjeri su dostupna udruživanja poljoprivrednika i/ili unajmljivanje profesionalnih usluga s visokoučinkovitim strojevima. Treba voditi računa o isplativosti ulaganja u mehanizaciju s obzirom na proizvodne površine i klimatske uvjete u razdoblju spremanja krme. Profesionalni davatelji usluga i poljoprivrednici s velikim poljoprivrednim gospodarstvima mogu nabavljati samokretne kosilice, silažne kombajne, rotacijske grablje s 4 ili 6 rotora, dok je „klasična" mehanizacija primjerena za poljoprivrednike koji koriste vlastitu mehanizaciju na manjim površinama. U odabiru mehanizacije bitan je i broj otkosa, u nekim državama se prva košnja najčešće prepušta profesionalnim davateljima usluga, dok ostale obavljaju sami poljoprivrednici s vlastitom mehanizacijom koja nije uvijek optimalna.

Kosilice

Radni zahvat kosilica uglavnom iznosi oko 3,00 m; a radna brzina ovisi o biljnoj masi i kreće se u opsegu od 10 km/h za prvi otkos do 16 km/h za treći otkos (Bernhardt, 2006). Teoretski najveća radna brzina koja osigurava dobru kvalitetu košnje može biti i do 19 km/h (Eickel, 2005). S radnim zahvatom od 3,00 m moguć je učinak i do 4 ha/h. Radi većeg učinka nošenih kosilica povećavaju se radni zahvati i do 4,35 m kojeg ima model Kuhn GMD 4410 s učinkom i do 5 ha/h. Masa kosilice je 1.080 kg i najmanja snaga traktora potrebna za njen pogon je 90 kW. Vučena kosilica Kverneland-Taarup 4340 CT/CR ima radni zahvat od 4,00 m i najmanja snaga potrebna na priključnom vratilu traktora je 70 kW uz kondicioniranje krme s valjcima ili 74 kW uz kondicioniranje krme s prstima. Izvedba kosilice s beskonačnom trakom na stražnjoj strani ima mogućnost spajanja otkosa odnosno polaganja pokošene krme na otkos prednje kosilice ili na otkos pokošen u prethodnom prohodu (sl.1).

Sl. 1 Vučena kosilica Kverneland-Taarup 4340 s mogućnošću spajanja otkosa

Fig. 1 Trailed mower Kverneland-Taarup 4340 with swath merging/gathering system

Potražnja za kosilicama s tanjurima je povećana, dok se kosilice s bubnjevima više koriste kao prednje-nošene. Kosilice s bubnjevima imaju značaj u područjima s lakšim tlima i gdje su prisutni krtičnjaci, a kod prednje kosilice s bubnjevima se bolje oblikuje otkos (Niemöller, 2009). Razvoj sustava za mehaničko tretiranje pokošenih biljaka u svrhu ubrzavanja sušenja (kondicioniranje) omogućuje izostavljanje ili kraće trajanje radne operacije rastresanja-okretanja. U suradnji s Institutom za poljoprivrednu tehniku u Wageningenu, Pötteinger je razvio kondicioner sa spiralno postavljenim čeličnim zupcima V-oblika od kaljenog čelika pričvršćenim na gumenim ležajevima radi veće elastičnosti. Sustav osigurava kontinuirani protok krme, bolje i nježnije tretiranje, brže sušenje krme i duži vijek trajanja. Za košnju krmnim kombajnom se koriste rotacijske kosilice velikog radnog zahvata. Krmni kombajni Jaguar proizvođača Claas koriste uređaj Direct Disc 610 radnog zahvata od 6,10 m ili Direct Disc 520 radnog zahvata od 5,20 m, a krmni kombajni BiG X proizvođača Krone uređaj XDisc radnog zahvata od 6,20 m.

U košnji se uz povećanje radnog zahvata i radne brzine dodatno poklanja pažnja zaštiti tla i kvaliteti krme. Zbog velikog radnog zahvata i visoke radne brzine poteškoće nastaju u prilagođavanju kosilica neravninama terena, te u potrebi za konstantnim održavanjem smanjenog pritiska kosilice na tlo radi zaštite travnjaka i dobivanja kvalitetnije krme. Za prilagodbu kosilice neravninama terena osim mehaničkog sustava sa oprugama sve više se koristi aktivni hidropneumatski sustav (Mumme, 2009). Tvrtka Pöttinger je za prednje kosilice razvila „alpha-motion“ aktivni ovjes koji omogućuje učinkovito prilagođavanje neravninama terena i umanjeni pritisak kosilice na tlo. Kosilica se kroz plivajući položaj može prilagođavati terenu po visini +/- 250 mm, kao i pod kutom od +12° i -9° što osigurava vodoravnu košnju i postizanje većih radnih brzina. Radi lakšeg okretanja na uvratinama i transporta moguće je podesiti razmak između najniže točke kosilice i tla za 350 mm. U razvoju kosilica smanjenje njihove mase bit će značajan kriterij kao i dizajniranje optimalnih okvira izrađenih od materijala visoke čvrstoće, što će utjecati na cijenu kosilica. Masa prednjih kosilica se smanjuje radi zaštite travnjaka, manjeg opterećenja prednje osovine traktora i pogodnosti pri radu na nagnutim terenima.

U razvoju kosilica se nastoji skratiti vrijeme potrebno za njihovo podešavanje i održavanje, te omogućiti brzu izmjenu potrošnih dijelova kao što su noževi. Radi spremanja što kvalitetnije krme podešava se visina reza, za 1 cm viši rez može smanjiti prinos suhe tvari za 100 kg po hektaru, ne računajući sadržaj vode u biljci (Wörle i Bockholt, 2003). Premda niži rez osigurava veći prinos preporučuje se visina reza između 5 i 7 cm zbog očuvanja rezervnih tvari u donjem dijelu stabljike koje pospješuju regeneraciju travnjaka za slijedeću košnju. Kod višeg reza pokošena krma je položena na duljim nepokošenim stabljikama a ne na tlo te se bolje suši, a strojevi za rastresanje-okretanje i zgrtanje djeluju manje agresivno na krmu koja se manje prlja tlom (Ligocki, 2003).

Cilj je smanjiti troškove spremanja krme po jedinici površine kroz povećani učinak strojeva i smanjene potrošnje goriva. Redovitom izmjenom noževa moguća je ušteda goriva i do 15%, razlika u potrošnji goriva između kosilica s gornjim pogonom (bubnjevima) i kosilica s donjim pogonom (tanjurima) više nije naglašena. Korištenjem uređaja za mehaničko tretiranje pokošenih biljaka (kondicionera) uz oblikovanje jednog velikog otkosa moguće je izostaviti radnu operaciju rastresanja i okretanja a samim time smanjiti ukupnu potrošnju goriva (Kowalewsky, 2009), nakon košnje se spojeni otkosi mogu skupljati u velike zbojeve s rotacijskim grabljama velikog radnog zahvata (sl. 8). Sustav za automatsko vođenje traktora i priključnog oruđa/stroja prema John Deer-u omogućuje povećanje učinka u košnji za 10 do 20% i smanjenje utroška goriva za više od 10%, zbog manjeg preklapanja radnog zahvata u prohodima, veće radne brzine, te lakšeg i bržeg okretanja na uvratinama (Niemöller, 2008).

Snaga potrebna za pogon kosilice može se podijeliti na snagu potrebnu za rezanje koja iznosi od 30 do 40% i na gubitke snage koji iznose od 60 do 70% od ukupne snage. Gubitak snage se sastoji od gubitaka nastalih u pogonskom mehanizmu, u trenju pokošene krme sa tanjurima kosilice i zbog otpora zraka nastalog pri velikoj rotacijskoj brzini tanjura kosilice (Niemöller et al., 2007). Navedeno upućuje na potrebu smanjenja visokog udjela gubitka snage. Tvrtka Pöttinger vidi potencijal u razvoju kosilica pogonjenih elektromotorom ako će na traktoru biti raspoloživo više električne energije, te ako električni motori budu jeftiniji i lakši (Wiedermann, 2010).

Kombinacije kosilica velikog radnog zahvata

Kombinacije s tri kosilice imaju značaj u primjeni zbog velikog radnog zahvata. Dvije kosilice su priključene na stražnjoj lijevoj i desnoj strani a treća na prednjoj (tzv. butterfly – leptir kombinacija) ili su sve tri kosilice priključene na stražnjoj ili prednjoj strani traktora (sl. 2). Kombinacije s nošenim kosilicama su ograničene radnim zahvatom do 10,00 m; zbog opterećenja poteznice i stražnje osovine traktora, te transportne visine kosilica. Kombinacija stražnjih kosilica s prednjom se koristiti sa standardnim traktorom, dok u slučaju priključivanja svih triju kosilica sa stražnje strane potrebna je mogućnost okretanja sjedala i upravljačkih uređaja zbog kretanja traktora unatrag (sl. 2 desno). Prednost sustava kod kojeg su sve tri kosilice sa stražnje strane traktora je što nema suvišnog preklapanja radnih zahvata u košnji ili nepokošenih traka. Da bi ostvario navedenu prednost u kombinaciji stražnjih kosilica s prednjom Pöttinger je razvio model NovaCat V10 ED sa učinkom od 10 ha/h koji ima mogućnost nezavisnog bočnog pomicanja stražnjih kosilica za 400 mm radi preciznijeg usklađivanja radnog zahvata stražnjih kosilica sa prednjom.

Sl. 2 Kombinacije kosilica: Claas DISCO 9300 C DUO s prednjom kosilicom na standardnom traktoru (lijevo) ili s prednje strane sistemskog kompaktnog traktora (u sredini) i Pöttinger NovaCat X8 sa sve tri kosilice na stražnjoj strani traktora koji se kreće unatrag (desno)

Fig. 2 Mower combinations: Claas DISCO 9300 C DUO with front mower for use on a standard tractor (left) or in front combination for use on a compact tractor (middle) and Pottinger NovaCat X8 in rear combination for use on a tractor with reverse drive systems (right)

U tablici 1 su prikazane kombinacije kosilica radnog zahvata od 8,30 do 11,55 m. Najmanja snaga traktora potrebna za pogon kombinacije nošenih kosilica radnog zahvata od 8,30 m je 99 kW, a za pogon kombinacije s vučenim kosilicama radnog zahvata od 11,55 m je 257 kW. Za model Pöttinger NovaCat V10 ED za postizanje visokog radnog učinka uz kondicioniranje potrebna je snaga traktora od 265 kW (Wilmer, 2009), u prospektu se navodi da najmanja snaga traktora potrebna za pogon iznosi 110 kW. Za sve modele u tablici 1 je predviđeno priključivanja sa stražnje strane traktora u kombinaciji s prednjom kosilicom, a modeli na sl. 2 imaju dodatnu mogućnost priključivanja kosilica s prednje strane kompaktnog sistemskog traktora ili sa stražnje strane traktora. Prikazani modeli za mehaničko tretiranje pokošenih biljaka (kondicioniranje) koriste rotor s prstima a za neke modele su opcija valjci.

Tablica 1 Kombinacije kosilica s velikim radnim zahvatom

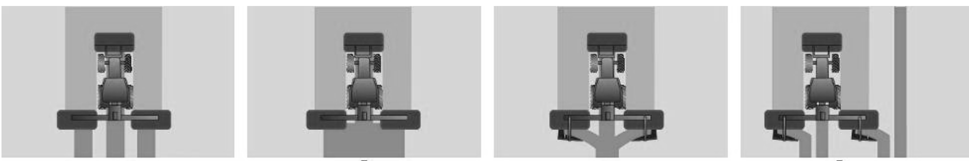
Table 1 Mower combinations with large working widths

Proizvođač i model [1]	Ukupni radni zahvat s prednjom kosilicom (m)	Mogućnost spajanja otkosa, oblikovanja jednog, dva ili tri otkosa	Priključivanje u kombinaciji s prednjom nošenom kosilicom	
Claas				
DISCO 9300 C DUO	9,10	ne	nošena	stražnje[2]
DISCO 9100 C AUTOSWATHER	9,10	da	nošena	ili samo prednje[3] stražnje
JF Stoll				
GX 9005 SM	8,60	ne	nošena	stražnje
GXT 12005 SM Collector	11,50	da	vučena	prednje i stražnje
John Deere				
488	8,80	da	nošena	stražnje
Krone				
EasyCut B 1000 CV Collect	10,00	da	nošena	stražnje
Kuhn				
FC 883 RA	8,80	da	nošena	stražnje
Kverneland Taarup				
5090 MT BX	9,00	da	nošena	stražnje
Lely				
900 MC	8,90	ne	nošena	stražnje
Pöttinger				
NOVACAT V10 ED/RC	9,98	ne	nošena	stražnje
NOVACAT X8 ED/RC	8,30	ne	nošena	stražnje
NOVACAT X8 ED/RC Collector	8,30	da	nošena	ili samo stražnje[3] stražnje
Vicon				
690 T	9,00	da	nošena	stražnje

1. modeli se kombiniraju s prednjom kosilicom
2. tzv. leptir (butterfly) kombinacija prednje kosilice s dvije bočne stražnje kosilice
3. tri kosilice s prednje strane kompaktnog sistemskog traktora ili sa stražnje strane uz kretanje traktora unatrag

Većina kombinacija kosilica prikazanih u tablici 1 ima mogućnost spajanja otkosa odnosno oblikovanja jednog zajedničkog otkosa (sl. 3). Na stražnjoj strani bočnih kosilica su beskonačne trake (sl. 5) koje usmjeravaju pokošenu krmu prema traktoru i polažu je na otkos prednje kosilice, te se bočni otkosi spajaju sa središnjim. Kombinacija s tri kosilice ili samokretna kosilica radnog zahvata većeg od 9,00 m nakon dva prohoda mogu pokositi više od 18,00 m u širini i spajanjem otkosa oblikovati samo dva otkosa, te ih rotacijske grablje s četiri ili šest rotora mogu spojiti u jedan veliki zboj (sl. 8), što prema navodu proizvođača (Claas i Pöttinger) a temeljem iskustava na terenu ubrzava spremanje krme i do 40%. Prema potrebi se beskonačna traka može isključiti i podignuti radi oblikovanja tri ili dva zasebna otkosa umjesto jednog zajedničkog (sl. 4).

Kod Kverneland-Taarup i Vicon kombinacije kosilica moguće je oblikovati otkos izvan radnog zahvata i položiti ga uz otkos iz prethodnog prohoda, to se postiže promjenom smjera kretanja beskonačne trake na stražnjoj desnoj kosilici (sl. 3 d). Središnji otkos se oblikuje od prednje i stražnje lijeve kosilice. Koncepcija spajanja otkosa se može koristiti u kombinaciji jedne stražnje i prednje kosilice ukupnog radnog zahvata od 6,00 m gdje se oblikuje jedan otkos širine od 1,60 do 2,50 m ili se deflektorskim pločama oblikuju dva uža otkosa manjeg razmaka ukupne širine od oko 3,00 m. U oba slučaja ih sakupljački pick-up uređaj radnog zahvata od 3,80 m može pokupiti u jednom prohodu.



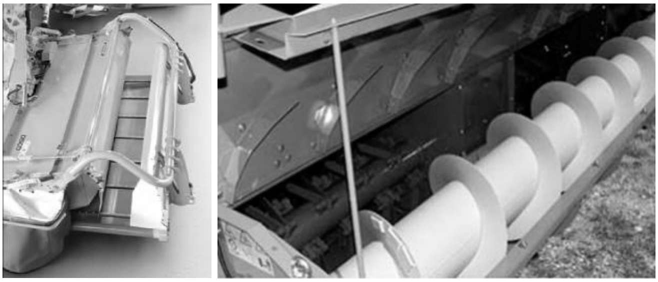
a b c d

Sl. 3 Mogućnosti oblikovanja otkosa u kombinaciji kosilica: a) tri zasebna otkosa, b) jedan širom razasuti otkos, c) jedan otkos, d) dva otkosa (Kverneland-Taarup i Vicon sustav)

Fig. 3 Mower combinations can be set for: a) three single swaths, b) wide spreading hood, c) one swath d) two swaths (Kverneland-Taarup and Vicon system)

Sl. 4 Oblikovanje dva otkosa podizanjem i isključivanjem uređaja s beskonačnom trakom na desnoj kosilici, Pöttinger kombinacija kosilica

Fig. 4 The collector/conveyor belt on the right mower can be deactivated for gathers the crop in two swaths, Pöttinger mower combination



Sl. 5 Beskonačna traka (Claas DISCO 9100 C Autoswather) ili pužnica (samokretna kosilica Krone Big M) za spajanje otkosa

Fig. 5 The collector/conveyor belt (Claas DISCO 9100 C Autoswather) or auger (self-propelled mower Krone Big M) for swath merging/gathering

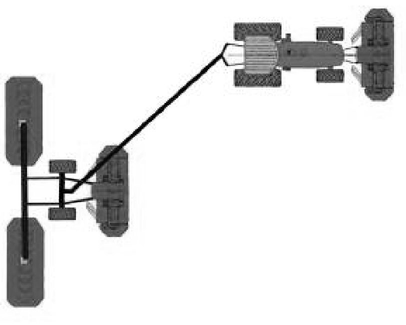
Za radne zahvate iznad 10,00 m prikladna je kombinacija prednje nošene kosilice s dvije ili tri vučene kosilice koje su priključene na stražnji jednoosovinski okvir. Proizvođač JF-Stoll je razvio modele GXT 12005 SM Collector i GFX (sl. 6), ukupnog radnog zahvata od 11,55 m s mogućnošću oblikovanja jednog zajedničkog otkosa širine od 2,00 do 2,80 m. Masa stražnjih dviju kosilice je 7.100 kg i najmanja snaga traktora potrebna za pogon je 257 kW uključujući i pogon prednje kosilice, odnosno 184 kW za model bez mogućnosti spajanja otkosa. Masa prednja kosilica ovisno o modelu je 1.150 ili 1.250 kg, te ukupna masa kosilica može iznositi 8.350 kg. Prema navodu proizvođača moguć je učinak i od 20 ha/h.

Sl. 6 Kombinacija vučene kosilice JF-STOLL – GXT 12005 SM Collector i prednje nošene kosilice GFX, radni zahvata je 11,55 m

Fig. 6 Trailed triple set JF-STOLL – GXT 12005 SM Collector with a GFX front mounted mower, working width is 11,55 m

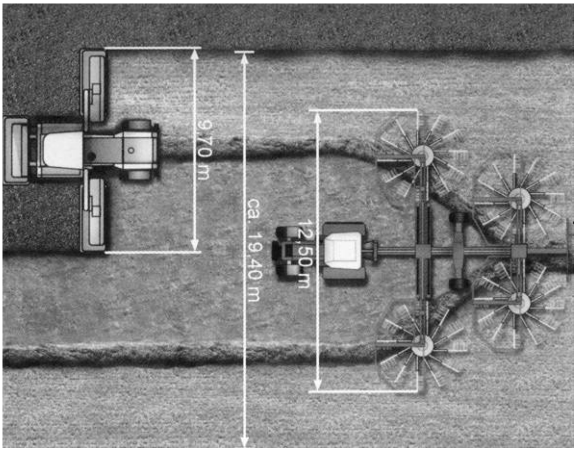
Učinak standardnog traktora s kombinacijom prednje i stražnjih kosilica velikog radnog zahvata je približno isti kao i učinak samokretnog stroja za košnju, a cijena triju kosilica je puno niža od cijene samokretne kosilice. Ispitivanja tvrtki Deutz-Fahr, Kverneland i visoke tehničke škole FH Neubrandenburg su utvrdila da traktor s prednjom i stražnjim kosilicama za 24 h može pokositi 280 ha raspoređenih na 27 parcela. Potrošnja diesel goriva je bila niska, oko 2 l po jednom hektaru i prema cijeni goriva takva proizvodnja se pokazala isplativija od korištenja samokretne kosilice (Niemöller, 2008).

Na Agritechnici 2007. godine je predstavljena vučena kosilica NovaCat T8 proizvođača Pöttinger sa tri tanjuraste kosilica na jednoosovinskom okviru s radnim zahvatom od 8,30 m i u kombinaciji s prednjom nošenom kosilicom se može postići ukupni radni zahvat od 11,00 m (sl. 7). Kao prednost ove koncepcije se smatra postizanje velikog radnog zahvata korištenjem standardnog traktora.



Sl. 7 Stražnja vučena kosilica Pöttinger NovaCat T8 u kombinaciji sa prednjom nošenom kosilicom

Fig. 7 Rear trailed mower Pöttinger NovaCat T8 in combination with front mounted mower



Sl. 8 Krone Big M II samokretna kosilica i rotacijske grablje Krone Swadro 1400

Fig.8 Krone self-propelled mower Big M II and rotary rakes Krone Swadro 1400

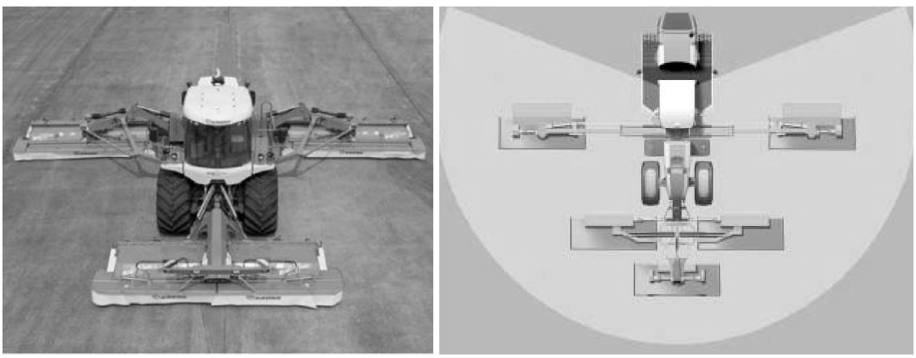
Za košnju na manje pristupačnim terenima, te za komunalne potrebe i održavanje eko-loški zaštićenih krajolika zanimljiva je koncepcija velikog radnog zahvata sa oscilirajućim kosilicama proizvođača Kunzelmann Maschinen-& Gerätebau GmbH. Kosilice su s dvostrukom kosom brzine noževa od 30 m/s čime se mogu postići radne brzine od 15 km/h, snaga potrebna po jednom metru radnog zahvata je 2,5 kW. Radni zahvat može biti od 3,75 m, a s tri kosilice do 12,00 m u leptir (butterfly) kombinaciji ili do 12,50 m s učinkom do 8 ha/h ako su kosilice priključene sa stražnje strane uz kretanje traktora unatrag.

Samokretna kosilica

Tvrtka Krone je razvoj i proizvodnju samokretnih kosilica započela još u prošlom stoljeću. Krone Big M 500 (sl. 9) je samokretna kosilica s mehaničkim tretiranjem pokošenih biljaka s radnim zahvatom od 13,20 m, od čega dvije stražnje kosilice bočno kose 2 x 4,40 m i prednja kosilica 5,30 m. Učinak stroja može biti i do 20 ha/h. Samokretnu kosilicu pogoni motor snage od 382 kW, kosilicama se može upravljati nezavisno i moguće je spajati otkose odnosno oblikovati tri, dva ili jedan zajednički otkos pomoću pužnica na stražnjim kosilicama.

Samokretna kosilica Class Cougar 1400 (sl. 9) je radnog zahvata od 14,00 m s pet kosilica koje se prilagođavaju nagibima terena, svaka kosilica ima sedam tanjura i pogoni ih motor snage od 350 kW. Učinak stroja može biti 20 ha/h ili veći. Zbog intenzivnog kondicioniranja krme ubrzano je njeno sušenje te je moguće izostaviti radnu operaciju rastresanja i okretanja. Umjesto tanjura s noževima može biti model s rotoudaračima za malčiranje, te je radni zahvat 12,60 m s učinkom od 10 ha/h ili većim.

Prema ispitivanjima Državnog instituta za poljoprivredu u Freising-u učinak samokretnih kosilica je od 9,0 do 12,0 ha/h, čak i u Bavarskoj gdje su nešto manje parcele (Niemöller, 2007). Površina pokošenih područja je bila od 0,1 do 16,0 ha s prosječnom površinom od 2,8 do 3,4 ha. Računajući da vrijeme potrebno za transport prometnicama iznosi 50% dobiva se učinak od približno 5,0 ha/h (Geischeder et al., 2005). Prema tome učinak samokretnih kosilica velikog radnog zahvata uvelike ovisi o vremenu potrebnom za transport stroja s jedne parcele na drugu, pogotovo u područjima gdje prevladavaju poljoprivredna gospodarstva s većim brojem manjih parcela.



Sl. 9 Samokretne kosilice: Krone Big M 500 (lijevo) i Class Cougar 1400 (desno)

Fig. 9 Self-propelled mowers: Krone Big M 500 (left) and Class Cougar 1400 (right)

ZAKLJUČAK

Povećanje učinka kosilica i dobivanje visokokvalitetne krme zahtjeva velike radne zahvate i visoke radne brzine uz što uspješnije prilagođavanje kosilica neravninama terena. S vučenim kombinacijama kosilica i sa samokretnim kosilicama su postignuti radni zahvati iznad 10,00 m. Smanjenjem broja prohoda u spremanju krme smanjuje se utrošak goriva, onečišćenje krme, gubitak hranjivih tvari i oštećenje travnjaka. Intenzivnim kondicioniranjem se može izostaviti radna operacija rastresanja i okretanja te spajanjem otkosa dodatno smanjiti potrošnja goriva (Kowalewsky, 2009), jer je moguć manji broj prohoda s rotacijskim grabljama ili sa strojevima sa sakupljačkim (pick-up) uređajem velikog radnog zahvata. Od ukupne snage potrebna za pogon kosilice od 60 do 70 % su gubici nastali u pogonskom mehanizmu, u trenju pokošene krme sa tanjurima kosilice i zbog otpora zraka nastalog pri velikoj rotacijskoj brzini tanjura kosilice. Visoki udio navedenih gubitaka je potrebno smanjiti. Razvoj kosilica je usredotočen i na brzu izmjenu potrošnih dijelova, također se nastoji skratiti vrijeme potrebno za podešavanje i održavanje kosilica. Sustav za automatsko vođenje traktora i priključnog stroja omogućuje povećanje učinka u spremanju krme i smanjenje utroška goriva. Za manja i srednja gospodarstva je za prvu košnju kad vremenski uvjeti mogu biti nepovoljni i kad je veća biljna masa preporučljivo koristiti mehanizaciju visokog učinka kroz udruge poljoprivrednika (strojni prsten ili slično) ili unajmljivanjem profesionalnih usluga.

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THE TRENDS IN THE DEVELOPMENT OF MOWERS

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The need for more profitable forage production and the use of energy crops in biofuel production is directing mower development towards a greater working efficiency and quality of forage. The mounted triple mower combinations reaches a working width of 10,00 m; while trailed-mounted triple mower combinations or self-propelled mower must be chosen for greater working widths. Depending on the conditions it is possible to achieve very large area capacity in the range of 10 to 20 ha/h. A high intensity conditioning is used to shorten drying time and to reduce treatment of hay after mowing. Swath formation of mowing width greater than 9,00 m can significantly reduce the number of passes with either four-rotor rakes or pick-up with large working width and thus increasing performance, reducing contamination of forage and turf damage. The increase of working speed is achieved by improving systems for the reduction of contact pressure of the mower on the ground and topsoil contour adaptation. The reduction of fuel consumption can be achieved by reducing the number of passes, using automatic steering system and by changing the mower blades regularly.

Key words: *mowing, mower combinations, self propelled mower, mower combinations, swath merging*

41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.333:631.8
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Expert paper

INFLUENCE OF PHYSICAL – MECHANICAL PROPERTIES OF FERTILIZER ON UNIFORMITY OF DISTRIBUTION

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ABSTRACT

The main purpose of man's activities in crop production is to provide such a final product which will, by its quality and quantity, meet the basic principles of cost-effective and cost-efficient production. High yields are leaving soli with the lower productivity and with much worse physical and mechanical properties. In this sense, application of fertilizers is of a great importance. The aim of this study was to demonstrate how much the uniformity of distribution depends of the applied fertilizers physical-mechanical properties and technical system of application. The paper gives the results of two centrifugal spreaders working quality in relation to physical and mechanical properties of applied fertilizers. Variation coefficients showed that no good uniformity was achieved. Real application varied significantly along the swath having the oscillations from 82% lower to 56% higher than the nominal application rate.

Key words: *fertilizers, mechanical properties, fertilizer disk spreaders, distribution uniformity*

INTRODUCTION

Generally, farmers work to achieve the best results from their farming. This leads them to the area of intensive farming where crop yields are increased through intensified inputs in labour and capital in the form of mechanization, use of nutrients and chemicals for plant protection. In the frame of compensating the lack of organic and mineral materials in the soil farmers are not so careful in the area of fertilizing management (Laegried et al, 1999). The intensive use of fertilizers can lead to the misbalance that is environmental in the nature but also imposes the energy and economy concern. In arable farming the fertilizers used account for the largest cost and energy factor among other farming inputs. In the crop production, energy consumption through the fertilizer application accounts for 2/3 of total energy inputs (Ortiz-Canavate and Hernanz, 1999).

Mineral fertilizer distribution on the field is of a great importance (Scheufler, 2010) and must be accurate and adapted to the nutrient requirements. New technologies in the frame of precision agriculture concept allow application of very precise fertilizers quantities. In this situation it is of great importance to know the physical properties of the used fertilizers since segregation of fertilizers or caking can put question mark to fertilizer application quality (Laegried et al, 1999). Most of the fertilizers are solids and their physical strength is an important aspect of application quality. Particles must be able to withstand the transport, storage and other manipulation procedures. They must not deteriorate into powder or cake into the larger pieces. The fertilizer must not absorb water during transport but, on the other side should dissolve rapidly in the soil after application.

The aim of this paper was to analyse physical properties of the commonly used mineral fertilizers and the efficiency of their application with the disc fertilizer spreaders. The paper should emphasize the importance of the correlation of the physical properties of the mineral fertilizers with their efficient application in the field.

MATERIAL AND METHOD

In this paper working quality of two centrifugal fertilizer spreaders is analysed. Testing of the machines was carried out in production conditions of the Agricultural Company Belgrade during maize production in the season 2009/10. Tested fertilizer was UREA with the nitrogen content of 46% (produced by "AZOT", 75 Churtanoskoe shosse, Berezniki, Perm, Russia). Standard maximal humidity of the fertilizer was 0.5%, specific mass 0.73 g/cm^3, porosity coefficient 0.22 and the angle of the internal friction 27.5^0. Two spreaders analysed (Tab. 1) were Vicon Rota Flow i RCW (Agromehanika Kranj).

Table 1 Basic characteristic of the tested spreaders

Technical data	Vicon Rota Flow	RCW
Capacity, l	2000	3500
Working width, m	10 to 36	10 to 20
Type	Mounted	Trailed
Spreading element	Two discs	Two discs

Testing procedure for the spreaders is defined by ISO 5690/2 and ASAE 343.1. standards. Three probes were carried for each spreader in order to determine working speed, fertilizer distribution uniformity and particle size distribution. Spreaders were tested while distributing fertilizer on the seed bed prepared soil for maze. Nominal application rate was 250 kg/ha.

Uniformity of fertilizer distribution was analysed from the samples gathered along the spreader working width. For sample collection 20 cylinder plastic trays were placed along the spreader width. The tray diameter was 10.5 cm. Sample mass was determined by means of precise weighing machine Kern 572/573/KB/DS/FKB/FCB Version 5.8, 04/ 2010 with the precision level of 0.01 g. Particle size distribution within the sample was determined with the Vicon Greenland Art.nr. meter 797770150 with the hole diameters of smaller than 2 mm, larger than 2 mm and larger than 3.3 mm.

RESULTS AND DISCUSSION

Testing results for the VICON RS – XL spreader

Working speed of the spreader was 12.63 km/h in the first probe and in the other two 11.8 km/h. Air temperature in the field was 23 ºC, air relative humidity 40.9% and wind speed 1.5 m/s. Results of the gathered sample mass are show in Figure 1. It can be seen that spreader has no uniform distribution along the working width. Better uniformity can be observed in the central part and on the fertilizer left side.

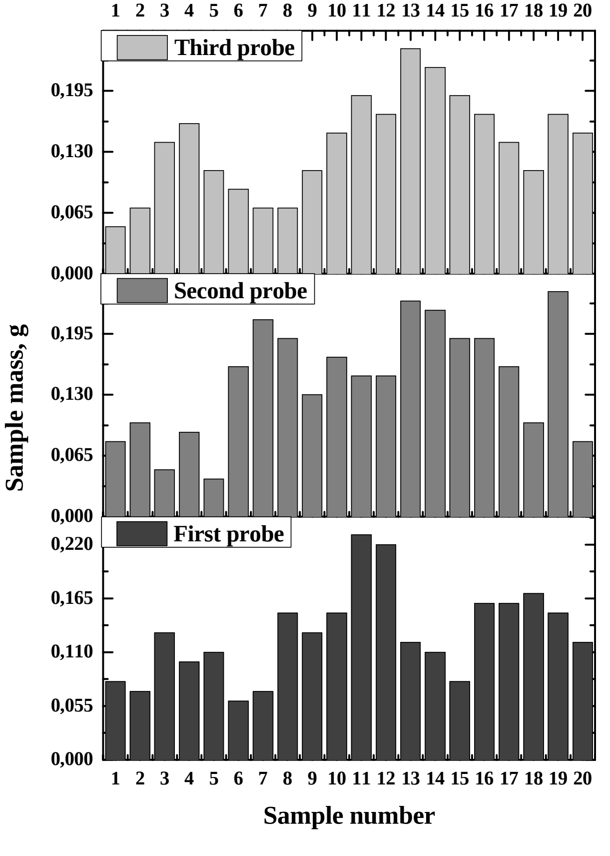

Figure 1 Uniformity of fertilizer distribution for the VICON RS – XL spreader

Based on the measured sample mass it was possible to calculate the real application rate. As uniformity of distribution varied, so did the application rate. Average values are shown in Table 2. It can be seen that average application rate was lower than nominal (30-40% lower). The lowest value of application rate was 45.98 kg/ha and the highest was 275.86 kg/ha. In the first probe application rate varied from 68.97 to 264.37 kg/ha, in the second probe from 45.98 to 275.86 kg/ha and in the third probe application varied along the working width from 54.47 to 275.86 kg/ha.

Table 2 Uniformity distribution parameters for the VICON RS – XL spreader

Parameter	I probe	II probe	III probe
Average sample mass, g	0.13	0.15	0.14
Standard deviation, g	0.0458	0.0588	0.0513
Variation coefficient, %	35.23	39.2	36.64
Average application rate, kg/ha	149.4	172.41	160.92

Variation coefficients confirm the fact that distribution along the spreader width is not uniform. The possible source of variation could be windy conditions during filed testing and poor seedbed preparation.

Testing results for the RCW spreader

Measured working speed of the spreader was 13.09 km/h in the first probe, in second 12.41 km/h and 12 km/h in the third probe. Working width of spreaders was 12 m. Microclimatic conditions were the same as for the Vicon spreader. Fertilizer samples along the working width of the spreader were collected in the 15 plastic trays placed on the 0.8 m distance.

Based on the measured sample mass it was possible to calculate the real application rate. As uniformity of distribution varied, so did the application rate. Its average value (Tab. 3) was closer to the nominal application rate if compared with the Vicon spreader. It was 17% lower and maximum 8% higher compared to the nominal value.

The lowest value achieved was 45.98 kg/ha and the highest 390.8 kg/ha. Along the spreader working width application rate varied in the first probe from 91.95 to 367.82 kg/ha, in the second probe it varied from 45.98 to 390.8 kg/ha and in the third probe the lowest application rate was 57.47 kg/ha and the highest was 379.31 kg/ha. The variation coefficient was higher than 40% in all probes and also verifies the conclusion that the good distribution uniformity was not achieved. The reasons for this can also be searched in windy conditions and poor seedbed preparation. Similar conclusions can be made for this spreader like for the first one emphasizing the need for optimizing the overlapping of the spreader working width.

If the sample distribution on the figure 1 and 2 are looked at, it can be seen that distribution pattern for the first spreader is not obvious. It seems like so called “w” pattern that consists of three areas with higher application rate. This pattern is often associated with the twin-spinner spreaders and needs to be corrected by overlapping and better adjusting of the spreader itself. But overlapping itself can only lead doubling of the fertilizer quantities applied in the places where fertilizer has already been applied. The second spreader has some kind of pattern that is often called "pyramid pattern" (Stewart and Bandel, 2002). This makes it more suitable for the modelling and optimisation. Although this is an acceptable pattern, the effective swath width is only 50% of the theoretical. For the tested spreader calculated effective swath width was 7.2 m of total 12 m having the effectives of 60%.

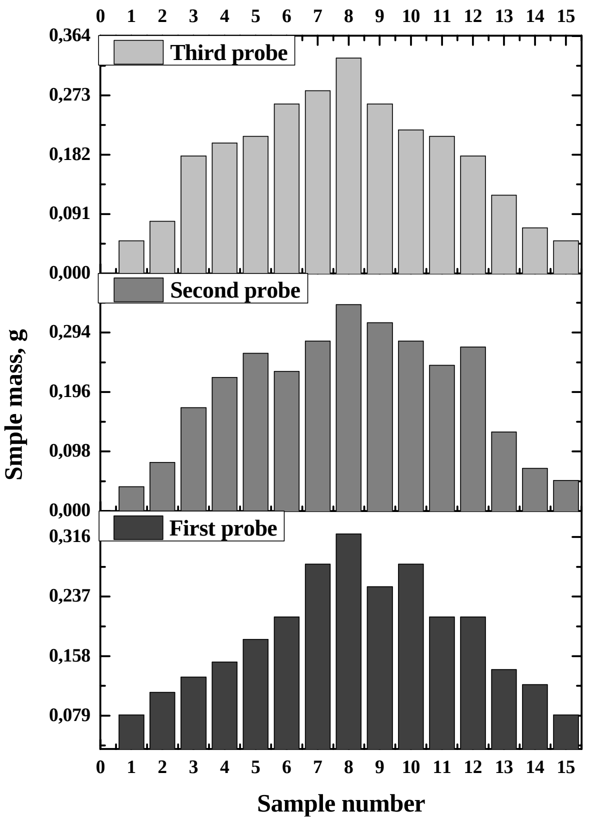

Figure 2 Uniformity of fertilizer distribution for the RCW spreader

Table 3 Uniformity distribution parameters for the RCW spreader

Parameter	I probe	II probe	III probe
Average sample mass, g	0.18	0.20	0.18
Standard deviation, g	0.0732	0.097	0.0851
Variation coefficient, %	40.67	48.5	47.28
Average application rate, kg/ha	206.90	229.89	206.90

Further analysis was carried in order to define particle size distribution for defining the possible correlation between distribution uniformity and particle size distribution. Three samples were taken - fertilizer from the storage, from the spreader prior to application and fertilizer after the application (Tab. 4).

Table 4 Particle size distribution in the samples

Particle size	Fertilizer from the storage, sample mass 85.5 g	Fertilizer in the spreader, sample mass 85.9 g	Fertilizer after application, sample mass 85.8 g
> 3.3 mm	0.82 %	0.93%	0.93%
> 2 mm	96.84 %	95.00%	94.63%
< 2 mm	2.34 %	4.07%	4.44%

Results show that the samples are of a good uniformity. The influence of manipulation prior to application is evident since the percentage of the smaller particles is higher after the transportation to the field. The spreader itself caused further destruction of the particles having as a consequence higher percentage of the particles for the application that are smaller than 2 mm in the diameter. Part of the fertilizer poor distribution uniformity along the spreader working width can be justified by this higher share of smaller particles susceptible to windy conditions.

CONCLUSIONS

Filed testing of the two disk fertilizer spreaders showed that, even with the same working conception, their distribution patterns were different. For the first spreader the pattern was unacceptable and for the second was acceptable. Real application varied significantly along the swath having the oscillations from 82% lower to 10% higher rate in the case of first spreader and 82% lower to 56% higher application rate for the second spreader. Variation coefficients showed that no good uniformity was achieved. The reasons for poor spreader patterns can be searched in the windy conditions, incorrect swath width due to no properly adjusted overlapping and the problem with the poor field conditions that resulted in uneven terrain that affected the driving pattern of the spreader. Further analysis of the particle size distribution showed that fertilizer manipulation prior to application (storage, transportation...) caused the creation of larger number of smaller particles that were susceptible to wind conditions during the field testing.

Result show that the mechanical properties such as particle size influence the overall spreader efficiency and that lot of care should be taken in processes of manipulation with the fertilizers prior to their application. Optimisation and modelling for calculating the optimal overlapping of the spreader working width, based on the mechanical properties of the fertilizer, local weather conditions during the application and the characteristic of the spreader will be future part of the research.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

RASPODJELA TEKUĆINE S MLAZNICAMA TVRTKE LECHLER OC3 I OC4

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SAŽETAK

U radu su prikazani rezultati istraživanja površinske, volumne raspodjele tekućine s njihovim protocima za mlaznice koje se primjenjuju u zaštiti od korova ispod stabala trajnih nasada. Istraživanja su provedena s mlaznicama proizvođačke oznake OC3 i OC4 izrađene od mesinga i otvrdnjelog čelika, tvrtke Lechler pri radnim tlakovima od 2, 3 i 4 bar, te radnim visinama od 30, 40, 50 i 60 cm od tla. Utvrđeno je da su mlaznice oznake OC3 ostvarile prosječnu vrijednost protoka pri provjeri kod radnog tlaka od 2 bar, vrijednost od 1,05 l/min, uz standardnu devijaciju od 16,07 i koeficijent varijacije 1,52%. Ispitivane mlaznice OC4 kod radnog tlaka propustile su 1,36 l/min. Povećanjem tlaka na 3 bar mlaznice OC3 ostvarile su protok od 1,27 l/min, a mlaznice OC4 1,36 l/min uz standardnu devijaciju od 18,660 i koeficijent varijacije od 1,36%. Pri radnom tlaku od 4 bar prosječna vrijednost protoka mlaznica OC 3 iznosila je 1,45 l/min a kod kod mlaznica OC4 1,87 l/min. Na radnoj visini od 50 cm od tla i tlaku od 3 bar mlaznica OC3 imala je prosječni radni zahvat od 128,7 cm, a OC4 114, 2 cm. Podizanjem mlaznice OC3 na radnu visinu na 60 cm uz tlak od 3 bar ostvaren je radni zahvat od 139,2 cm a kod OC 4 mlaznice 125,1 cm uz standardnu devijaciju 27,037 i koeficijent varijacije od 2,16%. Smanjenjem radne visine na 30 cm i uz radni tlak 4 bar utvrđen je radni zahvat od 82,09 cm kod mlaznice OC3, a kod mlaznice OC4 74,41 cm. Pri povećanju radne visine na 50 cm ostvaren je radni zahvat od 130,0 cm kod mlaznice OC3 i 121,2 kod mlaznice OC4 uz standardnu devijaciju od 72,390 i koeficijent varijacije od 5,97%.

***Ključne riječi**: raspodjela tekućine, mlaznica, radni zahvat, radni tlak*

UVOD

Svakodnevna primjena pesticida u poljoprivredi nameće potrebu utvrđivanja većeg broja čimbenika koji direktno ili indirektno djeluju na biološku efikasnost. Tehnički čimbenici u postupku izrade su od presudnog značaja za ravnomjernu raspodjelu škropiva po ratarskoj površini. Nastalu tehničku pogrešku u procesu proizvodnje najbolje je odmah utvrditi jer se na taj način nastale pogreške u postupku aplikacije umanjuju na minimum. Svaka mlaznica određena je svojom bojom koja označava njezin protok po ISO standardima (ISO 10625). Ako se vrijednost tlaka mijenja, mijenja se protok i radna širina mlaza. Radna širina mlaza uvjetovana je isto tako i radnim kutem te visinom rada u odnosu na predmet zaštite. Tako kod mlaznice oznake 11004 radna teorijska širina s visine prskanja od 50 cm, prema navodima autora Banaj i Šmrčković (2003.) iznosi 143 cm pri 2,8 bara. U stvarnosti ne ostvarujemo teorijsku širinu, navode autori, nego dobivamo mlaz koji je nešto uži. Mlaznice kako navode autori Banaj i suradnici (2000.), obavljaju važne funkcije tj. propuštaju zadanu količinu tekućine u jedinici vremena, raspršuju tekućinu tvoreći kapljice odgovarajućih veličina, te formiraju mlaz odgovarajućeg oblika. Banaj i suradnici (2009.) navode da pri istraživanju čistom vodom mlaznice tvrtke Kovin, oznake 110-04, mogu poprskati 3000 ha ili imati 180 radnih sati, a da pri tome nisu prešli granicu istrošenosti od 5 ili 10% povećanja protoka pri radnom tlaku od 2,8 bara. Kontroliranjem površinske raspodjele dodatno utječemo na povećanje efekta djelovanja primijenjenog pesticida, a ujedno možemo djelovati na smanjenje primijenjene količine ili doze pesticida.

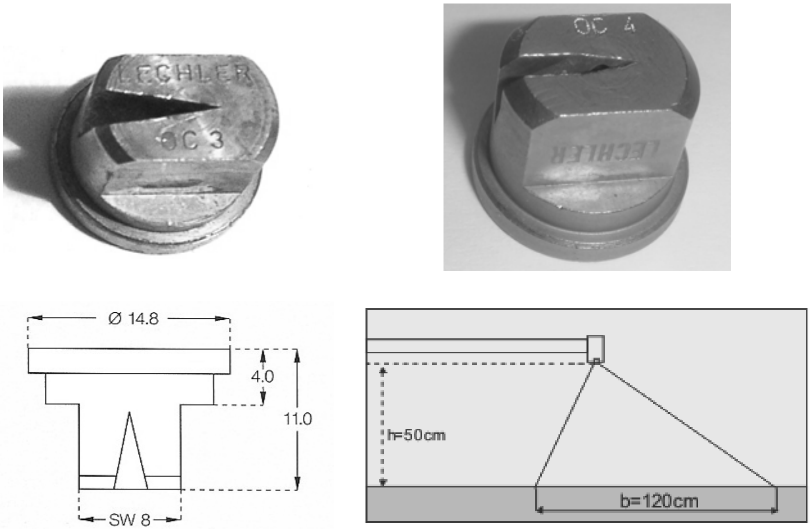
CILJ ISTRAŽIVANJA

Cilj ispitivanja je bio, primjenom standardne metode provjeriti s tri radna tlaka dolazi li kod ispitivanih mlaznica do promjene protoka, oblika površinske raspodjele, te radne širine. Temeljem dosadašnjih saznanja i dobivenih rezultata treba odrediti radne visine i udaljenosti mlaznice od stabla trajnih nasada kako bi se ostvarila najbolja površinska raspodjela tekućine na tlo u zoni ispod stabala nasada.

MATERIJAL I METODA RADA

Mlaznice serije OC, proizvod tvrtke Lechler namjenjene su za uporabu kao krajnje mlaznice na nosećoj armaturi prskalice ili mlaznice za primjenu kod zaštite radnih površina unutar redova stalnih nasada. Mlaznica posjeduje asimetričan mlaz radnog kuta $\alpha = 90°$, a namijenjena je za tlakove p = 1,5 - 5 bara, te posjeduje srednje do fine kapljice.

Istraživanja su obavljena u praktikumu Zavoda za mehanizaciju Poljoprivrednog fakulteta u Osijeku. Zavod posjeduje ispitni stol za ispitivanje mlaznica koji je izrađen po uzoru na ispitni stol kojeg posjeduje laboratorij tvrtke *Hardi* u Danskoj. Mlaznice za kontrolu postavljaju se u nosač okomito iznad pregradnih limova ispitnog stola. Na nosaču se nalazi pet mjesta za mlaznice koje imaju svoj nosač te se mogu mijenjati bez skidanja. Iznad mlaznica postavljen je kontrolni manometar promjera 160 mm točnosti razreda 06 za kontrolu tlaka u vrijeme istraživanja. Na kraju pregradnih limova na ispitnom stolu nalaze se epruvete promjera ϕ= 25 mm koje su poslagane jedna do druge, u dužini od 2 m tako da tekućina koja dođe na širinu stola od 25 mm bude usmjerena u kontrolne epruvete na kojima se nalaze oznake po 1 ml. Mjerenja površinske raspodjele obavljena su 5 puta na 10 mlaznica slučajnim izborom pri radnim tlakovima od p = 2, 3 i 4 bara. Temperatura zraka iznosila je t = 20 do 23 ˚C, a temperatura vode iznosila je t = 18,48 - 22,56 °C, dok je relativna vlažnost zraka bila ispod 65%.



Slika 1 Tehničke odlike ispitivanih mlaznice OC3 i OC4

REZULTATI ISTRAŽIVANJA

Protok

Tablica 1 Statističke vrijednosti testiranja protoka tekućine ovisno o tlaku

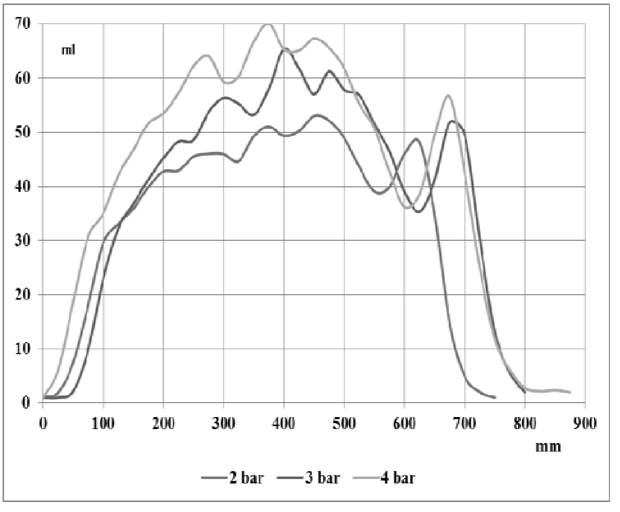
Mlaznica oznake	Radni tlak (bara)	Protok (ml min^{-1})	s.d. (ml)	KV (%)	ISO^{*} (ml)	ISO^{**} (%)
OC 3	2,00	1053,60	16,072	1,52	43,6	4,25
	3,00	1275,33	26,311	2,06	35,33	2,84
	4,00	1458,33	28,005	1,92	28,33	1,98
OC 4	2,00	1362,49	18,660	1,36	82,49	6,05
	3,00	1658,50	22,643	1,36	98,50	5,93
	4,00	1879,93	20,001	1,06	69,93	3,71

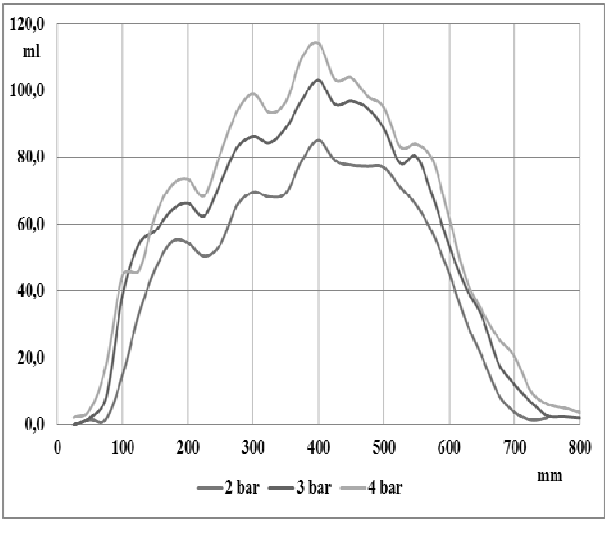
*Odstupanja od ISO 10625 standarda, **Odstupanja od ISO 10625 standarda

Nakon provedenih istraživanja može se zaključiti da su mlaznice OC3 ostvarile prosječnu vrijednost protoka od od 1,05 l/min kod radnog tlaka od 2 bar, a mlaznice 0C4 vrijednost 1,36 l/min. Kod radnog tlaka od 3 bar mlaznice OC3 polučile su protoku od 1,27 l/min, a mlaznice OC4 1,65 l/min. Mlaznica OC3 kod radnog tlaka od 4 bar imala je prosječnu vrijednost protoke od 1,45 l/min pri standardnoj devijaciji od 28,005 i koeficijentu varijacije od svega 1,92%. Pri istom tlaku (4 bar) mlaznice OC4 propustile su kroz sebe 1,87 l/min. Skupni prikaz statističkih vrijednosti prikazan je u tablici 1.

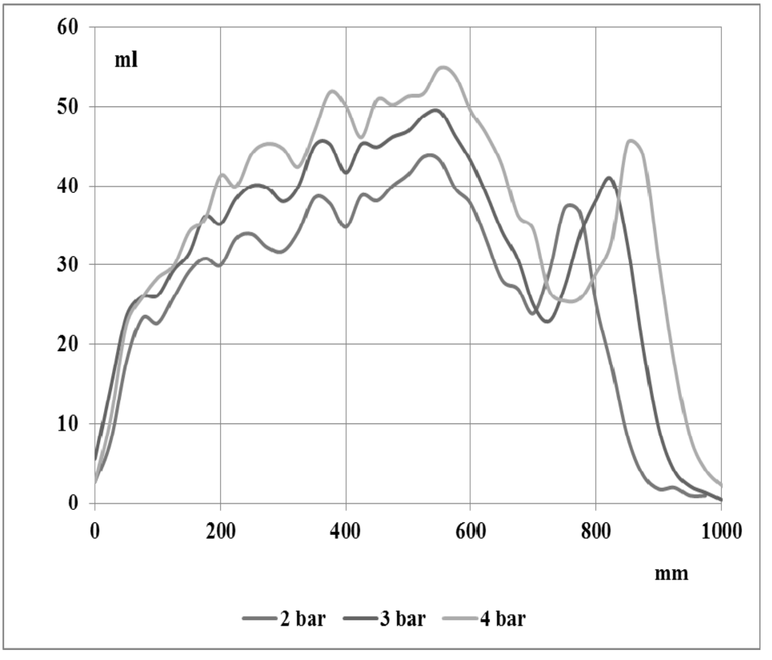
Površinska raspodjela

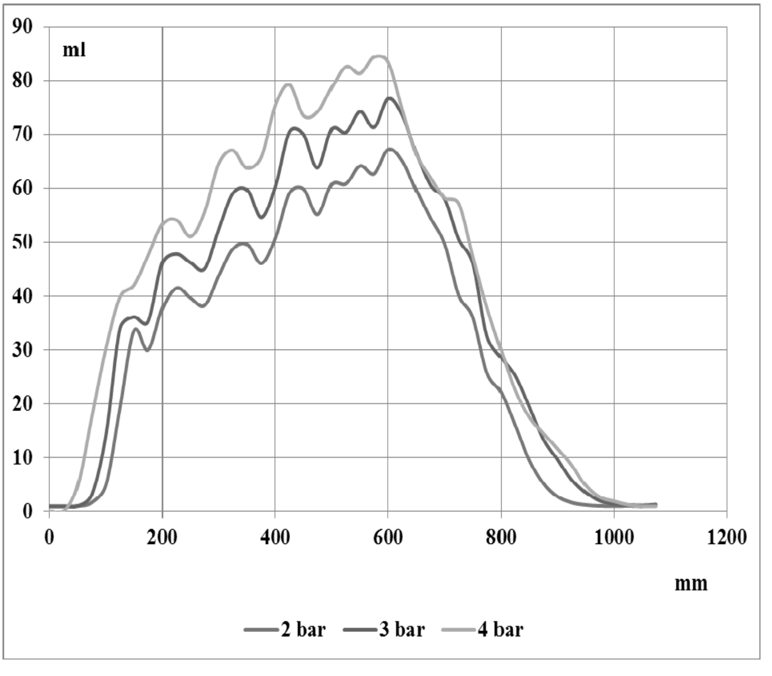
Prosječni rezultati površinske raspodjele tekućine ovisno o radnom tlaku i visini mlaznice prikazani su narednim slikama.



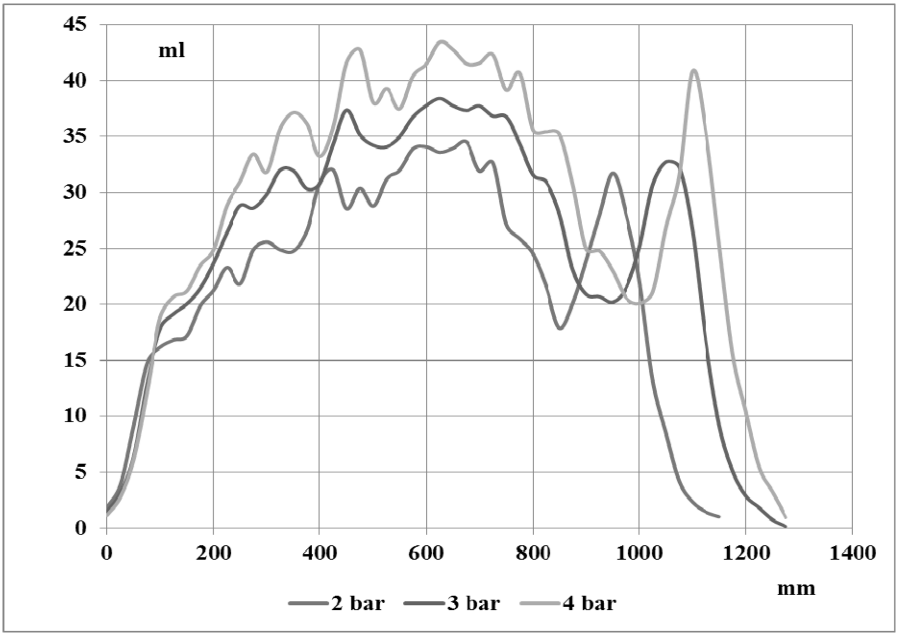


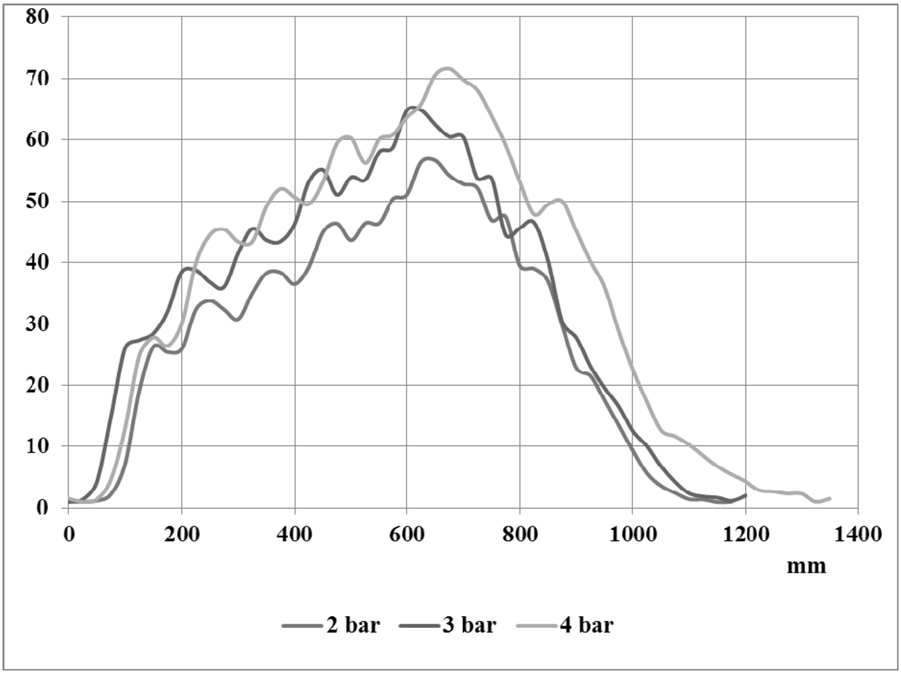
Slika 2 Prosječne vrijednost raspodjele tekućine kod mlaznica OC 3 i 4 pri različitim tlakovima kod radne visine od 30 cm



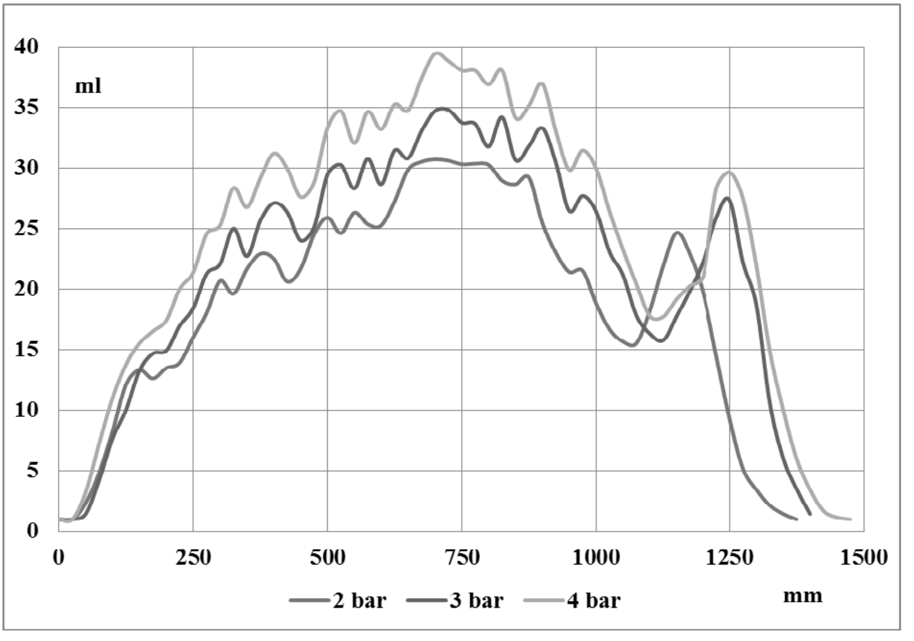


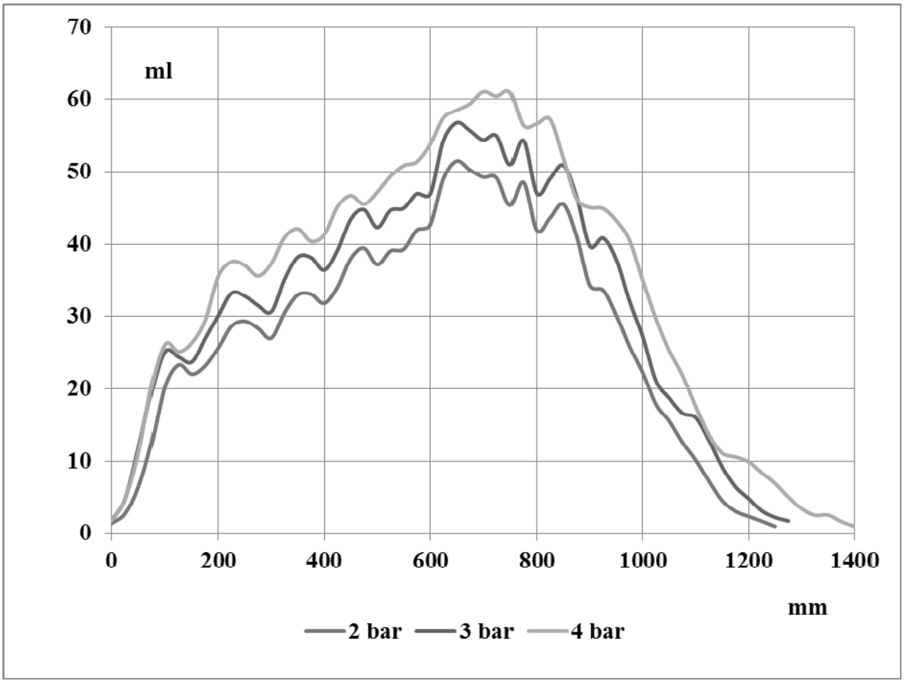
Slika 3 Prosječne vrijednost raspodjele tekućine kod mlaznica OC 3 i 4 pri različitim tlakovima kod radne visine od 40 cm





Slika 4 Prosječne vrijednost raspodjele tekućine kod mlaznica OC 3 i 4 pri različitim tlakovima kod radne visine od 50 cm





Slika 5 Prosječne vrijednost raspodjele tekućine kod mlaznica OC 3 i 4 pri različitim tlakovima kod radne visine od 60 cm

Radne širine ispitivanih mlaznica OC3 i OC4

Rezultati utvrđivanja širine rada ispitivanih mlaznica obavljeno je istovremeno s mjerenjem površinske raspodjele tekućine, a dobiveni rezultati prikazani su u narednim tablicama.

Tablica 2 Statističke vrijednosti radne širine ovisno o radnom tlaku

Mlaznica oznake	Radni tlak (bar)	Radna visina (cm)	Zahvat (mm)	s.d.	KV (%)
	2	30	740,33	9,720	1,30
OC 3	2	40	922,50	15,681	1,31
	2	50	1187,50	14,433	1,21
	2	60	1351,00	15,301	1,13
	3	30	780,16	6,942	0,89
	3	40	965,00	30,163	3,12
	3	50	1287,5	14,434	1,12
	3	60	1392,00	16,77	1,20
	4	30	820,99	29,85	3,59
	4	40	1015,00	13,695	0,12
	4	50	1300,00	20,412	1,57
	4	60	1450,00	23,384	1,61
OC 4	2	30	683,30	16,662	2,43
	2	40	1002,50	31,438	3,13
	2	50	1120,00	18,962	1,68
	2	60	1207,40	13,552	1,12
	3	30	713,00	22,649	3,17
	3	40	1140,00	13,696	1,20
	3	50	1142,40	27,756	2,42
	3	60	1251,20	27,037	2,16
	4	30	744,10	36,402	4,89
	4	40	988,30	33,636	3,40
	4	50	1212,30	72,390	5,97
	4	60	1378,30	31,505	2,28

ZAKLJUČCI

Na temelji iznesenog možemo donijeti slijedeće zaključke:

- ispitivane mlaznice OC3 ostvarile su prosječnu vrijednost protoka pri radnom tlaku od 2 bara od 1053,6 ml/min, a mlaznica OC4 1362,49 ml /min,
- iste mlaznice OC3 pri radnom tlaku od 3 bara propustile su prosječnu količinu od 1275,33 ml/min uz standardnu devijaciju od 26,31 i koeficijent varijacije od 2,06%, a mlaznice OC4 1658,50 ml/min ,

- pri radnom tlaku od 4 bar prosječna vrijednost protoka iznosila je 1458,33 ml/min, a kod mlaznica OC 04 1879,93 ml/min,
- testirane mlaznice OC3 ostvarile su prosječnu širinu mlaza kod 3 bar radnog tlaka pri radnoj visini od 50 cm od 1287,5 mm, a mlaznice OC4 pri istim uvijetima ostvarile su prosječni radni zahvat od 1142,40 mm,
- pri radnom tlaku 3 bar radni zahvat pri radnoj visini mlaznice 60 cm od tla iznosio je kod mlaznica OC3 prosječno 1392,00 mm, a kod mlaznica OC4 iznosi 1251,20 mm,
- na radnoj visini 50 cm uz vrijednost tlaka od 4 bar ostvaren je prosječni radni zahvat kod mlaznica OC3 od 1300,00 mm uz standardnu devijaciju 20,412 i koeficijent varijacije od 1,57 %, a kod mlaznica OC4 pri istim uvijetima ostvaren je radni zahvat 1212,30 mm,
- povećanjem radne visine na 60 cm od tla mlaznice OC3 su ostvarile prosječni radni zahvat od 1450, 00 mm pri radnom tlaku od 4 bar,
- mlaznice OC4 ostvarile su radni zahvat pri visini rada od 60 cm, i pri radnom tlaku od 4 bar od 1378,30 mm.

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LIQUID DISTRIBUTION WITH LECHLER NOZZLES OC3 AND OC4

Đ. BANAJ, V. TADIĆ, A. BANAJ, D. PETROVIĆ

This paper presents the results of investigations of surface and bulk liquid distribution, and their flows in nozzles that are used to protect against weeds under the trees of permanent crop.Investigations were carried out on nozzles manufacturing marks OC3 and OC4 made of brass and stainless steel; Lechler company at operating pressures of 2, 3 and 4 bar, and working heights of 30, 40, 50 and 60 cm from the ground. It was found that the nozzles with mark OC3 achieved an average flow rate during testing at an operating pressure of 2 bar, the value of 1,05 l / min, with a standard deviation of 16,07 and coefficient of variation of 1,52%. OC4 investigatednozzles had liquid flow of 1,36 l/min. Increasing pressure to 3 bar OC3 nozzles achieved a flow rate of 1,27 l / min and nozzle OC4 1,36 l / min with a standard deviation of 18,660 and the coefficient of variation of 1.36%.At working pressure of 4 bar average flow rate OC3 nozzles was 1,45 l / min, and for the OC4 nozzle was 1,87 l / min. At a working height of 50 cm from the ground and a pressure of 3 bar OC3 nozzle had an average working width of 128,7 cm, and OC4 nozzle had 114,2 cm.OC3 nozzles with raising the working height to 60 cm at a pressure of 3 bar was achieved working width of 139,2 cm, while OC 4 nozzles had 125,1 cm with a standard deviation of 27,037 and coefficient of variation of 2,16%. Reducing the working height at 30 cm and with a working pressure of 4 bar from OC3 nozzles was founded that they had working width of 82,09 cm, and 74,41 from OC4 nozzles.When is the working height increased at 50 cm we achieved working width of 130.0 cm from the OC3 nozzle and 121.2 cm at OC4 nozzle with with a standard deviation of 72.390 and the coefficient of variation of 5.97%.

Key words: *liquid distribution, nozzle, working width, working pressure*

41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.67:628.1
Originalni znanstveni rad
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ENERGY CONSUMPTION OF THE MOBILE IRRIGATION SYSTEMS

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SUMMARY

In this paper results of different irrigation systems, regarding to energy consumption and energy ratio, are presented. Energy consumption in irrigation and energy output through yield were analyzes for three different irrigation systems (self-propelled rain wing, self-propelled rain gun and linear system) in order to establish the optimal exploitation and energy parameters of the given irrigation systems. Results show that, concerning the depth of irrigation, good results can be obtained with the lower depths (0-30 cm). Concerning the irrigation application rate it was concluded that with the lower application rate and higher number of irrigation cycles better water usage can be obtained.

Energy consumption of the mobile irrigation systems shows that the optimal relation of the energy output (yield energy) and energy input through the irrigation process in case of mobile rain wing is the lowest (12.29) and that with mobile linear device highest (288.19). Energy consumption in tillage and sowing in the system of conventional tillage was 2519.31 MJ/ha. Energy of irrigation varied depending on type of irrigation system. With the mobile linear system energy consumption was 814.35 MJ/ha, with mobile irrigation wing 1338.54 MJ/ha and with the self-propelled rain gun 8041.17 MJ/ha.

Key words: *energy, irrigation, yield, mobile irrigation systems*

INTRODUCTION

Modern competitive agriculture can not survive without irrigation, what was the main motive for engineers worldwide to study problems in this area (Miodragović 2009). Being the important part of agricultural production, some of the problems in irrigation are energy consumption and energy efficiency of the applied system as well as how to obtain maximal yields with minimum energy input. Miodragovic et al. (2011) define the most important working parameters for the mobile linear irrigation system and how they influence the water distribution uniformity, energy consumption and overall system productivity. Thormann and Sourell (1998), analyzing the potato production in the conditions of irrigation with the mobile linear system, emphasize that one of the most important advantages of this system is lower energy consumption compared to the other systems. For the easier irrigation scheduling

Bošnjak (1996) proposes preparation of the water balances which enable day-to-day planning of the water needs for the irrigation.

Based on the several years' investigation of the different irrigation systems and their application in the crop production, two main working parameters are defined (Miodragović et al 2012). First one is the compatibility of the technical and tecnological parameters. The other one is the compatibility of the technical parameters of the irrigation system itself. The first parameter refers to the compatibility of the achieved irrigation rate and the crop evapotranspiration. Mobile linear system, self-propelled rain gun and self-propelled rain wing are the systems that provide irrigation rate in the large span, having the possibility to choose from 4.5 mm to over 100 mm. Uniformity of water distribution for the self-propelled rain gun can be adjusted from 1 to 88%, having the average value of 62% (Wigginton and Raine 2001). Lack of uniformity is due to poorly managed irrigation process in the production conditions.

The plant needs for water, during the production cycle, determine the application rate and thus determine the irrigation surface in the “critical” period. Achieved productivity in conditions of maximal crop evapotranspiration defines the maximal irrigation area during the production cycle of the crops with the similar water demands thus careful calculation of the water losses in the pipeline must be carried (Tabesh et al 2009). Maize and vegetables, in the critical time of the year have a water demand of 6 - 7 mm which makes real productivity of the irrigation systems during the season lower than the calculated one. In the real production conditions actual productivity is calculated based on the technical characteristics of applied systems (Kresović 2002).

The compatibility of the technical parameters refers to the optimisation of the functional parameters of the pump and irrigation device itself (Kuol and Liu 2003, Lohani et al 2004, Sahoo et al 2006). Pump capacity should be adjusted to the irrigation system capacity and pressure. The pump capacity goes lower with the increased pressure. Depending on the nozzle diameter and pump pressure irrigation system has its working capacity and working width. Optimisation of this part of irrigation system is done within the case study of the complete irrigation system for one enterprise. It is used when there are more than one pump stations in the field and when there is a possibility for their connection and combination in order to have more energy efficient irrigation system. If the nozzle is selected properly then pressure – working width relation will be functional and rational having as an output better water distribution uniformity and working efficiency.

The aim of this paper was to define the energy and working parameters of the tree different irrigation systems in order to give to evaluate their influence on the efficiency of the each irrigation systems.

MATERIAL AND METHOD

Here presented testing included three types of mobile irrigation systems:

- Linear system that was used in the green beans, silage maize and maize production in conditions of Agricultural Corporation Belgrade. Dominant soil types for this region are chernozem soil and humoglay.
- Self-propelled rain wing that was used in green beans and peas production. Dominant soil type in this region was humoglay.
- Self-propelled rain gun that was used in potato, green beans and seed maize production. The dominant soil type in this region is humoglay.
- For the purpose of energy analysis energy output as well as energy input for soli tillage and irrigation, were determined (Ortiz–Cañavate and Hernanz, 1999).

RESULTS AND DISCUSSION

Results showed that with the lowering of system productivity energy consumption of the system was increasing. In the same time increasing of application rate for every 10 mm cause the rapid increasing of the energy consumption. From the application rate of 20 mm to 60 mm energy consumption was increased by 50, 100, 150 and 200% respectively. Table 1 shows the energy consumption thorough the irrigation system. In order to calculate the energy consumption energy equivalent of 3.597 MJ for 1 kWh was used (Ozkan et al, 2007).

Table 1 Exploitation parameters of the tested mobile irrigation systems

Irrigation system	Working width	Effective work	Productivity	Energy consumption		
	m	h	ha/h	kWh/ha	MJ/ha	MJ/yr
Linear system	1000	6.30	2.47	45.28	162.87	814.35
Self-propelled rain wing	400	5.85	0.55	62.02	223.09	1338.54
Self-propelled rain gun	80	6.65	0.12	131.50	473.01	8041.17

It can be seen that the highest productivity was obtained when using the linear system but this is due to its working width. At the same time this system had the lowest energy consumption per hectare. If compared to the linear system self-propelled rain gun had 190% higher energy consumption per hectare.

Further energy analysis is given in table 2 and it is based on average yield for three years and average energy input for this period. For calculating the energy output energy equivalents were used. For maize 16.02 MJ/kg, silage maize 5.2 MJ/kg, green beans 1.30 MJ/kg, peas 1.55 MJ/kg and potato 3.57 MJ/kg.

Table 2 Irrigation energy consumption and energy output

	Irrigation system		
	Linear	Self-propelled rain wing	Self-propelled rain gun
Yield - P (t/ha)			
Green beans	8.13	7.10	-
Silage maize	31.30	-	-
Maize	3.83	-	-
Seed maize	-	-	7.70
Peas	-	4.66	6.80
Potato	-	-	33.60
Energy analysis			
Energy output - Ep (MJ)	234685.60	16453.00	253846.00
Irrigation input - En (MJ)	814.35	1338.54	8041.17
Ep / En	288.19	12.29	31.56
En share in Ep (%)	0.35	8.13	3.16
En / P (MJ/t)	56.47	227.64	501.62

Concerning the obtained yields it can be said that the ratio of energy output and energy consumption thorough the irrigation is the lowest in case of self-propelled rain wing (12.29) and the highest is in the case of linear system (288.19). It can be concluded that the highest share of irrigation input energy in the output energy was 8.13% for the self-propelled rain wing and the lowest 0.35% for the linear system (Fig. 1).

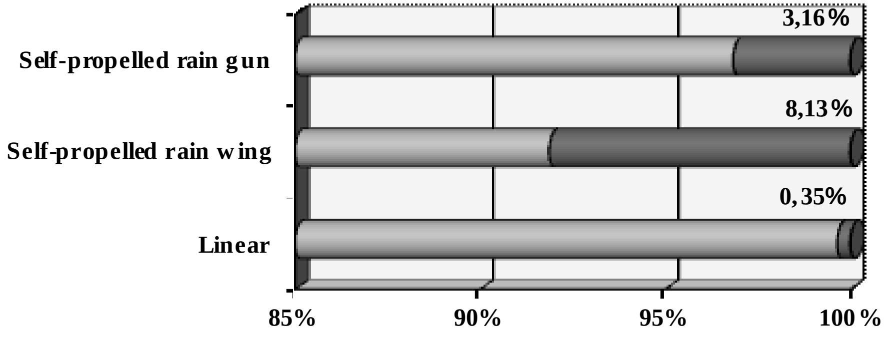

Figure 1 Irrigation energy consumption share in output energy

In the case of linear system average energy consumption per 1 t of the achieved yield was 56.47 MJ/t, for self-propelled rain wing energy consumption was 227.64 MJ/t. The highest energy consumption thorough the irrigation was obtained with the self-propelled rain gun (501.62 MJ/t). It can be concluded that, if compared to energy consumption of the self-propelled rain gun by using the self-propelled rain wing 83.35% of energy can be saved and with the using of linear system up to 89.97%.

Irrigation influencing the energy consumption in tillage

The irrigation influence on the plant production process was analysed using the average yield in the case of irrigated and non-irrigated conditions. Results showed increased yields in case of irrigated conditions, which contributes to the intensifying of agricultural production in sense of having the two harvests during the year. Smaller differences in yield were observed in the periods with higher participation, while this ratio is lower in the dry years.

Average energy consumption via tillage and sowing (Eo) in conventional tillage systems is 2519.31 MJ/ha. Energy input via irrigation varies depending on the irrigation system used (Tab. 2). Based on these results energy consumption through tillage and irrigation was calculated (Tab. 3).

Table 3 Tillage and irrigation energy consumption and energy output ratio

Energy parameter	Type of irrigation system		
	Linear	Self-propelled rain wing	Self-propelled rain gun
Yield difference - P (t/ha)	4.39	2.89	8.01
Energy output - Ep (MJ)	33217.67	4118.25	56470.50
Tillage and irrigation input - E (MJ)	3333.66	3857.85	10560.84
Ratio - Ep/E	9.96	1.07	5.35
E / Ep (%)	10.04	93.68	18.70
E / P (MJ/t)	759.38	1334.90	1318.46

Average share of input energy through irrigation and tillage (E) in the energy output, depending on the used system, varies from 1.42% in case of linear system, to 23.45% in case of self-propelled rain wing. High share of irrigation input energy for the self-propelled rain wing can be explained with the fact that this system was used vegetable production which energy output are very low concerning their energy equivalents.

As it can be seen in table 3, achieved yield difference varied from 2.89 t/ha in case of self-propelled rain wing to 8.01 t/ha in case of self-propelled rain gun. The reason for higher yield difference can be found in crop production that in conditions of irrigation can yield higher yields (Tab 3).

Ratio of energy output and energy input thorough the irrigation was lowest for the self-propelled rain wing (1.07) and highest in case of linear system (9.96). In this case the share of tillage and irrigation input (Fig. 2) in the obtained energy output difference was highest for the self-propelled rain wing (93.68 %) and the lowest was calculated for the linear system (10.04%).

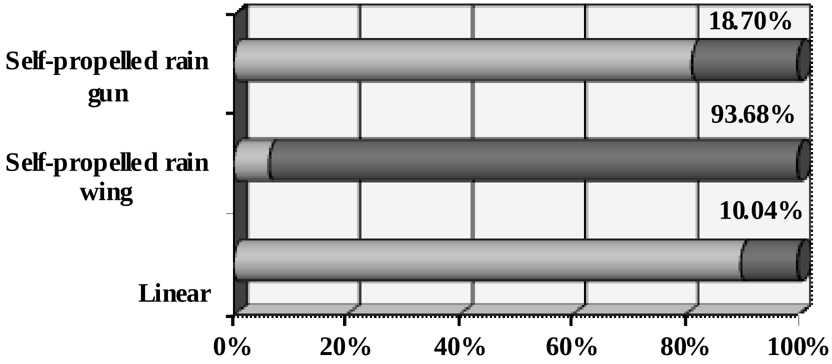

Figure 2 The share of energy input through the irrigation in the output energy of the achieved yield difference

It can be stated that during the testing of the irrigation systems, depending of the system, the energy input for 1 t of product, via tillage, sowing and irrigation varied from 759.38 MJ/t (linear system) to 1334.90 MJ/t (self-propelled rain wing).

Energy is always analysed in sense what can be done with it and how can it be reused again. The most important part of the energy analysis is energy input output ratio. As long as input energy source is higher than the energy consumed the earning power of the energy source will be higher. Using the crop energy output is suitable for the energy rationalization because the energy output that is not economical and financially in nature and thus it is not dependent on market oscillation, currency and inflation.

CONCLUSIONS

In the current global climatic situation irrigation must be a regular part of the agricultural crop production cycle. Regarding the higher summer temperatures and the lower intensity of precipitation the necessity for the well managed irrigation is of a great interest. Apart from the ecology concern there is a great interest in solving the energy issues of the irrigation process. Analysing the energy consumption of the different mobile irrigation systems following conclusions can be given:

- Energy input through the irrigation depends on the irrigation systems used and varies from 162.87 MJ/ha, for the linear system, to 473.01 MJ/ha for the self-propelled rain gun. On the yearly basis the overall energy consumption via irrigation system varied from 814.35 MJ/yr, for the linear, to 8041.17 MJ/yr for the self-propelled rain gun.

- Ration of the energy output and the energy input through the irrigation was lowest in case of self-propelled rain wing (1.07) and the highest was calculated for the linear system (9.96).
- The share of energy input thorough the irrigation, tillage and sowing in the energy output is highest in case of self-propelled rain wing (93.68) and the lowest was in case of linear system (10.34).

ACKNOWLEDGEMENTS

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41.
SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.353
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Expert paper

PROBABILISTIC APPROACH REGARDING THE CLEANING PROCESS EFFICIENCY FROM HARVESTING MACHINES

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SUMMARY

A correlation between the driving mechanism operational conditions and the distribution of the kernels sorted on the length of the sieve from the cleaning system of the harvesting combine were developed based on experimental tests carried out in laboratory conditions. A laboratory test stand was used and the kernels which cross the sieve were collected in a tray divided into 72 equal taps.

Using an electronic device design for this purpose, the driving system parameters were collected in real time (revolution per minute of the driving system, power consumption and the kernels flow in cubic meter per minute).

Regarding the average kernels quantity sorted on the length and the width of the sieve the quantities collected in each tap were measured. The evaluation results consist of statistic data processing and probabilistic approach of the kernels collected through distribution.

The final aim of this research was to identify a correlation between the mean kernels advance and the sorting process efficiency. In this respect a probabilistic approach was used and this offers a distribution law by Lorentz exponential depending on the sieve dimensions, revolution per minute of driving system and the kernels flow delivered from trashing system.

Key words*: sieve, kernels, statistic, Lorentz distribution*

INTRODUCTION

The mixture reaching the cleaning system depends on the grain content of the material introduced in threshing, its humidity, type and mode of operation of the threshing machine etc. Humidity material (straw, chaff, grain) varies between 5 and 44%, and the content of impurities straw between 5 and 40%, of which 8-32% are chaff. For cereals with humidity between 8 and 15%, grain is 60-75% of the total amount of material threshing, and for plants with more than 15% grain moisture is 75-85%, 8-20% is short straw, but the chaff 8-15% [2]. Kutzbach H.D., proposes a model for assessing the likelihood of sorting exponentially from experimental tests performed on the laboratory bench [3]. A further approach examines the cleaning process dependent on threshing in this case following the same method of probability based on experimental results obtained in the laboratory [4]. Other approach refers to evaluating the effectiveness of sorting and developing probabilistic distribution models sorted by length sieve fractions [6]. In this case it is considered that kinematic parameters of cleaning systems (sieve oscillation frequency and length) can be optimized with models developed. Simulation of grain movement on sieve sorting process is less represented in the literature. We considered a model developed on the basis of differential equations that describes the alternating movement of kernels on sieve using Autodesk Inventor 3D design Pro8 software and finally the shares were assembled using Working Model 4D software [1]. The purpose of the research conducted by the author is to identify the correlation between kinematic parameters of the mechanism of the filter type actuator beam and sorted grain distribution relative to the sieve length and breadth of culture.

MATERIALS AND METHODS

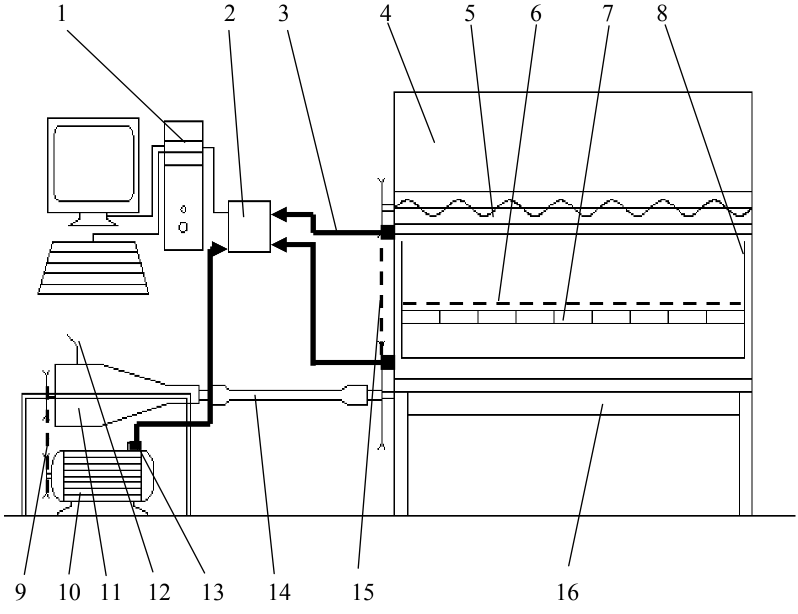

Figure 1 The experiment setup; 1-PC, 2-data acquisition system, 3-conectors, 4-grain tank, 5-rotative grain distributors, 6-cleaning sieve, 7-calibrate plate grain collect, 8-cleaning system, 9-wheels, 10-electric engine, 11-gear box, 12-gear box coupling, 13-Hall transducer, 14-crank shaft transmission, 15-drawing wheel, 16-MOG collect device

The way to assess the efficiency on sorting sieves from cereal combines was to conduct laboratory tests on a stand of its own building. For collect the measured parameters a novel data acquisition system, were used [5]. The measured parameters were: revolution speed of the sieve driving mechanism, power consumption to drive cleansing system, speed distribution mechanism of the material on the sieve.

The laboratory stand set up scheme is presented in figure 1.

In working conditions the seeds from the tank are spread by distributors in well defined quantities. The seeds that get to the sieve are sorted and fall into a collection box attached under the sieve. The collection box is partitioned into 72 equal components, inside which the grains will be taken by suction and weighed. The stand driving system includes a gearbox that allows the selection of two different speeds. The continuous measurement of kinematic parameters with a recording frequency of 4 Hz, ensures sufficient control of the development process of sorting. The experiments consisted of performing one of the 7 samples for two-speed drive cleaning system of 254 and 415 rpm.

EXPERIMENTAL RESULTS AND DISCUSSIONS

The evaluation of the efficiency of sorting was to measure the distribution amount of the material passing through the sieve openings analyzed against a reference system linked to the sieve. The grain distribution sorted by width and length of the sieve, it was identified by direct measurement resulting in tabular format data files and graphics distribution that could be analyzed by statistical criteria. It was considered that the purpose of the research conducted is useful to highlight the percentage distribution of material sorted by length and width sieves (Fig. 2).

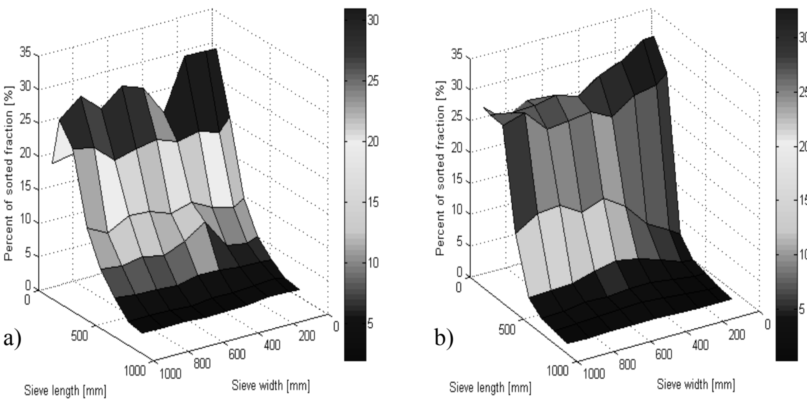

Figure 2 The distribution of sorted collected kernels (in percent) for two driving mechanism speed sets: a) 415 rpm; b) 254 rpm

In order to assure the optimum validation of the test, 7 replicates of measurements were done. As shown in figure 2, for low speed (close to the theoretical limit of the imposed oscillation frequency) in the first half of the sieve most of the seeds were sorted which indicates that at least one third of the final sieve is not used in the sorting process.

At the speed of 415 rpm, it is found that there is a sort more pronounced in the first half of the sieve and in the final part the percentage of sorted material decreases exponentially.

To identify the distribution law of the material sorted by length and width of the filter statistical averages corresponding to length and width of the sieve were calculated.

Based on the experimental results it was considered appropriate to identify the probabilistic law which estimates with high confidence the sorted material distribution on the sieve length, depending on driving speed.

Through probabilistic estimations the Lorentz function was found which approximates the effective distribution of material on the sieve as:

$$f(x) = y_0 + \frac{2 \cdot A}{\pi} \cdot \frac{w}{4(x - x_c)^2 + w^2} \tag{1}$$

where: y_0 is the free term of the Lorentz function (distribution positions in a coordinate system); A - total area under the curve; x_c - ratio of peak curve; x - independent variable of the function; w - width ratio of the peak curve.

Figures 3 and 4 show the length distribution of Lorentz sorting sieve for average values resulting from statistical processing of data.

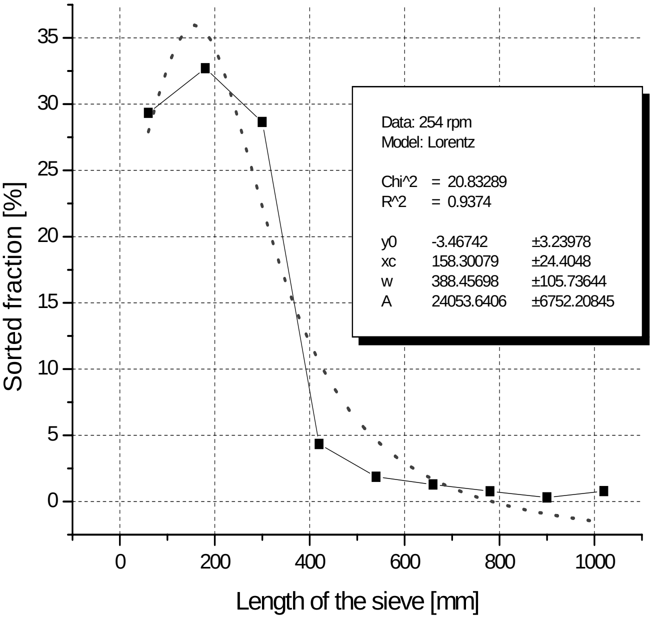

Figure 3 Lorentz distribution of the experimental results for 254 rpm

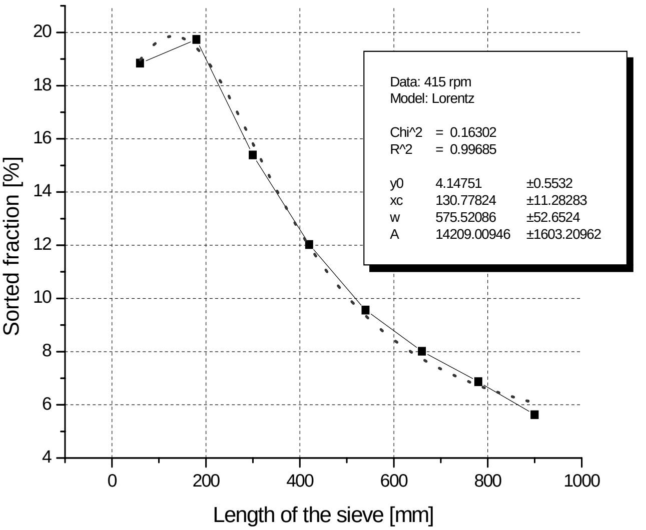

Figure 4 Lorentz distribution of the experimental results for 415 rpm

Table 1 Lorentz distribution coefficients obtained for 254 rpm

Column	Revolution speed [rpm]	Moisture input [kg/s]	Lorentz function coefficients				
			y_0	x_c	w	A	R^2
1	254	3,737	-0,03808	0,19593	0,35229	0,36728	0,99648
2			-0,04163	0,17875	0,38147	0,37284	0,99777
3			-0,042	0,19662	0,36316	0,43283	0,99945
4			-0,04191	0,17755	0,41706	0,61694	0,98653
5			-0,07289	0,19993	0,43873	0,71932	0,99847
6			-0,1026	0,19032	0,42864	0,79334	0,99793
7			-0,12109	0,16588	0,55468	0,813	0,99388
8			-0,07372	0,21023	0,3923	0,50942	0,98952
9			-0,07937	0,22007	0,45087	0,48735	0,97599

Thus, the coefficients value (mentioned in equation no.1) y_0, A, x_c and w,of the Lorentz function were calculated for each column sorting box. In order to describe how well a regression line fits a set of data, the R square coefficient (R ^ 2) were calculate resulting that all values are above 0.9, indicating a good agreement with the experimental results and theoretical law at both speeds (Table 1).

To identify correlations between Lorentz function coefficients and sorting parameters the following grounds were found:

Central value x_c depends on the speed of the driving mechanism by an exponential variation law of the form:

$$x_c = e^{\frac{2}{f}} \cdot 100 \quad (2)$$

where: f is the oscillation frequency of the sieve in s^{-1}.

The width coefficient of the peak of the Lorentz curve directly depends on the sieve length segment for which around 90% of the grain volume is sorted.

Thus, for the speed of 254 rpm the sorting takes place in the first half of the sieve (465 mm) and for the speed of 415 rpm results a specific length of 90% of material sort of 564 mm.

Of interest is the value of coefficient y_0, too. At low speeds it is negative and this indicated that the material gets crowded at the front of the sieve. At the speed of 415 rpm, the value is within acceptable limits of positioning the material falling from the oscillating platform.

CONCLUSIONS

Experimental results showed that the sorting process is modeled with better fidelity through Lorentz distribution. Distribution coefficients were identified depending on the sorting characteristics on the sieve. The result is that the two speed limits considered for experimental tests results are validated and can be taken into consideration in order to optimize the sorting parameters. The optimization of the sorting process is directly dependent on the oscillation frequency and the length of the sieve.

The equation found (eq. 2) explains the influence of sorting frequency which allows the development of algorithms useful for the design of sorting systems.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

MATHEMATICAL MODELS PROPOSED FOR KINEMATICS ANALYSES OF THE KERNELS TRAVEL ON THE SIEVES DURING THE SORTED PROCESS AT HARVESTING COMBINES

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SUMMARY

In the paper the work carried out by the authors is presented in order to develop a mathematical model for describing the kernels displacement on the sieve until its leases it.

In this respect transmission functions by order zero were used and the kernels displacement was detailed on two coordinate systems: one related to the driving mechanism and the second (a mobile one) related to the sieve.

The results of proposed of mathematical model consist of kinematic relations for describe the space, speed and acceleration of the kernels.

A numerical simulation of the mathematical model offers information regarding the characteristics of the kernel displacement, regarding the absolute advance, sorting duration and the number of the travel distance.

***Key word**: sorting system, mathematical model, kinematics parameters.*

INTRODUCTION

Improving grading for sorting systems with plane sieves is an important requirement to cereal harvest quality. In this respect, modeling of grain separation was investigated often resorting to the statistical criteria of probability based on experimental results obtained both in laboratory conditions but also by monitoring the harvest [4].

Craessaertsa proposed a nonlinear prediction model to identify the product fraction contained MOG resulting from threshing process, based on modeling technique [2].

A real-time evaluation of the quantity of sorted wheat is using the proposed control system based on control surfaces containing piezoelectric sensors, the signal recorded and is processed by a microcontroller, is Zao's case [9].

All references consulted consider that grain movement on this site is accompanied by random collisions, jumps and directional changes due to contact with the surface of the partition walls sort [1, 3]. Therefore Maertens proposes "An analytical grain flow model for a combine harvester" [6].

DEVELOPMENT OF MATHEMATICAL MODEL FOR THE STUDY OF THE SORTING OF THE KERNELS ON PLAN SIEVES

The proposed method to determinate the kinematics parameters of the beans moving on flat sieves is based on the study of relative motion of the material point of mass m. We are using vector equation of the relative motion described on the specialty literature [7]:

$$m \cdot \bar{a}_r = m \cdot \bar{a}_0 - m \cdot \bar{a}_t - m \cdot \bar{a}_c \,, \tag{1}$$

in which: $\bar{a}_r$ - the relative acceleration of the material point; $\bar{a}_0$ - the acceleration determinated by the forces acting on the material point independent of the movement of transport; $\bar{a}_t$ - transport acceleration; $\bar{a}_c$ - Coriolis acceleration.

To develop analytical equations is considered the mechanical system used in construction of grain harvesters, shown in figure 1. This one includes the drive mechanism O_0ABO, a crank-rocker type and the sorting system $OCDO_1$, a deformable parallelogram mechanism type. The CD sieve performs a pendulum motion; which is always parallel with the OO_1 direction, inclined with α angle to the horizontal plane.

In the mathematical model described in this paper, the next simplifying assumptions are required:

- Neglecting the interactions between kernels, it can be studied the individual motion of one single m mass kernel.
- It is considered that the kernel is performing a sliding motion on the plan sieves, without any jumping.
- The interaction forces between the kernels and the sieves are reduced to the force of gravity of the material point, the normal interaction forces and the friction forces.
- Being provided the previously condition imposed, the mechanical system can be reduced to a plan system xO_0y, all the components of the forces located on the normal direction being null.

To describe the components of the relative acceleration that appears in the vector equation (1) it will be defined two reference systems: the axes system xO_0y – fixed (inertial) and the mobile system tMn (non-inertial). The fixed system xO_0y is related to the fixed points O_0 – the center of rotation of the crank (O_0A) the training center of the mechanism, and O – the center of rotation of the rocker (OB). The Ox axis coincides with the OO_0 direction. The mobile system tMn is rigidly tied to the CD strainer. The Mt axis contained in the strainers plan it is parallel with the OO_1 direction, and the Mn axis is normal to the sieves plan. The tMn system effectuates an accelerated motion displacement on a circular trajectory, described by the transport acceleration $\bar{a}_t$ in relation to the fixed system xO_0y. Based on the above considerations may determine the components of the vector equation (1) as follows.

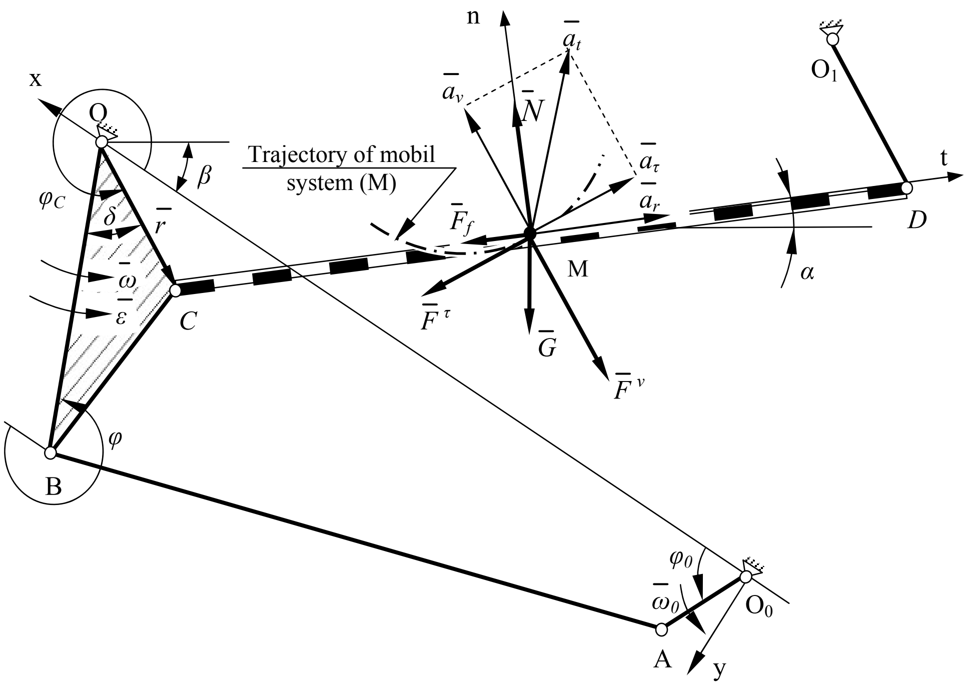

Figure1 The scheme of the sorting system with plan sieve

To calculate the term $m \cdot \bar{a}_0$, it is considered that above the material point acts the friction force $\bar{F}_f$,the normal interaction force $\bar{N}$ and the gravity force $\bar{G}$ as follows:

$$m \cdot \bar{a}_0 = \bar{G} + \bar{N} + \bar{F}_f \cdot \tag{2}$$

The transport acceleration in the case of a circular motion of the M point is described by the normal component $\bar{a}_v$ and the tangential component $\bar{a}_\tau$, which is expressed by the rotation speed $\bar{\omega}$, angular acceleration $\bar{\varepsilon}$ and the radius vector $\bar{r} = \bar{OC}$, using the expression:

$$\bar{a}_t = \bar{a}_v + \bar{a}_\tau = \bar{\omega} \times (\bar{\omega} \times \bar{r}) + \bar{\varepsilon} \times \bar{r} \tag{3}$$

Given that the mobile system tMn runs only a travel movement, without spinning, the Coriolis acceleration is zero. As follows:

$$m \cdot \bar{a}_c = 0\,. \tag{4}$$

Substituting the expressions (2), (3) and (4) in the equation (1) we will obtain the vectorial equation which characterize the kernel movement on the plan sieve like this:

$$m \cdot \bar{a}_r = \bar{G} + \bar{N} + \bar{F}_f - m \cdot \bar{\omega} \times (\bar{\omega} \times \bar{r}) - m \cdot \bar{\varepsilon} \times \bar{r} \tag{5}$$

To solve the 5th equation, you have to follow two distinct phases:

1. the determination of the laws of variation of speed of rotation $\bar{\omega}$, of the angular acceleration $\bar{\varepsilon}$ and of the angle of rotation of the vectorial radius $\bar{r}$, trough the kinematics analysis of the driving mechanism;
2. the determination of the parametric equations of the accelerations, speed and the relative positions of the kernel motion on the plan sieve.

The kinematic analysis of the driving mechanism

For the kinematic analysis of the driving mechanism O_0ABO (Figure 2), we will use the function method of transmission considerating the superior precision of the grafo-analytical methods and the possibility of using calculus techniques to solve the problem.

According to the research published in the specialty literature [5], the zero-order transmission will be:

$$R(\varphi_0, \varphi) = 0\,, \tag{6}$$

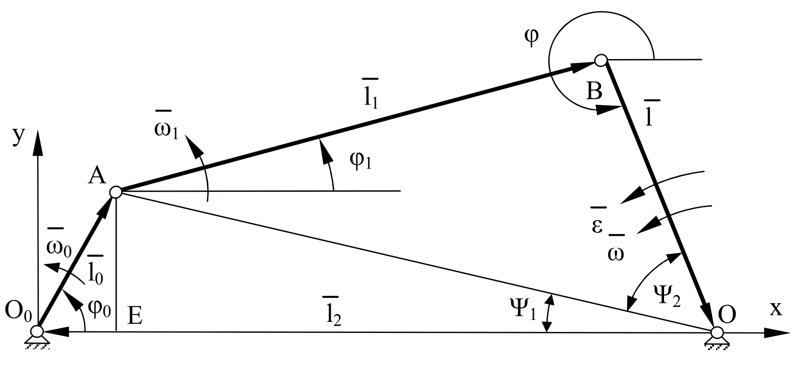

Figure 2 The kinemathic scheme of the driving mechanism O_0ABO

Determining the correlation between the rotation angle φ who characterizes the location of the OB rocker and the rotation angle of the O_0A crank (φ_0 –independent parameter), for the plane mechanism with one freedom degree, represented in the figure 2 in xO_0y coordinate system imposed in the previous chapter.

For more specifications of the transmission function we will use the vectorial relationship:

$$\bar{l}_0 + \bar{l}_1 + \bar{l} + \bar{l}_2 = 0\,, \tag{7}$$

we have: $\bar{l}_0 = \overline{O_0A}$, $\bar{l}_1 = \overline{AB}$, $\bar{l} = \overline{BO}$ si $\bar{l}_2 = \overline{OO_0}$.

Using the equations of the projections on the axes of the coordinate system xO_0y:

$$\begin{cases} l_0 \cdot \cos(\varphi_0) + l_1 \cdot \cos(\varphi_1) + l \cdot \cos(\varphi) - l_2 = 0 \\ l_0 \cdot \sin(\varphi_0) + l_1 \cdot \sin(\varphi_1) + l \cdot \sin(\varphi) = 0 \end{cases}, \tag{8}$$

by removing the parameter φ_1 the result is:

$$\begin{aligned} R(\varphi_0,\varphi) = {} & l_0^2 - l_1^2 + l^2 + l_2^2 + 2 \cdot l_0 \cdot l \cdot \cos(\varphi_0 - \varphi) - \\ & - 2 \cdot l_0 \cdot l_2 \cdot \cos(\varphi_0) - 2 \cdot l \cdot l_2 \cdot \cos(\varphi) = 0 \end{aligned}, \tag{9}$$

in which:

$$\varphi = 2 \cdot \pi - (\psi_1 + \psi_2)\,. \tag{10}$$

The ψ_1 and ψ_2 angles shall be determined by the trigonometric relations between the angles and the sides of a triangle applied in EOA and OAB triangles. So we get:

$$\varphi = 2 \cdot \pi - arctg\left(\frac{l_0 \cdot \sin(\varphi_0)}{l_2 - l_0 \cdot \cos(\varphi_0)}\right) - \arccos\left(\frac{l_0^2 - l_1^2 + l^2 + l_2^2 - 2 \cdot l_0 \cdot l_2 \cdot \cos(\varphi_0)}{2 \cdot l \cdot \sqrt{l_0^2 + l_2^2 - 2 \cdot l_0 \cdot l_2 \cdot \cos(\varphi_0)}}\right) \tag{11}$$

The (11th) expression permits us to determinate the angular position of the crank according to the independent angular parameter φ_0.

In order to establish the laws of variation of the rotation speed ω, and the angular acceleration ε, we will determine the transmission functions, first-order and second-order, through successive derivation of the zero-order transmission function, respectively:

$$R'(\varphi_0,\varphi) = -\frac{\dfrac{\partial R}{\partial \varphi_0}}{\dfrac{\partial R}{\partial \varphi}} \quad \text{and} \quad R''(\varphi_0,\varphi = -\frac{\dfrac{\partial^2 R}{\partial \varphi_0^2} + 2 \cdot R' \cdot \dfrac{\partial^2 R}{\partial \varphi_0 \cdot \partial \varphi} + (R')^2 \cdot \dfrac{\partial^2 R}{\partial \varphi^2}}{\dfrac{\partial R}{\partial \varphi}}, \tag{12}$$

where:

$$\frac{\partial R}{\partial \varphi_0} = -2 \cdot l_0 \cdot l \cdot \sin(\varphi_0 - \varphi) + 2 \cdot l_0 \cdot l_2 \cdot \sin(\varphi_0)\,, \tag{13}$$

$$\frac{\partial R}{\partial \varphi} = 2 \cdot l_0 \cdot l \cdot \sin(\varphi_0 - \varphi) + 2 \cdot l_0 \cdot l_2 \cdot \sin(\varphi)\,, \tag{14}$$

$$\frac{\partial^2 R}{\partial \varphi_0^2} = -2 \cdot l_0 \cdot l \cdot \cos(\varphi_0 - \varphi) + 2 \cdot l_0 \cdot l_2 \cdot \cos(\varphi_0)\,, \tag{15}$$

$$\frac{\partial^2 R}{\partial \varphi^2} = -2 \cdot l_0 \cdot l \cdot \cos(\varphi_0 - \varphi) + 2 \cdot l_0 \cdot l_2 \cdot \cos(\varphi)\,, \tag{16}$$

$$\frac{\partial^2 R}{\partial \varphi_0 \cdot \partial \varphi} = -2 \cdot l_0 \cdot l \cdot \cos(\varphi_0 - \varphi)\,. \tag{17}$$

Substituting the (13 – 17) expressions in (12) we will have:

$$R'(\varphi_0, \varphi) = \frac{l_0}{l} \cdot \frac{l \cdot \sin(\varphi_0 - \varphi) - l_2 \cdot \sin(\varphi_0)}{l_0 \cdot \sin(\varphi_0 - \varphi) + l_2 \cdot \sin(\varphi)}\,, \tag{18}$$

$$\begin{aligned} R'(\varphi_0, \varphi) = {} & \frac{l_0 \cdot [l \cdot \cos(\varphi_0 - \varphi) - l_2 \cdot \cos(\varphi_0)] + 2 \cdot R' \cdot l_0 \cdot l \cdot \cos(\varphi_0 - \varphi)}{l \cdot l_0 \cdot \sin((\varphi_0 - \varphi) + l_2 \cdot \sin(\varphi)} + \\ & + \frac{l \cdot (R')^2 \cdot l_0 \cdot \cos(\varphi_0 - \varphi) - l_2 \cdot \cos(\varphi)}{l \cdot l_0 \cdot \sin((\varphi_0 - \varphi) + l_2 \cdot \sin(\varphi)} \end{aligned}\,. \tag{19}$$

For the independent parameter $\varphi_0(\omega_{0,}t) = \omega_0{\cdot}t$ (ω_0 = constant and ε_0 = 0) and $\varphi = \varphi(\omega_{0,}t)$ in (18th) and (19th) equations, it will determine the laws of variation of the angular speed and of the angular acceleration what characterizes the movement of the led element(OB crank) with the help of relations:

$$\omega(\omega_0, t) = \omega_0 \cdot R'(\omega_0, t) \quad \text{and} \quad \varepsilon(t) = \omega_0^2 \cdot R''(t) \tag{20}$$

Knowing $\varphi = \varphi\ (\omega_{0,}t)$, $\omega = \omega(\omega_{0,}t)$, and $\varepsilon = \varepsilon\ (\omega_{0,}t)$,you can determine the laws of variation of the speed and acceleration of any point that belongs to the crank. So on to characterize the movement of the C point (the crank-strainer articulation) whose location is determined by the radius vector $\bar{r}$ (see figure 1), issues:

$$\varphi_C(\omega_0, t) = \varphi(\omega_0, t) + \delta\,, \tag{21}$$

$$v_C(\omega_0,t)=\omega\cdot r\ , \tag{22}$$

$$a_C^{\nu}(\omega_0,t)=\omega^2\cdot r \quad \text{and} \quad a_C^{\tau}(\omega_0,t)=\varepsilon\cdot r \tag{23}$$

The (20th), (21th), (22th) and (23th) equations define the variation laws of the parameters that characterize the movement of transport of the flat sieve.

Modeling the relative movement of kernel on plan sieves.

For the study of the relative movement we will write the equations of equilibrium of forces projection system acting on the kernel in tMn axis system (Figure 3), like this:

$$-m\cdot g\cdot con(\alpha)+N+m\cdot\omega^2\cdot r\cdot\cos(\theta)+m\cdot\varepsilon\cdot r\cdot\cos\left(\theta-\frac{\pi}{2}\right)=0\ , \tag{24}$$

$$m\cdot a_r-m\cdot g\cdot\sin(\alpha)\pm F_f+m\cdot\omega^2\cdot r\cdot\sin(\theta)+m\cdot\varepsilon\cdot r\cdot\sin\left(\theta-\frac{\pi}{2}\right)=0\ , \tag{25}$$

where: $\theta = \varphi_C - \alpha - \beta$; $\pm F_f = \pm\ \mu\cdot N$ – changes his sign by the kernel movement on the sieve.

Based on the relationship between (24th) and (25th) equation, we will have:

$$N=m\cdot[g\cdot\cos(\alpha)-\omega^2\cdot r\cdot\cos(\theta)-\varepsilon\cdot r\cdot\sin(\theta)]\ , \tag{26}$$

$$\begin{gathered}a_r=g\cdot\sin(\alpha)\pm\mu\cdot[g\cdot\cos(\alpha)-\omega^2\cdot r\cdot\cos(\theta)-\varepsilon\cdot r\cdot\sin(\theta)]-\\ -\omega^2\cdot r\cdot\sin(\theta)+\varepsilon\cdot r\cdot\cos(\theta)\end{gathered}\ , \tag{27}$$

where: $\mu = tg(\psi)$, where ψ is the friction angle, we will have:

$$a_r=\frac{1}{\cos(\psi)}\left[g\cdot\sin(\alpha\pm\psi)-\omega^2\cdot r\cdot\sin(\theta\mp\psi)+\varepsilon\cdot r\cdot\cos(\theta\pm\psi)\right], \tag{28}$$

The variation laws of the speed and the relative position on the flat sieve is determined by successive integration of the (28th) expression:

$$v_r=\int a_r dt+C_1 \quad \text{and} \quad s_r=\int v_r dt+C_2\ , \tag{29}$$

in which C_1 and C_2 are constants of integration.

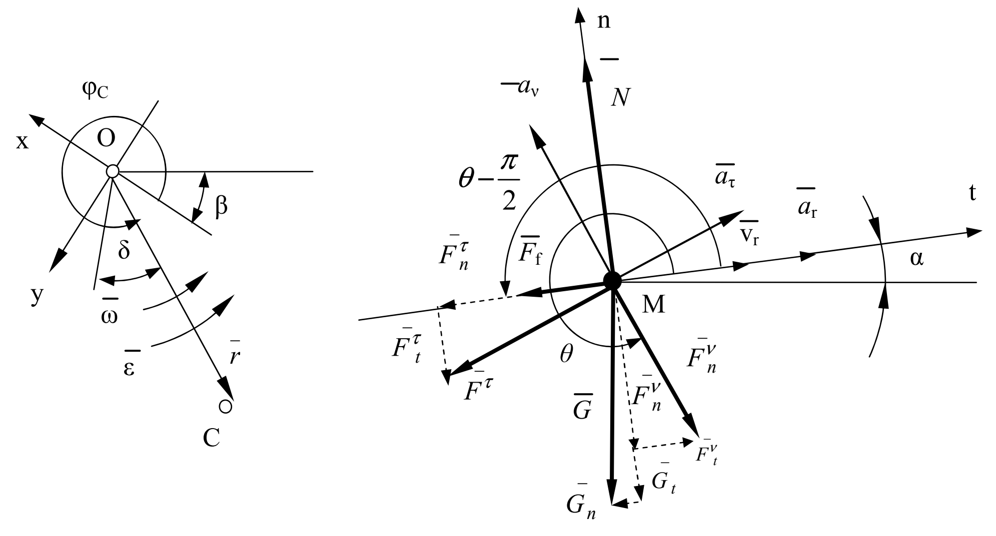

Figure 3 The kinematics parameters of the relative movement

DESCRIPTION OF THE <*SSKS*> PROGRAM USED FOR THE FLAT SIEVES SORTING STUDY

To solve the proposed problem it was elaborated the <*SSKS*> program, using the MathCAD soft, 14x version, considerating the facilities offered for the vectorial calculus, graphic representation of the vectorial functions and to solve the optimization problems.

The program is structured in 8 steps: initialization data, the calculus of kinematic parameters of the driving mechanism, the analysis of the relative movement of the kernels on the flat sieves and the displaying of the results in graphical and numerical form (Figure 4).

The data initialization. To use the program the initial data entry are required: the constructive parameters of the driving mechanism, the functional parameters of the assorting system and the physical characteristics of the seeds (Figure 5).

The calculus block. In <*SSKS*> program, we use the (6 – 23) equations for the calculus of the kinematics parameters of the driving mechanism, that characterizes the transport motion of the sieve and the (24 – 29) equations to describe the relative motion of the grains on the flat sieves.

Displaying the results. The graphic representation of the variation laws of the kinematics parameters characterizing the transport motion of the sieves and the relative movement of the grains on the flat sieves according to the independent parameter *t* (time), ensures their easy interpretation.

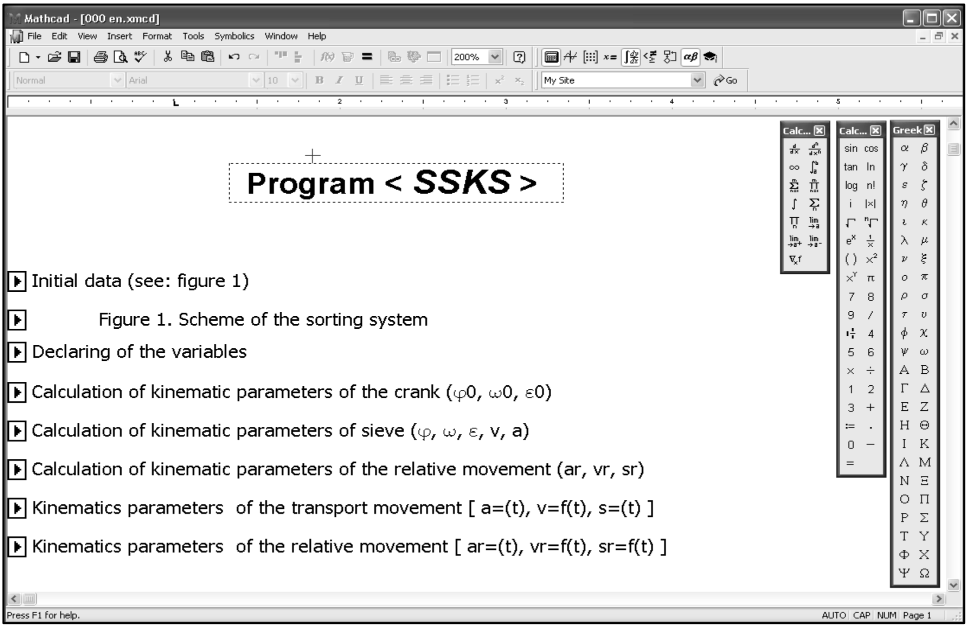

Figure 4 The structure of the SSKS program

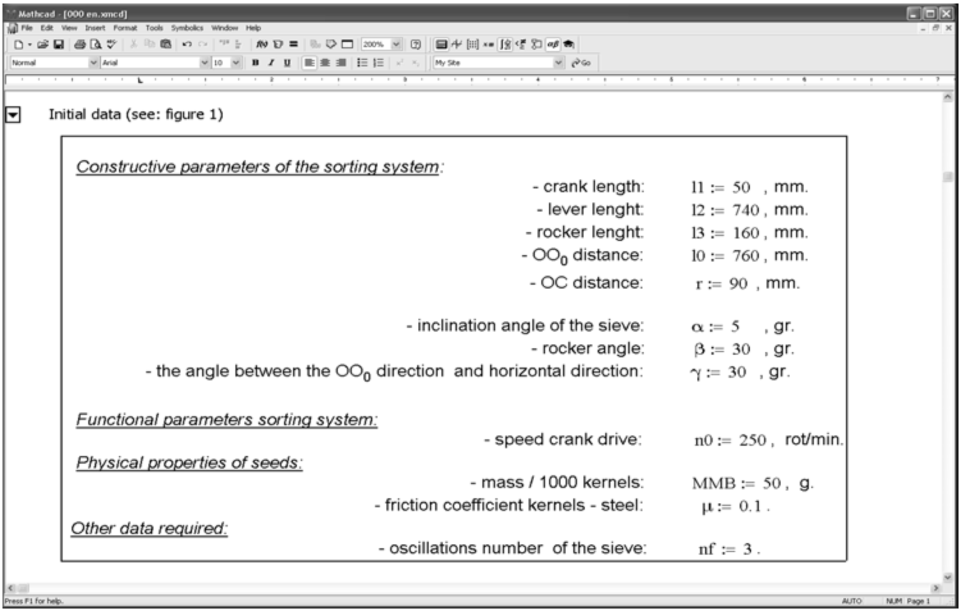

Figure 5 The interface for the data initialization

RESULTS AND DISCUSSIONS

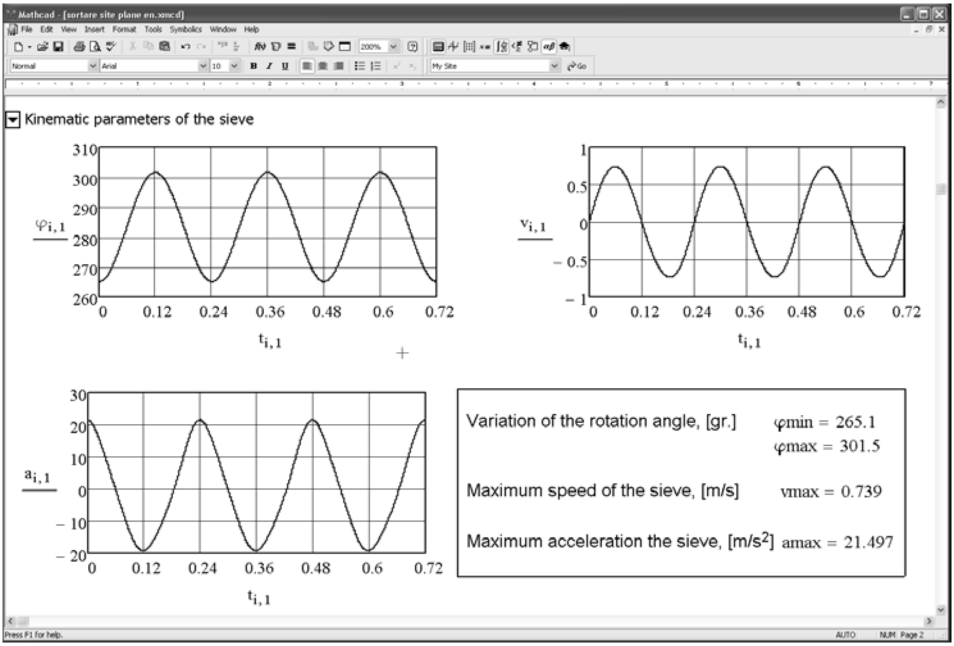

Figure 6 The kinematics parameters of the transport movement

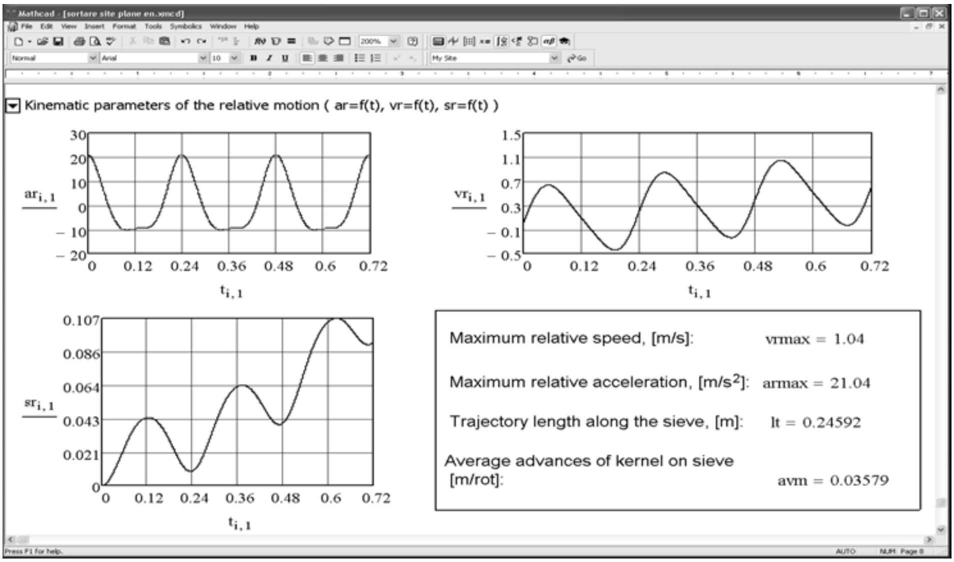

Figure 7 The kinematics parameters of the relative movement

The 6th figure plots the laws of variation of the rotation angle $\varphi_c = f(t)$, of the speed $v_c = f(t)$ and the acceleration $a_c = f(t)$, which characterizes the motion of every point placed on the strainers surface.

The results prove that the sieve executes a pendulum motion in vertical plane. The speed of each point positioned in the sieve's plan are maximal for the rotation angles of the crank $\varphi_0 = k \cdot \pi + \pi/2$ and the acceleration has extreme values for $\varphi_0 = k \cdot \pi$.

In figure number 7 are the laws of variation that characterizes the relative movement of the grains on flat sieves, for a rotation angle of the crank drive $\varphi_0 = 6 \cdot \pi$ (three complete rotations).

The obtained theoretical results do confirm that the sorted material executes oscillatory movement on the surface of the sieves, which assures fulfillment of necessary condition for sorting.

Comparing the results with some experimental research results published in the specialty literature [8], proves that the described method, approximates with sufficient precision the assorting process.

CONCLUSIONS

The developed mathematical way and the PC program are designed so that will allow generalization of the proposed methods to study the influence of constructive parameters of the sorting system on effectiveness of the sorting.

Also, knowledge of the laws of variation of the kinematics parameters of the sieves allows the possibility of optimization of the sorting systems with flat sieves to increase their reliability.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Preliminary communication

THE OPTIMIZATION OF THE TECHNOLOGICAL PROCESS OF THE BULBS OR TUBERCLES HARVESTERS

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SUMMARY

An optimizing analysis of the bulb or tubercles harvesters technological process is presented in this paper, which is based on the explicit expressions of the technological process output flows, obtained by mathematical modeling. The output flows are the useful products flow and of the total separated impurities flow. The explicit forms of the expressions of these flows are found by introducing the specific relations of the technological process input flows in the initial general expressions of the output flows.

The optimizing analysis is especially applied to the explicit expressions of the useful products output flows, which are the flows that mainly present interest. This optimization refers to the consequences suffered by the useful products output flows to the variation of their determinant factors, by means of recommending the factors variation tendencies in order to achieve the optimal technological process of the bulb or tubercles harvesters.

Key words: *bulb or tubercles harvesters, mathematical modeling, technological flows optimization*

INTRODUCTION

In a previous paper [1] of the first author (included in the proceedings of the 40-th International Symposium on Agricultural Engineering "*Actual Tasks on Agricultural Engineering*", Opatija, Croatia, February 2012) it was presented a mathematical modeling of the variation of the materials flows during the technological process of the bulb or tubercles harvesters. These technological flows are: *the useful products flow*, which contains the cleaned harvested products with corresponsive quality, and which, in certain cases, is evacuated behind the harvesting aggregate, like windrows formed directly on bands of soil, especially prepared for this purpose, or mostly, is directed towards different storage means (hoppers, boxes, storage platforms) wherewith the harvesters are fitted, and *the impurities flows*, which are specific mainly to the different kinds of impurities separators from the harvesters structure and which are regularly evacuated on the ground, beneath or in the lateral sides of the harvesting aggregate.

According to the demands of the bulbs or tubercles harvesting technologies and to the complexity of the harvesting machines, there was developed two great categories of harvesting machines, namely: *bulbs or tubercles diggers* and *bulbs or tubercles harvesting combines*. *The bulbs or tubercles diggers* are harvesting machines with low or medium complexity, which in the great majority of the cases, work in aggregate with tractors, but rarely can be self-propelled.

The bulbs or tubercles harvesting combines are high capacity harvesting machines with great or very great complexity, which process many rows of the culture at one passage. Generally, the bulbs or tubercles harvesting combines are self-propelled, but in practice, variants of combines with lower capacity (which process one or maximum two rows of the culture at one passage) which work in aggregate with tractors are met too. Also, it can be mentioned that the tubercles harvesting combines are much prevalent to the bulb harvesting combines.

In the great majority of the cases, the working process of the bulbs or tubercle harvesting machines presumes the several main phases, indifferently of the complexity of the harvesting machines:

- the cutting and the taking up of the portions of soil wherein they are developed the useful products of the bulb or tubercle cultures;
- the mobilization of the useful products from the taken up soil and the crumbling the most intensely possible of the remaining soil;
- the separation of the impurities from the useful products and the elimination of the extracted impurities;
- the evacuation of the cleaned useful products by discharge them to storage or transportation means or on the soil like windrows.

For the purpose of achieving the phases of the working process of the harvesting machines, the material taken up by the machines from the cultures, is transmitted *successively* to assemblies of specialized organs. It can be mentioned that the transmission of the taken up material between successive specialized organs is done directly or by the medium of some conveyors which do not change from point of view quantitative or qualitative the carried material.

So, the working process of the harvesting machines may be represented in systemic mode like the structural schema from figure 1 [1].

As it can be observed from the schema from figure 1, the structural blocs of a bulbs or tubercle harvesting machine, significant from point of view of the quantitative and/or qualitative modifications of the technological flows, are placed in a *serial* type structure. So, to an analyzed harvesting machine to each bloc of systemic structure complies with a real ensemble which achieves a precise function.

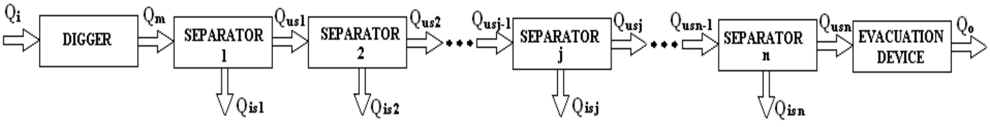

Fig. 1 The structural schema of the working process of the harvesting machines [1]

From this point of view the significant blocs from the bulbs or tubercle harvesting machines can be classified in three categories, namely: *digger*, *separator* and *evacuation device* (of the useful products cleaned of impurities).

For a general structure of the bulbs or tubercles harvesting machines (see the schema from figure 1), where it is considered that the impurities cleaning system is composed of k screen separators and l extractor separators (k + l = n), successively disposed, they were established [1], by the aggregation of the individual mathematical model of the significant structural blocs, the expressions for the exit flows, namely the *cleaned useful products evacuation flow Q_o [kg/s]* and the *separated and eliminated impurities total flow $Q_{is\ tot}$ [kg/s]*, in relation with *the flow input Q_i [kg/s]*, composed of the portions of soil wherein they are developed the useful products of bulb or tubercle cultures, separated and taken up by the harvester, are the followings:

$$Q_o = Q_i \cdot \left((1-\lambda) + \lambda \cdot \prod_{k=1}^{k} \xi_k \right) \cdot \prod_{l=1}^{l} (1-\zeta_l) \tag{1}$$

$$Q_{is\,tot} = Q_i \cdot \left((1-\lambda) \cdot \prod_{l=1}^{l} \zeta_l + \lambda \cdot \left(\prod_{k=1}^{k} \xi_k \cdot \prod_{l=1}^{l} \zeta_l + \prod_{k=1}^{k} (1-\xi_k) \right) \right) \tag{2}$$

where:

λ – the index of crumbling of the material taken on the working process of the digging device, which indicates the ponderosas of the corresponsive crumbled material mass (which can be separated by screening on separators of *screen* type) from the total mass of the material taken on the digger;

ξ_k – the precision of separation of the current separator of *screen* type (k=1…k) which indicates the rate of the specific flow of material which must be separated along the active surface of the current screen, but is not separated;

ζ_l – the coefficient of extraction of the current separator of *extractor* type (l=1…l), which represents the ratio between the extracted impurities mass and the mass of the mixture of material submitted to the separation process on the current extractor.

Analyzing the expressions 1 and 2 it results that both the flow Q_o of evacuation of the cleaned useful products and the total flow $Q_{is\ tot}$ of separated impurities on the impurities cleaning system, depend on the input flow Q_i, on the value of the the index λ of crumbling of the material taken on the digging device, on the values of the precision of separation ξ_k of all the separators of screen type and on the values of the coefficient of extraction ζ_l of all the separators of extractor type.

MATHEMATICAL MODELING

The input flow in the technological process of the bulb or tubercle harvesting machines is the flow Q_i of material taken on by the bulb or tubercle harvesting aggregate from the harvested culture during the working process (namely when the harvesting aggregate is moving along the culture rows at one passage). The mathematical expression of the input flow Q_i is done with the following relation [2]:

$$Q_i = m_{hz} \cdot v_h \tag{3}$$

where:

m_{hz} [kg/m] – the specific mass of the harvested culture zone taken on by the bulb or tubercle harvesting aggregate at one passage, (considered per meter along the rows);

v_h [m/s] – the working velocity of the bulb or tubercle harvesting aggregate.

The specific mass m_{hr} of the harvested culture zone processed at each passage by the harvesting aggregate depends of the initial profile (shape) of the terrain whereon were established the harvested cultures of bulbs or tubercles, of the number of rows of plants disposed on every profile element and of the number of profile elements concomitantly processed at one passage of the harvesting aggregate. Generally, both the bulb culture and tubercle culture are set up on profiled terrains, but the culture schemas are different for the two kinds of cultures and even for each kind of culture, depending of the characteristics of the used species and varieties, of the culture technology and of the culture conditions.

The cultures of bulbous plants are regularly established on layer shape profiled terrains [3], on each layer being planted 3 - 4 rows of plants. In the great majority of the cases, a bulb harvester processes at one passage a single layer of the culture (see figure 2). In this case it can be defined *the effective working width* of the harvesting aggregate, noted as b_p, being the distance between the centers of the processed layer side drains. Moreover, in the moment of the bulbous culture harvesting, it can be easily determined by measuring the *average height of the layers* towards the bottom of the drains, noted as h_{hl}.

Knowing the characteristics of the bulbous culture which is harvested, namely: *the density of plants per hectare*, noted as D [plants/ha], *the average volume of the bulbs*, noted as V_{ba} [m^3], *the average density of the bulbs*, noted as ρ_{ba} [kg/m^3] and the *apparent density of the soil* wherein the bulbs are developed, noted as ρ_s [kg/m^3], and considering (see figure 2) *the digger working width*, noted as b_h [m] (which in most of the cases is near or coincides with the effective working width b_p of the harvesting aggregate) and *the working depth* of the digging device, noted with a [m], it can be estimated *the specific mass, per* *linear meter along the layer (rows)* of the bulbous culture zone processed at one passage, noted as m_{bhz} [kg/m], with the following relation [3]:

$$m_{bhz} = b_h \cdot (a + h_{hl}) \cdot \rho_s + 10^{-4} \cdot D \cdot V_{ba} \cdot (\rho_{ba} - \rho_s) \cdot b_p \quad (4)$$

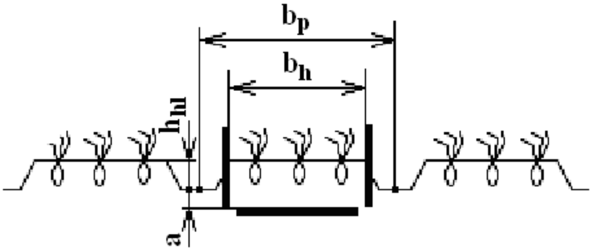

Fig. 2 The scheme of the mechanical harvesting of a layer from a bulbous culture

The cultures of tubercles plants (potatoes especially) are established on ridge (billow) shape profiled terrains [3], each ridge corresponding to a row of plants. The tubercle harvesters process regularly 1 - 4 rows of plants (ridges) at one passage (see figure 3). In this case *the effective working width* of the harvesting aggregate, noted as b_p, is defined that being the distance between the centers of the processed to one passage extremes ridges side drains (it is mentioned that the value of the effective working width of a tubercle harvester is determined by multiplying *the number of rows concomitantly processed at one passage*, noted as n_r, with the *distance between the rows of the tubercle culture*). In this case too, it can be easily determined by measuring in the moment of the tubercle culture harvesting, the *average height of the ridges* towards the bottom of the drains, noted as h_{hb}.

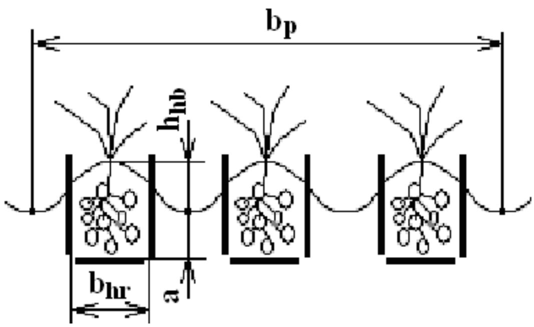

Fig. 3 The scheme of the simultanously mechanical harvesting of many rows from a tubercle culture

Knowing the characteristics of the tubercle culture which is be harvested, namely: *the density of plants per hectare*, noted as D [plants/ha], *the average number of tubercles from* *one nest*, noted as n_{atn}, *the average volume of the tubercles*, noted as V_{ta} [m^3], *the average density of the tubercles*, noted as ρ_{ta} [kg/m^3] and the *apparent density of the soil* wherein the tubercles are developed, noted as ρ_s [kg/m^3], and considering (see figure 3) *the working width of one section of the digging device* (which process a single row of the culture), noted as b_{hr} [m] and *the working depth* of the digging devices, noted with a [m], it can be estimated *the specific mass, per linear meter along the rows* of the tubercle culture zone processed at one passage by the harvesting aggregate, noted as m_{thz} [kg/m], with the following relation [3]:

$$m_{thz} = n_r \cdot b_{hr} \cdot (a + h_{hb}) \cdot \rho_s + 10^{-4} \cdot D \cdot n_{atn} \cdot V_{ta} \cdot (\rho_{ta} - \rho_s) \cdot b_p \qquad (5)$$

Taking into account the relations 1, 2 and 3 and the relation 4 for the bulbous cultures harvesting, respectively relation 5 for tubercle cultures harvesting, they can be written the explicit relations for the output flows, represented by *the cleaned useful products evacuation flow Q_o* and *the separated and eliminated impurities total flow $Q_{is\ tot}$* from the impurities cleaning system of the harvester, namely:

- for bulbous cultures harvesting:

$$Q_o = \left(b_h \cdot (a + h_{hl}) \cdot \rho_s + 10^{-4} \cdot D \cdot V_{ba} \cdot (\rho_{ba} - \rho_s) \cdot b_p\right) \cdot v_h \cdot \left((1-\lambda) + \lambda \cdot \prod_{k=1}^{k} \xi_k\right) \cdot \prod_{l=1}^{l} (1-\zeta_l) \qquad (6)$$

$$Q_{istot} = \left(b_h \cdot (a + h_{hl}) \cdot \rho_s + 10^{-4} \cdot D \cdot V_{ba} \cdot (\rho_{ba} - \rho_s) \cdot b_p\right) \cdot v_h \cdot \left((1-\lambda) \cdot \prod_{l=1}^{l} \zeta_l + \lambda \cdot \left(\prod_{k=1}^{k} \xi_k \cdot \prod_{l=1}^{l} \zeta_l + \prod_{k=1}^{k} (1-\xi_k)\right)\right) \qquad (7)$$

- for tubercle cultures harvesting:

$$Q_o = \left(n_r \cdot b_{hr} \cdot (a + h_{hb}) \cdot \rho_s + 10^{-4} \cdot D \cdot n_{atn} \cdot V_{ta} \cdot (\rho_{ta} - \rho_s) \cdot b_p\right) \cdot v_h \cdot \left((1-\lambda) + \lambda \cdot \prod_{k=1}^{k} \xi_k\right) \cdot \prod_{l=1}^{l} (1-\zeta_l) \qquad (8)$$

$$Q_{istot} = \left(n_r \cdot b_{hr} \cdot (a + h_{hb}) \cdot \rho_s + 10^{-4} \cdot D \cdot n_{atn} \cdot V_{ta} \cdot (\rho_{ta} - \rho_s) \cdot b_p\right) \cdot v_h \cdot \left((1-\lambda) \cdot \prod_{l=1}^{l} \zeta_l + \lambda \cdot \left(\prod_{k=1}^{k} \xi_k \cdot \prod_{l=1}^{l} \zeta_l + \prod_{k=1}^{k} (1-\xi_k)\right)\right) \qquad (9)$$

TECHNOLOGICAL PROCESS OPTIMIZATION WAYS

The optimization of the technological process of the bulbs or tubercles harvesters refers to the determination of the working regime parameters such as to obtain an greater output flow of as clean as possible useful products (without impurities) and with good quality (with no damages). For the establishment of the ways of the bulbs or tubercles harvesting machines technological process optimization it will be effectuated an analysis of the relations resulted from the mathematical modeling of the output flows, which present interest, more precisely of the relations of *the cleaned useful products evacuation flow* Q_o (namely the relation 6 for the bulbous cultures harvesting, respectively the relation 8 for tubercle cultures harvesting).

By analyzing relations 6, respectively 8, it can be observed that the cleaned useful products evacuation flow Q_o depends on the following factors: *the characteristics of the bulbous or tubercle culture which is harvested*, *the velocity* v_h *of the bulb or tubercle harvesting aggregate*, the value *of the index* λ *of crumbling of the material taken on digging device*, the values of *the precisions of separation* ξ_k *of the separators of screen type* and the values of *the coefficients of extraction* ζ_l *of the separators of extractor type*. For the optimization purpose it is recommended to:

- *the characteristics of the bulbous or tubercle culture* which are mechanically harvested must be as uniform as possible in order to effectuate precise adjustments and settings of the harvesting aggregate for obtaining optimal working regimes:
- the working velocity v_h of the harvesting aggregates must be situated in optimal values ranges, specific to each harvesting aggregate; it is mentioned that if *the values of the working velocity are lower then the optimal values ranges*, the cleaned useful products evacuation flow Q_o decreases and in this situation, albeit sometimes may occur improvements of the values of the index λ of crumbling of the material taken on the digging device, of the values of the precisions of separation ξ_k of the separators of screen type and of the values of the coefficients of extraction ζ_l of the separators of extractor type, *increases very much the probability of damaging the processed useful products* at the interaction with the digging or impurities cleaning organs because of the reduced quantity of material submitted to the working process of the harvesters; in the cases when *the values of the working velocity are greater then the optimal values ranges*, the cleaned useful products evacuation flow Q_o will increase (which is a positive tendency), but it will significantly decrease the quality of the cleaning of the processed useful products, because of the decreasing of the values of the index λ, of the values of the precisions of separation ξ_k and of the values of the coefficients of extraction ζ_l, as results of the abnormal increasing of the quantity of material which penetrates in the working process of the harvesters;
- *the index* λ *of crumbling of the material taken on the digging device*, which in fact constitutes a quality indicator of the digging device working process, must take values that tend to the values λ_{ib}, for bulbous cultures harvesting and λ_{it}, for tubercle cultures harvesting, which correspond to the ideal situations when all the quantity of material, taken on the digging devices organs, other then the useful products (namely: fragments of soil, vegetal remains, or boulders, practically all kinds of impurities) is crumbled inside of the digging device to particles with dimensions

lower than the reference dimensions of the separators of screen type; the ideal values λ_{ib} and λ_{it} of the index of crumbling depends only of the characteristics of the bulbous or tubercle culture which is mechanically harvested, and can be estimated in certain concrete cases with the following relations:

$$\lambda_{ib} = \frac{1}{1 + \frac{1}{\frac{\rho_s}{\rho_{ba}} \cdot \left(\frac{(a + h_{hl}) \cdot b_h}{10^{-4} \cdot D \cdot V_{ba} \cdot b_p} - 1 \right)}} \tag{10}$$

$$\lambda_{it} = \frac{1}{1 + \frac{1}{\frac{\rho_s}{\rho_{ta}} \cdot \left(\frac{(a + h_{hb}) \cdot n_r \cdot b_h}{10^{-4} \cdot D \cdot n_{atn} \cdot V_{ta} \cdot b_p} - 1 \right)}} \tag{11}$$

- it is mentioned that a very accentuated crumbling of the fragments of soil and impurities on the digging device involves a very aggressive working process of the digging device, utilizing active (mobile) digging organs or passive (fix) digging organs with special shapes, which may very probably cause damages to the useful products and therefore the optimal value of index λ of crumbling on digging must be such considered that the digging device performs *the most accentuated crumbling* of the processed material (namely the values of λ must tend to the ideal values λ_{ib}, respectively λ_{it}) *but without causing damages to the useful products* (it can be mentioned that the damaging sensibility of the useful products depends very much both of the their mechanical characteristics and of the characteristics of the soils wherein there are established the bulbous or tubercle cultures);

- *the precisions of separation ξ_k of the separators of screen type* depend on definition [1] of *the coefficients (rates) of separation* and of *the lengths of the active surfaces of the screens*; so, the *greater* the values of the coefficients (rates) of separation and of the lengths of the active surfaces of the screens, the *lower* the values of the precisions of separation ξ_k (it is mentioned that the *ideal value of the precision of separation is 0*, which is obtained for *infinite values of the coefficients (rates) of separation and of the lengths of the active surfaces of the screens*); anyway, in practice, both the values of the coefficients (rates) of separation and of the lengths of the active surfaces of the screens are *finites and limited*, because high values of the coefficients (rates) of separation means *very intense screening processes which surely produce damages to the useful products*, and high of the lengths of the active surfaces of the screens lead *to big overall dimensions and low maneuverability of the harvesting aggregates*; taking account of these considerations it can be affirmed that the *optimal values* of the precisions of separation ξ_k of the separators of screen type are the *lowest possible values* which can be obtained by respecting the conditions that both the *overall dimensions and the maneuverability of the harvesting aggregates have appropriate values* (condition that is provided by a judicious configuration of the impurities cleaning system, such conceived to offer maximized lengths to the separation active surfaces) and *to not produce damages of the useful products on the separators of screen type*;

- *the coefficients of extraction ζ_l of the separators of extractor type*, must have values which tend towards the values ζ_{il} correspondent to ideal working processes of the separators of extractor type; the ideal working processes of the separators of extractor type suppose that *each separator of extractor type must extract the entire quantity of a kind of impurities for which it was conceived*, from the material submitted to the impurities cleaning system process, *but without loses or damages of useful products*; in real conditions, the optimization of impurities extraction on extractor separators means to attain values of the coefficients of extraction of impurities ζ_l as near as possible to the homologous ideal values ζ_{il}, without loses or damages of useful products; in practice these desideratum are difficult to achieve mostly because the irregularity of the characteristics of the cultures and terrains, but optimized values of the coefficients of extraction of impurities ζ_l can be obtained in the conditions of achieving *bulb or tubercle cultures with uniform characteristics* and of making precise settings and adjustments of the extractor separators, permanently adapted to the harvested cultures conditions.

CONCLUSIONS

The optimizing analysis of the bulb or tubercles harvesters technological process, with active structures of serial type, starts from the general expressions obtained by means of mathematical modeling of the technological process output flows, namely the cleaned useful products evacuation flow and the separated and eliminated impurities total flow, in relation with the technological process input flow. By introducing the expressions of the input flow (separately for bulbous cultures, respectively for tubercle cultures) there are obtained *the explicit expressions of the cleaned useful products evacuation flow and the separated and eliminated impurities total flow*.

Looking thoroughly on the explicit expressions of the cleaned useful products evacuation flow and on the separated and eliminated impurities total flow it can be observed that those flows depend on the following factors: *the characteristics of the bulbous or tubercle culture which is harvested*, *the velocity v_h of the bulb or tubercle harvesting aggregate*, the value *of the index λ of crumbling of the material taken on the digging device*, the values of *the precisions of separation ξ_k of the separators of screen type* and the values of *the coefficients of extraction ζ_l of the separators of extractor type*.

The optimizing analysis is especially applied to the expressions of the cleaned useful products evacuation flow (bulbs or tubercles), which are the output flows of interest for the analysis, and is referring to the consequences suffered by the cleaned useful products evacuation flows when their determinant factors vary, making recommendations concerning the tendencies which these factors must have in order that the bulb or tubercles harvesters working process will be optimized.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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PULZNO ŠIRINSKO KRMILJENJE ELEKTROMAGNETNEGA VENTILA ZA NANOS PESTICIDOV S POMOČJO MEHKEGA REGULATORJA

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POVZETEK

V članku prikazujemo aplikacijo avtomatiziranega mehkega logičnega sistema s katerim zagotavljamo kontroliran nanos fitofarmacevtskega sredstva (FFS) na izbrane ciljne površine v prostoru habitusa dreves sadovnjaka ali vinograda. Na ta način zagotovimo nanos predvidene optimalne količine fitofarmacevtskega sredstva v odvisnosti od velikosti in gostote listne mase tretiranih dreves. Realni model avtomatiziranega mehkega logičnega sistema smo realizirali s pomočjo prenosnega računalnika HP Compaque 6830s NA779ES, programskim orodjem Matlab/Simulink R2011b, mehkim logičnim orodjem FIS (Fuzzy Inference System), elektromagnetnim ventilom, krmilnim vezjem elektromagnetnega ventila, NI USB-6009 ADDA kartico, ultrazvočnimi senzorji ter šobo Lechler TR-80-015C. Strojni del sistema predstavlja prenosni računalnik, ki smo razširili z vhodno-izhodno enoto za zajemanje podatkov. Programski del sistema oz. algoritem za pulzno širinsko krmiljenje elektromagnetnega ventila pa smo razvili s pomočjo orodja Matlab, kjer smo optimirali pravila in pripadnostne funkcije mehkega regulatorja. Rezultati so pokazali, da s pomočjo kontroliranega mehkega pulzno širinskega krmiljenja elektromagnetnega ventila prihranimo na porabi fitofarmacevtskega sredstva, predvsem tam kjer nismo zaznali gostote listne mase tretiranih dreves preko ultrazvočnega senzorja.

Ključne besede: *avtomatizacija, mehka logika, elektromagnetni ventil, blokovna shema*

UVOD

Evropa je pristopila k sistematičnemu urejanju rabe FFS na izvoru, to je registraciji FFS, ko je z direktivo EES 91/414, natančno predpisala orodja in merila za ocenjevanje primernosti sredstev za varstvo rastlin. Na ta način se je zmanjšala nevarnost za rabo ljudem in okolju spornih FFS, pa vendar to ni rešilo vseh problemov rabe FFS. Neprimerna ali pretirana raba še vedno pušča negativne posledice na okolju in ljudeh. Nekatere države kot na primer Danska, so zaradi očitnih nepravilnosti in negativnih vplivov industrijskega tipa kmetijske pridelave pristopile k izdelavi načrta za zmanjšano in trajnostno rabo rabo FFS že v drugi polovici osemdesetih let. Po nekoliko več kot dvajsetih letih od danskega primera, sta Evropski parlament in svet sprejela zakonodajni paket o trženju in rabi FFS. Direktivi 79/117/EEC in 91/414/EEC je 14. Junija 2011 nadomestila uredba 1107/2009/ES o dajanju FFS na trg, ki zagotavlja večje varstvo ljudi, živali in okolja ter določa jasnejše pogoje pri registraciji FFS. Hkrati je bila v EU sprejeta direktiva 2009/128/ES o trajnostni rabi pesticidov, ki jo morajo države članice prenesti v nacionalne zakone in do konca leta 2012 implementirati skozi nacionalne akcijske načrte za trajnostno rabo FFS.

Glede na številke objavljene s strani Evropske komisije je bila med 60.450 vzorci živil vključenimi v monitoring Evropske komisije leta 2006 v 40 % vzorcev najdena vsebnost zaznanih ostankov pesticidov, dodatni 3 % vzorcev so vsebovali ostanke pesticidov, ki so presegali maksimalno dovoljeno mejno vrednost (MRL). V EU hrani je bilo tako v celoti odkritih 324 različnih ostankov pesticidov, med posameznimi vzorci so nekateri vsebovali tudi po 8 različnih ostankov pesticidov hkrati. Celo v hrani za dojenčke so bile najdene nezanemarljive količine ostankov pesticidov.

Prisotnost visokih vsebnosti ostankov pesticidov v hrani, pridelani v EU, je neposredni rezultat odvisnosti EU kmetijstva od pesticidov. Vsako leto namreč evropsko okolje zasipamo z več kot 200.000 kilogrami pesticidov. Mnoge izmed teh kemikalij, še posebej insekticidi, ne zatirajo samo škodljivcev, katerim so dejansko namenjene, ampak imajo v mnogih primerih tudi potencial za povzročanje resne poškodbe zdravju človeškega organizma. V zadnjem desetletju se je uporaba insekticidov v EU več kot podvojila.

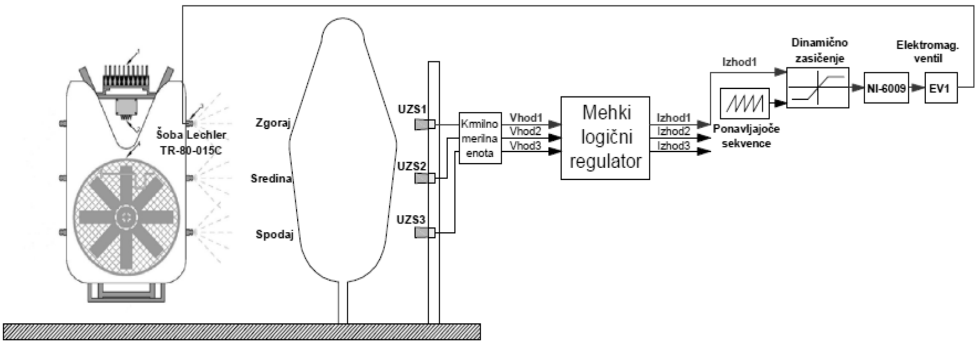
V raziskovalni skupini na katedri za biosistemsko inženirstvo (Univerza v Mariboru, Fakulteta za kmetijstvo in biosistemske vede) smo začeli razvijati okolju prijazno aplikacijo za zmanjševanje nanosa pesticidov, s čimer bomo lahko oblažili negativne vplive na okolje. Aplikacija v prvi vrsti vključuje alternativno tehniko, ki smo jo izvedli s pomočjo mehkega logičnega sistema. V okviru naloge smo naredili pulzno širinsko krmiljenje elektromagnetnega ventila v realnem času, ki krmili pretok FFS-ja v šobi tipa Lechler TR 80-015, preko mehkega logičnega sistema. Aplikacija bo služila kot strokovna podlaga pri izdelavi končnega realnega produkta. Na področju tehnik kontroliranega nanosa FFS tako srečamo naslednja pomembnejša področja uporabe, ki smo jih povzeli po naslednjih alinejah.

- Precizni nanos FFS-ja v nasadu jabolk in vinogradov je mogoče zagotoviti s pomočjo uporabe posebnih metod preko katerih lahko natančno opredelimo velikost in obliko krošenj dreves [1]. Z razvojem enostavnih in učinkovitih metod so določili osnovne parametere, kateri služijo v pomoč pri opredelitvi strukture krošnje dreves. V svojih raziskavah so uporabili ultrazvočne in LIDAR senzorje, ter z njihovo pomočjo opravili proces merjenja obsega in gostoto krošnje posameznega drevesa v nasadu habitusa. Predlagane nove tehnologije so zelo primerne kot dodatna oprema za izboljšanje učinkovitosti nanosa FFS. Za krmiljenje nanosa FFS so uporabili posebni algoritem, kjer so rezultati pokazali prihranke FFS do 52 % v nasadu habitusa dreves jabolk [1].

- V okviru projekta ISAFRUIT so razvili prilagodljivo aplikacijo za nanos FFS, ki so jo poimenovali s kratico CASA (Crop-Adapted Spray Application), [2]. S pomočjo te aplikacije lahko zagotovijo natančen, učinkovit in okolju prijazen nanos FFS v nasadu jabolk in sicer glede na dejanske potrebe nasada, pri čemer so upoštevali tudi spoštljiv odnos do okolja. S pomočjo sistema, ki so ga poimenovali s kratico EDAS lahko samodejno prilagajajo parametre nanosa FFS, kot so: velikost kapljic FFS, natančno lahko definirajo položaj pršilnika, če se ta giblje v območjih, ki so občutljiva na FFS (podtalnica, vodnjaki, sosednji sadovnjaki, javna mesta) in hitrost pretoka zraka v odvisnosti od hitrosti in smeri vetra, [2]. Na pršilniku, ki ga krmili sistem EDAS, so s pomočjo ultrazvočnega anemometra merili smer in hitrost vetra, pozicijo pršilnika so določili preko DGPS (Differential Global Positioning System) sistema. Krmiljenje šob za nanos FFS je potekalo avtomatsko glede na smer vetra, saj so tako lahko prilagajali velikost kapljic FFS, v odvisnosti od stopnje tveganja zanašanja (drifta) FFS, [2]. Novejša različica ventilatorja na pršilniku omogoča podporo zraka, katerega lahko kontrolirajo in nastavljajo nemoteno na obeh straneh pršilnika. Nastavitev se izvede avtomatsko v odvisnosti od smeri vetra in pozicije pršilnika. Poskusi v sadovnjaku so potrdili načrtovano delovanje pršilnika, ki ga nadzorujejo s pomočjo sistema EDAS.
- Ena izmed najbolj pogostih in učinkovitih metod za zmanjšanje zanašanja FFS je uporaba antidriftnih šob za nanos FFS, vsaj v primeru, ko lahko zanos FFS povzroči kontaminacijo na občutljivih območjih. Ta strategija je v kombinaciji z zmanjšanjem hitrosti pretoka zraka ventilatorja na pršilniku zelo primerna, saj lahko zmanjšajo zanašanje FFS v sadovnjakih ob visoki stopnji kontaminacije (npr., v bližini podtalnice), [3]. Wenneker s sodelavci, so s pomočjo antidriftnih šob in zmanjšanim pretokom zraka na zunanji vrsti dreves sadovnjaka ugotovili 80 % manjši zanos FFS, [4]. Vendar je potrebno upoštevati dejstvo, da komercialni pršilniki za nanos FFS ne omogočajo hitre menjave šob na škropilni garnituri, oz. prilagajanje pretoka zraka na obeh straneh pršilnika. Zato je potrebno za vsakršnokoli spremembo velikosti nanosa kapljic preko šob in nastavitev pretoka zraka poseg opraviti ročno, potem ko ustavijo delovanje pršilnika, [3].

MODEL PROCESA KRMILJENJA ELEKTROMAGNETNEGA VENTILA ZA NANOS PESTICIDOV (FFS) S POMOČJO MEHKEGA REGULATORJA

Model procesa krmiljenja elektromagnetnega ventila (BDA 8W ED 100 %) za nanos FFS s pomočjo mehkega regulatorja smo realizirali s programskim orodjem Matlab/Simulink, mehkim logičnim orodjem FIS (Fuzzy inference system) v podsistemu Matlab, prenosnim računalnikom HP Compaque 6830s NA779ES, krmilno-merilnim elektronskim vezjem, ki služi za zajem podatkov in proženje ultrazvočnih senzorjev PROWAVE 400EP250, šobo Lechler TR-80-015C ter NI USB-6009 ADDA kartico. S pomočjo programskega orodja smo najprej naredili model mehkega logičnega regulatorja za proces nanosa FFS. Optimiranje pravil in pripadnostnih funkcij smo izvedli s pomočjo skupine grafičnih urejevalnikov (programski paket Matlab; FIS). V primeru nezadovoljivih rezultatov smo definirali dodatne jezikovne spremenljivke, spreminjali smo pripadnostne funkcije in temu primerno napisali nova pravila. Pri definiciji jezikovnih spremenljivk smo upoštevali gradient naraščanja v obliki številskih vrednosti, v območju od [0-600], ki predstavljajo intenziteto odbitega signala, ki ga zajame ultrazvočni senzor. Pri snovanju mehkega regulatorja smo upoštevali tri delne postopke, ki predstavljajo osnovo delovanja mehkega regulatorja, [5]. Izvajanje modela procesa mehkega regulatorja smo ponazorili na primeru realizacije strukture nanosa FFS na izbrane krošnje habitusa dreves, slika 1.



Slika 1 Struktura aplikacije procesa nanosa FFS v sadovnjaku

Strojna oprema

Strojno opremo procesa nanosa FFS sestavljajo naslednje komponente:

- prenosnik HP Compaq 6830s NA779ES,
- krmilno-merilno elektronsko vezje,
- ultrazvočni senzor PROWAVE 400EP250,
- elektromagnetni ventil (BDA 8W ED 100 %),
- šoba Lechler, z oznako TR-80-015C,
- NI USB-6009 kartica.

Na prenosniku je dovolj prostora za aplikacije in orodne vrstice, uporabimo ga lahko na terenu, ker ima vgrajeno tehnologijo HP 3D DriveGuard, ki z merjenjem pospeška zazna nenadne premike in izvede zaščitne ukrepe ter nam pomaga varovati trdi disk pred udarci in padci. Prenosnik HP 6830s ima na voljo 3GB DDR2 800MHz pomnilnik, ki je razširljiv do 8GB. Trdi disk je velik 320GB-SMART SATA 5400 rpm.

Kot vhodno-izhodno enoto smo izbrali krmilno-merilno elektronsko vezje katerega smo razvili na katedri za biosistemsko inženirstvo (Fakulteta za kmetijstvo in biosistemske vede, Univerza v Mariboru) s katerim lahko programiramo mikrokrmilno enoto LPC 1343. Preko USB in RS-232 vmesnika lahko komuniciramo s prenosnim računalnikom HP Compaq 6830s na katerem nalagamo podatke glede intenzitete odbitega signala preko ultrazvočnega senzorja PROWAVE 400EP250. Omogočeno je programiranje s pomočjo vmesnika JTAG.

Ultrazvočni senzorji so bili zasnovani okoli mikrokrmilnika CYPRESS CY8C29466-24SX z 32 KB Flash in 2KB pomnilnika z naključnim dostopom. Mikrokrmilniku smo dodali še elektroniko za ultrazvočni aktuator Prowave 400EP250 in zanj spisali programsko opremo, razvito v programskem okolju PSOC designer, Senzor smo opremili s trobljo za namestitev kombiniranih oddajnikov oz. sprejemnikov in omejevanje širine ultrazvočnega signala v krošnjo. Vsa elektrinka tipala smo zaprli v industrijsko ohišje fi 30 mm iz niklanega jekla in sprogramirana tako, da kot rezultat meritev vračajo svojo identifikacijsko številko, izmerjeno celostno razdaljo in izmerjen največji integral odbojev v območjih velikih 15 cm.

Preko elektromagnetnega ventila tipa BDA 8W ED 100 % krmilimo pretok FFS skozi šobo tipa Lechler TR-80-015C. Napajanje tuljave dvo položajnega, zaprtega elektromagnetnega ventila je 12 voltov DC, električna moč, ki se troši na tuljavi znaša 8 watov.

Standardna vrtinčna šoba Lechler, z oznako TR-80-015C brez podpore zraka, ima 80° kot škropljenja, primerna je za nanos FFS v sadovnjakih in vinogradih, pa tudi v poljedelstvu za nanos fungicidov in insekticidov, ter kontaktnih herbicidov po vzniku plevelov. Uporablja se lahko za nanos FFs v pasove in zelenjadarstvu. V sadovnjakih in vinogradih se gibljejo delovni tlaki od 8-15 bar, v poljedelstvu pa od 2 do 8 barov.

NI USB-6009 kartica podjetja National instruments (NI) omogoča osnoven funkcionalen zajem podatkov in sicer v aplikacijah, ko gre za enostavno shranjevanje podatkov meritev na terenu in za akademske poskuse v laboratorijih. S plug-and-play komunikacijsko USB povezavo je preprosta naprava ustrezna za izvajanje merilnih aplikacij. NI merilna programska oprema pohitri izvajanje meritev na terenu. Zraven tega, USB-600x prototipna komponentna oprema ponuja možnost dodajanja večih analogno/digitalnih vhodov, ki jih lahko priključimo na USB-6009 kartico. Zajem podatkov omogočimo preko Matlab orodja DAQ (Data Acquisition Toolbox), kjer s pomočjo napisanih funkcij omogočimo komunikacijsko povezavo za zajemanje podatkov na kartici NI USB-6009.

Programsko orodje Matlab/Simulink R2011b

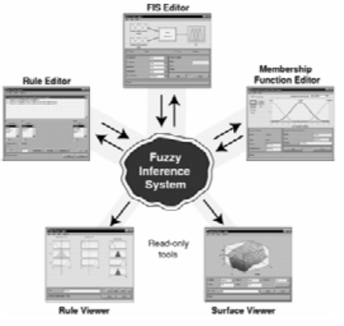
Matlab je programski paket namenjen numeričnemu računanju, kot so aritmetične operacije skalarjev, vektorjev, diferenčnih enačb, diferencialnih enačb in prikazovanju rezultatov, preko posebnih grafičnih uporabniških vmesnikov. Za tako obširno rabo ima posebne knjižnice, s pomočjo katerih lahko pridemo do podrobnejših znanj s področja regulacij (zveznih, diskretnih, mehkih itd.), načrtovanju filtrov itd. Zaradi enostavne uporabe je Matlab postal orodje, ki so ga začeli na široko uporabljati. Matlab je moderno programsko orodje za reševanje numeričnih problemov, [6]. Je primeren za pouk, raziskovanje in za reševanje praktičnih problemov. Matlabov jezik ima bogate podatkovne strukture in je tudi objektno orientiran. Ker Matlab svoje datoteke interpretira, se pri tem izgubi precej dragocenega časa, vendar je mogoče kodo-m datotek prevesti in s tem odločno pospešiti izvajanje programa. Po drugi strani lahko ozka grla izvajanja programa, to so tisti deli, ki porabijo največ časa, zakodirani v kakšen drug programski jezik, na primer C in prevedemo v mex-datoteko, ki jo Matlab zna uporabljati tako kot svojo lastno m-datoteko, le da prevedena koda teče mnogo hitreje.

Simulink je programsko orodje in podsistem Matlab-a. Namenjen je za modeliranje in simulacijo matematičnih modelov. Omogoča nam tudi enostaven grafični prikaz rezultatov simulacije. Zaženemo ga lahko v Matlab okolju z ukazom simulink, ali s pomočjo ikone v Matlab-ovi orodni vrstici.

Mehko logično orodje FIS (Fuzzy inference system)

Mehki regulator smo načrtovali s pomočjo mehkega logičnega orodja (FIS; Fuzzy inference system, [7]), ki se izvaja v podsistemu Matlab. Obstaja pet osnovnih orodij v FIS-u (urejevalniki, prikazovalniki pravil in grafov) za gradnjo, urejanje in opazovanje mehkih logičnih sistemov, ki jih prikazuje slika2. To so:

- urejevalnik za določitev mehkega inferenčnega sistema FIS (FIS Editor),
- urejevalnik pripadnostnih funkcij (Membership Function Editor),
- urejevalnik pravil (Rule Editor),
- prikazovalnik pravil (Rule Viewer),
- grafični prikazovalnik karakterističnega področja delovanja mehkega regulatorja (Surface Viewer).



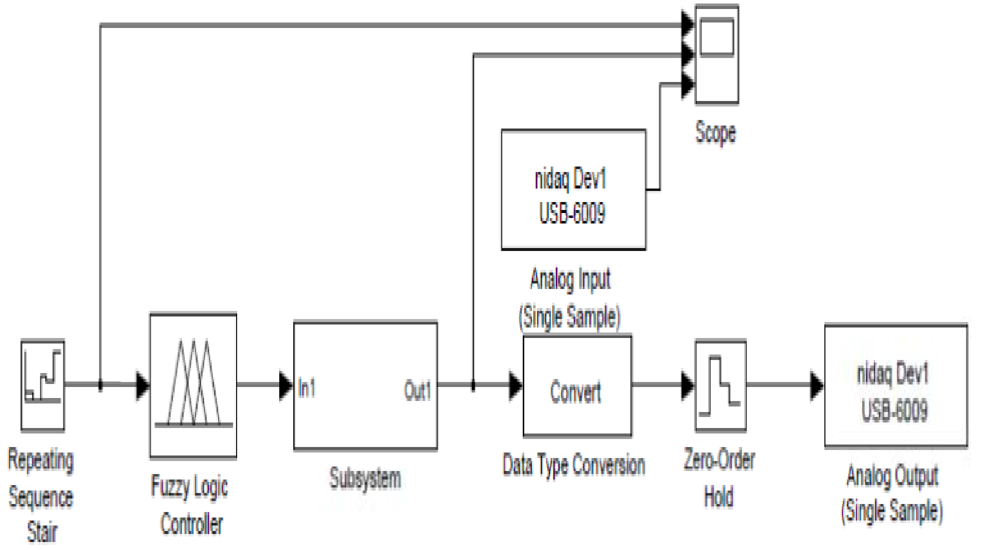
Slika 2 Osnovna orodja v FIS-u

Vsa osnovna orodja so v FIS-u med seboj dinamično povezana. Vse spremembe (različna nastavitev pripadnostnih funkcij za vhodne in izhodne spremenljivke), ki smo jih nastavljali v mehkem logičnem sistemu FIS-a, imajo vpliv na posamezna funkcijska orodja. V FIS urejevalniku smo tako nastavljali različno število vhodnih in izhodnih spremenljivk (jezikovne spremenljivke; M, S, V, MOV, SOV, VOV). V urejevalniku pripadnostnih funkcij smo opredelili njihove oblike (trikotne, trapezne, pravokotne ...). Urejevalnik pravil smo uporabili za urejanje seznama pravil s pomočjo katerega smo določili odziv mehkega sistema. Prikazovalnik pravil (grafični prikazovalnik) predstavlja Matlab-ovo tehnično orodje, ki prikazuje mehke diagrame pripadnostnih funkcij v področju delovne točke. Prikazovalnik služi za diagnozo, ki prikazuje, katera so dejavna pravila, oziroma kako posamezne oblike pripadnostnih funkcij vplivajo na končni izračun izhodne vrednosti spremenljivke mehkega regulatorja. S pomočjo grafičnega prikazovalnika karakterističnega področja prikazujemo izhodno vrednost spremenljivke mehkega regulatorja, ki je odvisna od različnega nabora vhodnih vrednosti spremenljivk regulatorja.

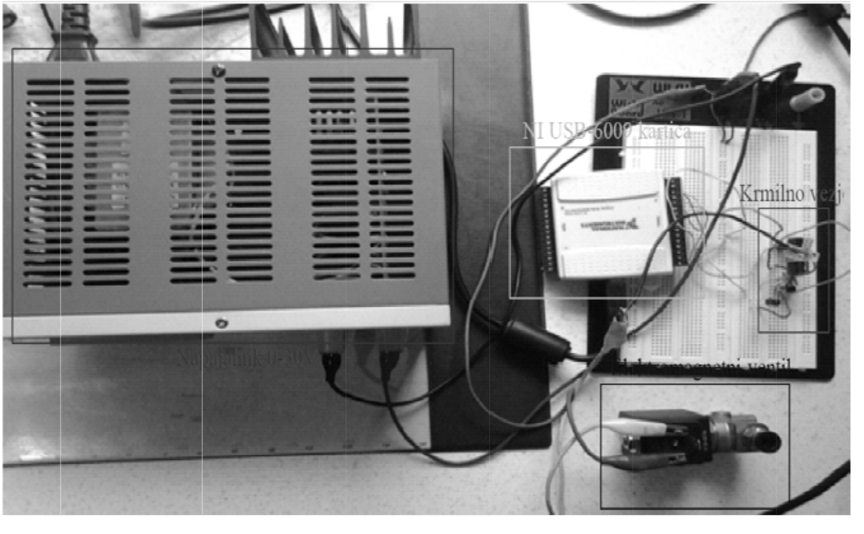
Modeliranje realnega mehkega regulatorja za pulzno širinsko krmiljenje elektromagnetnega ventila pri nanosu FFS

Mehki regulator za pulzno širinsko krmiljenje elektromagnetnega ventila lahko obravnavamo kot regulator z nelinearno statično karakteristiko v aplikaciji procesa nanosa

FFS, slika 3 in slika 4. Vhod v mehki regulator je jezikovna spremenljivka (Sensor1), ki predstavlja referenčno vrednost v območju [0-600]. Referenčna vrednost predstavlja proces nanosa FFS, kjer smo normirali nanos FFS glede na intenziteto odboja od krošnje habitusa dreves, s pomočjo ultrazvočnega senzorja.

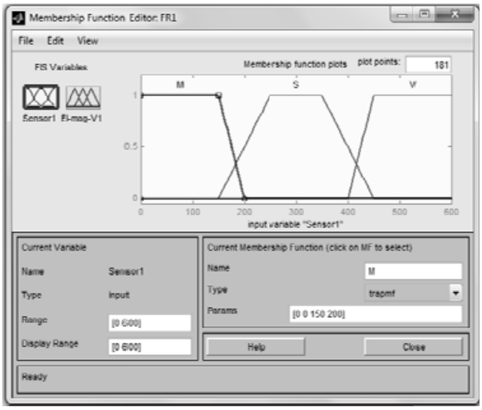


Slika 3 Blokovna shema mehkega regulatorja za proces nanosa FFS v programskem paketu Matlab/Simulink

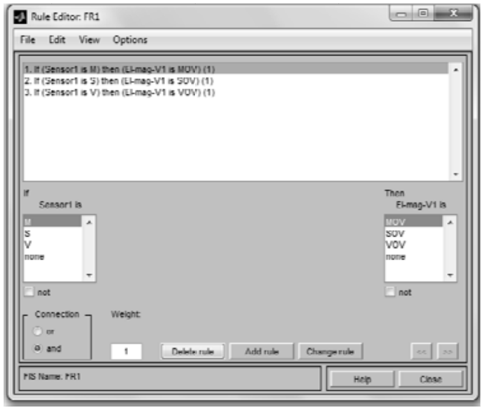


Slika 4 Realni model pulzno širinskega krmiljenja elektromagnetnega ventila za proces nanosa FFS

Izhod mehkega regulatorja (jezikovna spremenljivka El-mag-V1) predstavlja pulzno širinski napetostni signal velikosti 5V, ki zavzame tri jezikovne vrednosti (MOV, SOV, VOV). Jezikovno spremenljivko (Sensor1) smo opisali s tremi pripadnostnimi funkcijami trapezne oblike (mehko logično orodje FIS, slika 5), s tremi jezikovnimi vrednostmi (M, S, V). Na sliki 6 so prikazana pravila mehkega regulatorja procesa nanosa FFS, katera smo vpisali v FIS-ov urejevalnik pravil. Jezikovni opis sistema (mehki regulator za pulzno širinsko krmiljenje elektromagnetnega ventila) smo naredili s pravili oblike "ČE-TEDAJ" ("IF-THEN").



Slika 5 Pripadnostne funkcije vhodne jezikovne spremenljivke mehkega regulatorja



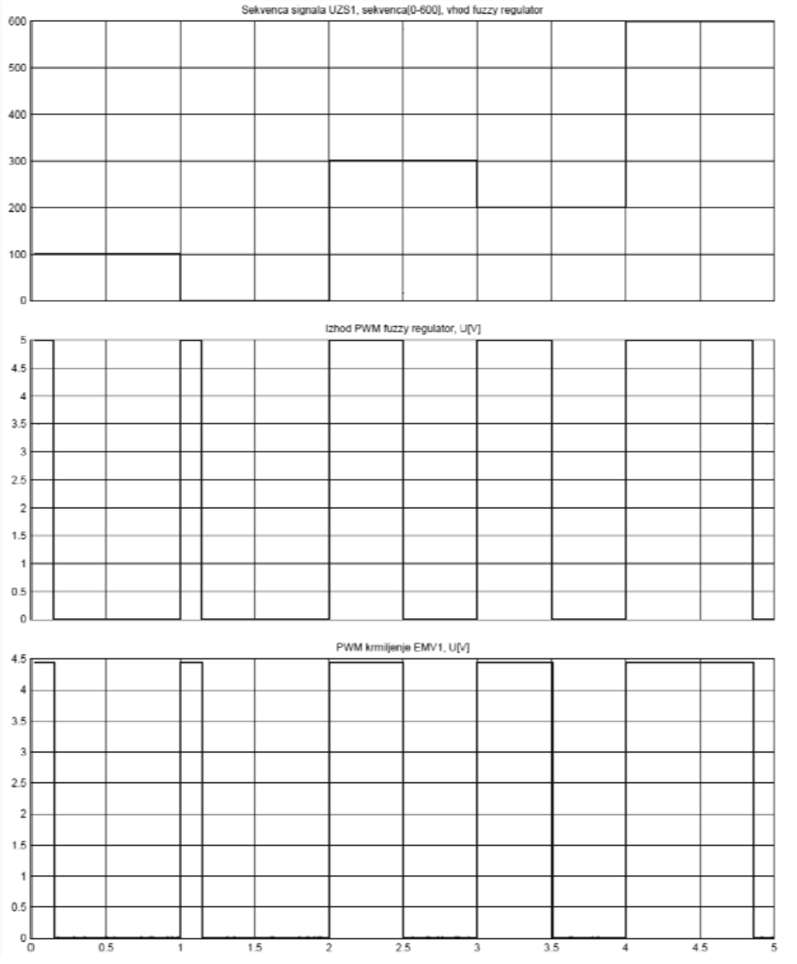
Slika 6 Pravila mehkega regulatorja za proces nanosa FFS

Predpostavili smo, da zavzemajo stopnje M (malo), S (srednje), V (veliko), vrednosti med 0 in 1. V mehkem regulatorju za pulzno širinsko krmiljenje elektromagnetnega ventila za proces nanosa FFS, smo uporabili Mamdan-ijevo implikacijo, ki je za izračun najbolj enostavna. Po opravljenih treh postopkih (mehčanje, inferenca, ostrenje) smo zaključili z načrtovanjem mehkega regulatorja. Nato smo izvedli optimizacijo delovanja mehkega regulatorja, tako da smo ob tem nastavljali stabilnost, robustnost, kvaliteto regulacije in obnašanje pri spremembah oblike pripadnostnih funkcij vhodne in izhodne jezikovne spremenljivke.

REZULTATI

V rezultatih smo primerjali klasično in avtomatizirano izvedbo krmiljenja nanosa FFS preko šobe tipa Lechler TR-80-015C, na izbrane dele habitusa dreves s pomočjo mehke odločitvene logike, ultrazvočnega senzorja, krmilnega vezja, NI USB-6009 ADDA kartice, elektromagnetnega ventila in DC napajalnika 0-30V/0-3A. Za primer smo naredili analizo nanosa FFS in sicer za pozicijo Zgoraj (slika 1), kjer smo zajemali podatke iz senzorja1, v obliki številskih vrednosti v območju [0-600]. Številske vrednosti smo normalizirali in jih uporabili v mehkem regulatorju, preko katerega smo pulzno širinsko krmilili elektromagnetni ventil, s pomočjo katerega smo krmilili pretok FFS, v šobi tipa Lechler, z oznako TR-80-015C. Naredili smo primer realnega nanosa FFS v intervalu od [0-5] sekund. V tem intervalu smo dobili sekvenco signalov iz senzorja1, v obliki številskih vrednosti (intenziteta odoja signala od krošnje habitusa), graf (Sekvenca signala UZS1, sekvenca [0-600], vhod fuzzy regulator), slika 7. Na podlagi pridobljene sekvence signalov iz senzorja1 smo naredili realno aplikacijo procesa nanosa FFS na izbrane dele krošnje dreves (Zgoraj) v nasadu jabolk (slika 1), preko mehkega logičnega modela (slika 3 in 4), ki je krmilil elektromagnetni ventil, s pomočjo katerega smo pulzno širinsko odpirali in zapirali pretok FFS skozi šobo na sadjarsko vinogradniškem pršilniku.

Grafa (Izhod PWM fuzzy regulator, U[V] in PWM krmiljenje EMV1, U[V]) na sliki 7 prikazujeta pulzno širinsko krmiljenje elektromagnetnega ventila preko mehke odločitvene logike, za primer nanosa FFS, preko šobe tipa Lechler.



Slika 7 Grafi pulzno širinskega krmiljenja elektromagnetnega ventila

V primeru klasične sinteze aplikacije nanosa FFS na krošnje habitusa (zgoraj) smo upoštevali, da je šoba tipa Lechler, v intervalih po 1 sekundo vedno odprta. Zato smo vzeli številsko vrednost 100 % za primer, ko je šoba v intervalu [0-5] sekunde konstantno odprta. V primeru realne aplikacije avtomatiziranega nanosa FFS (slika 7) smo ugotovili, da je ta vrednost manjša in sicer je za našo sekvenco značilno, da je elektromagnetni ventil za nanos FFS (Zgoraj) glede na številske vrednosti vhodnih in izhodnih pripadnostnih spremenljivk mehkega regulatorja (slika 5) povprečno v intervalu [0-1] sekunde procentualno odprta 14.43 %, v intervalu [1-2] sekunde procentualno odprta 14.43 %, v intervalu [2-3] sekunde procentualno odprta 50 %, v intervalu [3-4] sekunde procentualno odprta 50 % in v intervalu [4-5] sekunde procentualno odprta 75 %.

ZAKLJUČEK

Rezultati prikazujejo, da je mehka logika uporabna v aplikacijah za realni proces avtomatiziranega nanosa FFS na izbrane dele krošnje dreves, kjer ponavadi klasične metode s konstnatnim direktnim nanosom ne dajo zadovoljivih rezultatov. Mehki logični regulator omogoča uporabniku, da uporabi lastno znanje o problemu in ga prenese v primerno sistemsko okolje, ki je blizu človeškemu načinu razmišljanja. Ker je to bolj kompleksno opravilo, kot le vnašanje nekaj regulacijskih parametrov smo uporabili poseben uporabniški vmestnik (FIS) za načrtovanje mehke logične aplikacije. Mehki regulator se je v procesni aplikaciji krmiljenja elektromagnetnega ventila izkazal kot zelo dobra izbira, saj je postopek načrtovanja mehkega regulatorja dokaj preprost in primeren za inženirsko prakso. Rezultati prikazujejo v primeru nižje številske vrednosti, ki jo dobimo iz ultrazvočnega senzorja, manjše odprtje elektromagnetnega ventila, posledica tega je manjši nanos FFS, takrat kadar ne zaznamo krošnje drevesa, oz. ta ni tako bujna.

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PULSE WIDTH CONTROL OF THE SOLENOID VALVE FOR THE APPLICATION OF PESTICIDES USING FUZZY LOGIC CONTROLLER

PETER BERK, DENIS STAJNKO, MIRAN LAKOTA, PETER VINDIŠ, JURIJ RAKUN

ABSTRACT

This paper presents an application of automated fuzzy logic system which ensures controlled application of plant protection on the selected target areas in the habitus of tree orchard or vineyard. On this way we can provided in the application optimal amounts of plant protection depending on the size and density of their leaves of treated trees. Real fuzzy logical model of automated system was realized with the help of notebook HP Compaq 6830s NA779ES, MATLAB/Simulink R2011b, Fuzzy logic tool FIS (Fuzzy Inference System), solenoid valve, solenoid valve control circuit, NI USB-6009 ADDA card, ultrasonic sensor and nozzle type, Lechler TR-80-015C. Hardware part of the application system is a laptop, which was developed with the input-output unit for data acquisition. Part of the software system or algorithm for the pulse width control of solenoid valve, we have developed by Matlab tools, where we can optimized the rules and membership functions for the fuzzy logic controller. The results showed that by using of a controlled fuzzy pulse width controlled solenoid valve, we can save on the consumption of plant protection, especially there where we did not detect the density of the treated trees of their leaves through the ultrasonic sensor.

Key words: *automation, fuzzy logic, solenoid valve, block diagram*

41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Originalni znanstveni rad
Original scientific paper

INTRODUCING LOW-COST PRECISION GPS/GNSS TO AGRICULTURE

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SUMMARY

World-wide development of several Global Navigation Satellite Systems (GNSS) presents many new opportunities for their use in agriculture. To overcome a constraining high price of precision GPS/GNSS systems, some possibilities for low-cost system (under 500€) were considered. A system was build based on low-cost single-channel GPS module and low-cost GPS antenna. To calculate a precise position in time free open-source program package RTKLIB was used, running on a laptop computer. System was tested in static mode and kinematic mode in laboratory conditions and mounted on a tractor for kinematic mode field tests. With calculations based on Real-Time Kinematic (RTK) centimeter-level accuracy was achieved. For corrections (based on carrier phase measurements) two sources were tested: our own reference station and reference station from Slovenian national GPS network (SIGNAL). In the first case the reference station can be placed on any location provided its precise position is known. For real-time operation corrections were send through WLAN. In the second case corrections were obtained from internet using GSM connection. They can be also downloaded from SIGNAL servers later in case of post-processing. Both cases of corrections showed comparably good results. During field tests also some effects of clouds, vegetation, tractor speed and anti-hail nets were investigated. In general the low-cost system performed very well and also showed great potential for further developments.

Key words: *GNSS, precision GPS, Real-Time Kinematics, low-cost, agriculture*

INTRODUCTION

Evolution trends in the field of satellite positioning show increasing growth which can be observed in increasing numbers of positioning devices, applications and satellites. This continuous development presents many challenges for technologies that are connected with it [1, 10, 14]. Although the satellite positioning has been present in agriculture from the mid-1990s [2, 7] it is now actual more than ever [3, 8, 9, 12].

Among presently existing Global Navigation Satellite Systems (GNSS) the most widely used and known is the USA-owned NAVSTAR GPS (Navigational Satellite Timing and Ranging Global Positioning System). It provides location and time information when at least 4 satellites are in view. The satellites broadcast encoded/modulated signals at the carrier frequencies L1 (1.57542 GHz) and L2 (1.2276 GHz). The L1 carrier is modulated with Coarse-Acquisition (C/A) and encrypted precision P(Y) codes while the L2 carrier is modulated only with the P(Y) code. The C/A code is a 1023 bit sequence transmitted at 1023 Mbits/s. Each satellite transmits a unique code. A receiver must have appropriate codes for each satellite to be able to reconstruct the data. While the C/A code is available for civilian use the P(Y) code is only available for U.S. military use. Despite of this L2 can also be used for civilian purposes 'indirectly' through additional signal processing. In this way additional corrections (mainly ionospheric because ionospheric errors are frequency dependent) can be applied to positions obtained with L1. With that a basic precision of L1 can be improved from several meters to centimeter level. This capability makes dual frequency (L1/L2) receivers much more expensive in comparison with single frequency (L1) receivers (ratio of prices of dual/single frequency receivers can be 10-100).

An alternative way to obtain precise positions (to centimeter level) without using expensive dual L1/L2 receivers is to use Real Time Kinematic (RTK). It uses carrier phase measurements of the GPS signals and real-time corrections from a reference (base) station. For carrier phase measurements a general idea is to use much higher L1 carrier frequency instead of the C/A code frequency to determine a delay of received signal compared to a source. Theoretically the signals can be compared/aligned to accuracy of 1% of their wavelength. Signals with higher frequencies have shorter wavelength so the accuracy improves. To be able to properly detect significantly shorter timings of the L1 signal RTK receiver electronics must be able to measure time in nanosecond range. This means that precision timing modules are needed. Such modules are more expensive than non-RTK modules but much less than dual frequency receivers. Instead of comparing the received signal with a source which is not known (signal on the satellite) RTK receiver compares it with a signal from the base station. This reference signal is transmitted in real-time (internet, radio) and can be used by many RTK receivers. If there is a sufficient number of common satellites visible at both locations a 'fixed' solution is calculated, otherwise a solution is 'float'. While 'fixed' solution is precise to centimeters, 'float' is precise to decimeters. The precision is generally degraded by two errors: the first error comes from the RTK method (affects relative position) and the second comes from the position of the base station (absolute position).

Apart from the need for a base station (which should not be too far from a measured location, e. g., less than 100 km away) and a communication channel for corrections another disadvantage of RTK positioning is so called Time-To-First-Fix (TTFF). This is a time (from a start or after a break) required to obtain GPS data (signal, almanac, ephemeris) and calculate a 'fixed' position. Dual frequency receivers have in comparison with RTK receivers significantly reduced TTFF (tens of seconds vs. minutes).

In the next sections the paper deals with some practical capabilities of the experimental low-cost (under 500€) precision GPS system based on RTK. Considering features of the system its possible use in agriculture has been investigated.

METHODS

The low-cost system was build around a single-channel GPS receiver module from U-blox EVK-6T evaluation kit. The receiver uses LEA-6T precision timing chip. GPS antenna was Trimble Bullet III. It is an active antenna with high gain (35 dB) which is very robust and so suitable for continuous outdoor use in rugged conditions (as presumed in agriculture). The antenna was connected to the receiver with a coaxial antenna cable. The receiver was connected to a laptop computer with a USB cable which was also used for power. For corrections from the base station in one case an internet connection was established using a GSM modem Nokia 21-02m with a SIM card of a local mobile internet provider. The estimated cost (including VAT) of the equipment listed above is around 465 € (GPS kit 325€, antenna 80€, coaxial cable 5€, antenna mount 15€, modem 40€). This is less than desired 500€ limit which is satisfactory but at this stage the laptop computer (HP Compaq nc8230) is not included in the price.

Considering rovers, for laboratory tests the equipment was placed on a hand-pushed moving platform while for field tests it was mounted on a tractor Fendt FAVORIT 714 Vario (Figure 1).

Figure 1 Laboratory rover (left) with laptop computer (1), antenna cable (2), GPS antenna with mount (3), USB GSM modem (4), USB cable (5), GPS receiver (6) and moving platform (7), rover for field testing is tractor-based (right)

To analyze GPS signals and compute precise positions an open-source program package RTKLIB version 2.4.1 was used [13] (Figure 2).

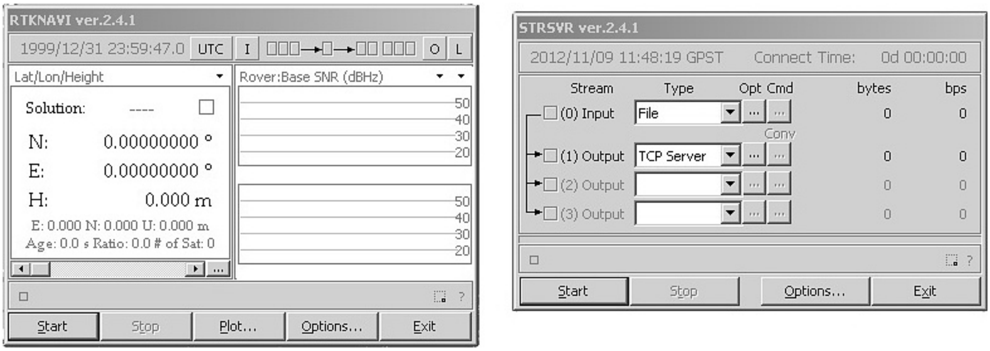

Figure 2 Interface of programs RTKNAVI and STRSVR from RTKLIB package

Two cases for sources of GPS corrections were tested: first our own reference station and secondly a reference station from Slovenian national GPS network (SIGNAL) [11]. A set-up for both cases is schematically presented in Figure 3.

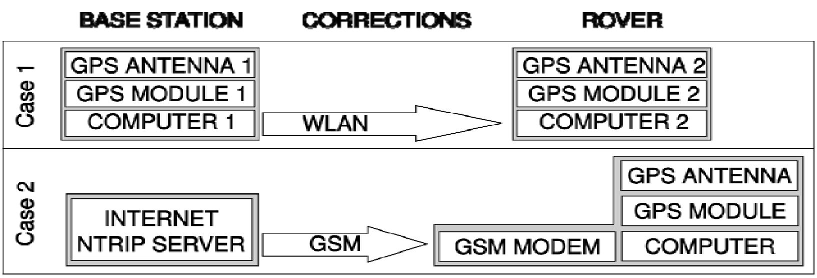

Figure 3 RTK precise positioning with different sources of corrections

Corrections from SIGNAL were accessed with a NTRIP (Networked Transport of RTCM via Internet Protocol) Client open-source program GNSS Internet Radio 1.4.11 [5]. Real-time corrections were provided in RTCM (Radio Technical Commission for Maritime Services) formats 2.3 and 3.1. For post-processing SIGNAL provides raw data in RINEX 2.11 and 3.0 format (Receiver Independent Exchange Format). Currently SIGNAL provides RTCM and RINEX data free of charge to registered users.

SIGNAL network (Figure 4) consists of 15 permanent GPS stations with dual frequency receivers. Distances between these reference stations are around 70 km or less. For the best precision it is desired that corrections are received from the closest station. To reduce this distance and remove distance-related errors corrections from Virtual Reference Station (VRS) can be obtained. The concept of VRS is based on modeling of satellite data (and errors) from three reference stations (at least) surrounding position of VRS which is normally near the measurement area. Our measurements were done using 2 permanent GPS stations (GSR1-Ljubljana and MARI-Maribor, distances from the site of the measurements were 10 km and 96 km respectively) and 1 VRS (on-site).

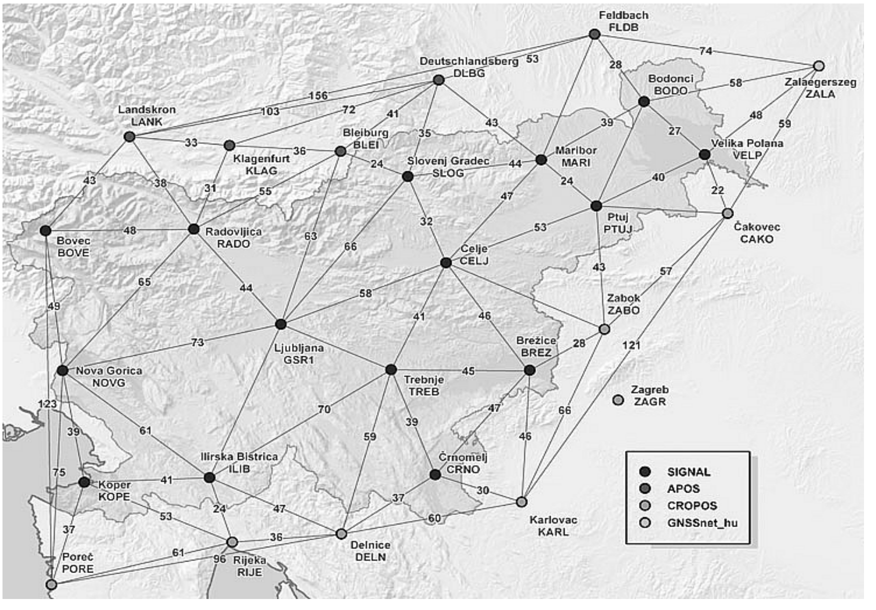

Figure 4 Permanent GPS stations [11]

Laboratory measurements were also performed using our own reference station. For this purpose another set of equipment of the same kind as for the rover was used. The precise position of our reference station was determined as the average position of a very long time period (24 h) of data. The data contained precise positions calculated with corrections from SIGNAL network. To transmit corrections from our own base station to the rover a local ad-hoc network was formed using WLAN. The base station computer hosted TCP Server from which TCP client on the rover computer accessed the corrections data.

RESULTS AND DISCUSSION

With presented experimental set-up achieved accuracy of calculated positions was in cm-range for all static tests for all choices of reference station (own, SIGNAL/permanent/close, SIGNAL/permanent/far, SIGNAL/VRS). The differences in obtained results were below standard deviation of calculated positions. An example of stationary measurements is presented in Figure 5. The gray measurements were obtained 1 week after the black measurements. From this comparison a very good repeatability can be seen. To illustrate precision of RTK measurements there is a black square of 4x4 cm. As mostly all points lie inside this square the precision is at least as good as ±2 cm in both directions (lateral, longitudinal). Although the first measurements show more drift in longitudinal direction this represents just small percentage (<1%) of all measured points. Generally precision of longitude is better than latitude.

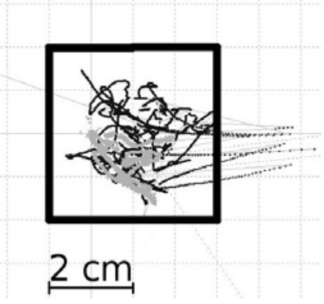

Figure 5 Static measurements with RTK

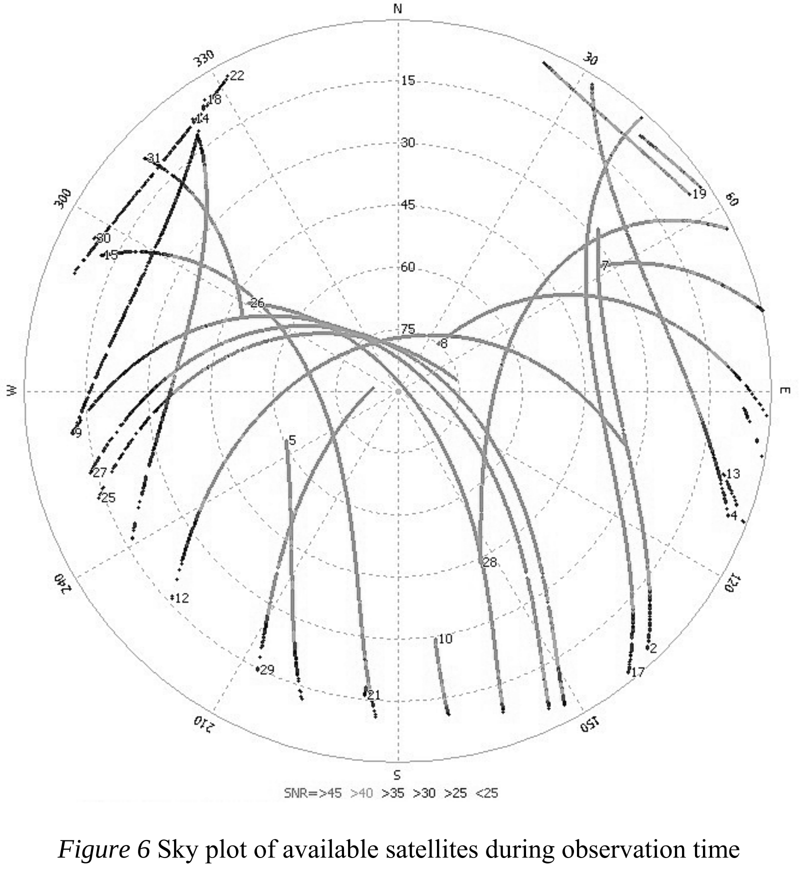

Figure 6 Sky plot of available satellites during observation time

For measurements in kinematic mode (referring to RTK calculations) there were no comparative measurements for the moving rover. However when the rover was not moving deviations of position were ±0.002 m (East-West), ±0.003 m (North-South) and ±0.01 m (Up-Down). Corresponding velocity fluctuations were ±0.01 m/s (E-W), ±0.02 m/s (N-S) and ±0.05 m/s (U-D). As the GPS receiver provides positions data at a rate of 10 Hz in laboratory tests when movements were done with walking speed measured positions were never more than 10 cm apart. Field tests at higher velocities also confirmed suitability of RTK GPS for accurate position and ground speed measurements, which is in accordance with [4, 6].

Regarding aforementioned 'fixed' solution it is necessary for a rover and a base station to have sufficient number of common satellites in view. Satellite positions during measurements can be presented in a sky plot (Figure 6). Each satellite is distinguished by its transmitted signal however when a satellite in view is close to a horizon its signal deteriorates as well as its Signal-to-Noise-Ratio (SNR) diminishes. When it is below a certain level a signal from another satellite in sight must be used for calculations. From the sky plot in Figure 6 it can also be seen that there is a certain area of sky without satellites (between 330°-30° longitude and 0°-70° latitude). This is probably due to the fact that measurements were taken at 46° N while the orbit planes of the GPS satellites have approx. 55° inclination towards the equator.

One of the fundamental characteristic of a single-channel RTK positioning is a long starting time which is commonly addressed as a Time-To-First-Fix (TTFF). TTFF can be further divided in three cases: cold, warm and hot start TTFF with regard to known amount of data required for 'fixed' position solution (respectively related roughly as none, some, all). Cold start is when a GPS receiver is new, has not been used for a long time or its current position significantly changed from the last. Long cold start TTFF (up to 15 minutes) may be a serious drawback for some applications. A warm start TTFF is usually less than a minute. For our low-cost system an example of RTK positioning during a cold start is presented in Figure 7. As can be seen from time axis positioning started at 6:00. Gray positions are resolved as 'float' and black as 'fixed'. Three graphs in Figure 7 are for position differences in longitude, latitude and elevation. Observed TTFF is around 2 minutes (first 'fixed' solution is at 6:02). After that solutions deteriorates to 'float' although in the first period of 'fixed' solutions they appear stable. Further on 'fixed' solutions are achieved and lost again (at approx. 6:06). Reliable positioning is finally established around 6:15.

As a part of laboratory measurements precise positions in foggy weather were determined. Horizontal visibility at the antenna height was between 100 m and 200 m. This measurements were compared to measurements in sunny conditions (bright sky with no clouds). In both cases 'fixed' solution was obtained with no difference in precision. For both cases the quality of satellite signals (in terms of SNR) is presented in Figure 8. Gray points represent satellite signals for sunny weather and are superimposed on black points which represents satellite signals recorded during foggy weather. It can be seen that in both cases SNR values cover the same range (from 25 to 51). As for GPS there was no effect of fog on WLAN either. WLAN antennas were positioned approx. 100 m apart with no solid obstructions or vegetation between them.

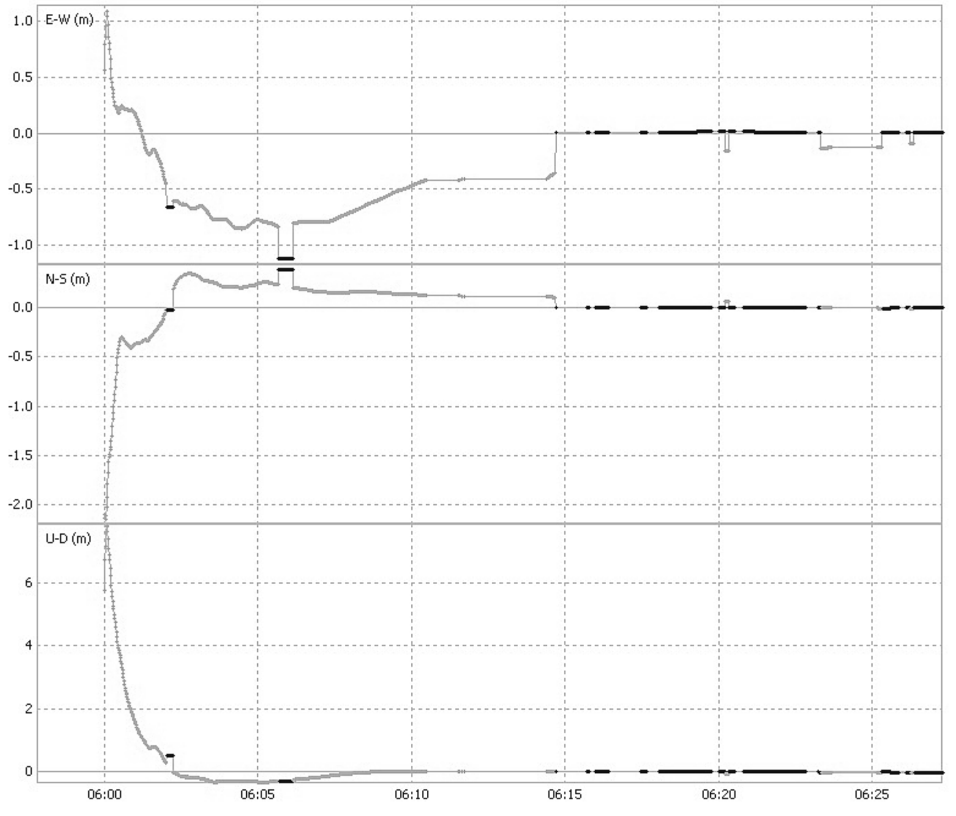

Figure 7 Cold start Time-To-First-Fix (TTFF)

Similarly the effect of plastic netting used for covering was measured. Two types of netting were tested: black PE anti-hail net and lighter green net for protection against birds. The netting was spread about 1m above the GPS antenna. In both cases 'fixed' solutions were obtained although the satellite signals were reduced in strength. For the green net attenuation was up to -2 dB while for the black net it was up to -4 dB.

The effect of netting on WLAN transmission was much larger. The set-up was such that it was as similar as possible to real working conditions under protective netting. The first WLAN antenna was positioned slightly higher than the other so that the covering net could be stretched horizontally between them. The second antenna was on the moving platform so it was possible to change distance between antennas. The netting was not stretched the complete distance between the antennas but it was placed so that the antennas were never in direct sight. Due to long horizontal distances relatively to mounting heights of antennas WLAN transmission worked well when the distance between the antennas was just a few meters. When the distance increased above 20 meters the transmission was so degraded that its speed was significantly reduced. With increasing distance the network soon became unreliable to the point that 'fixed' solution could not be achieved.

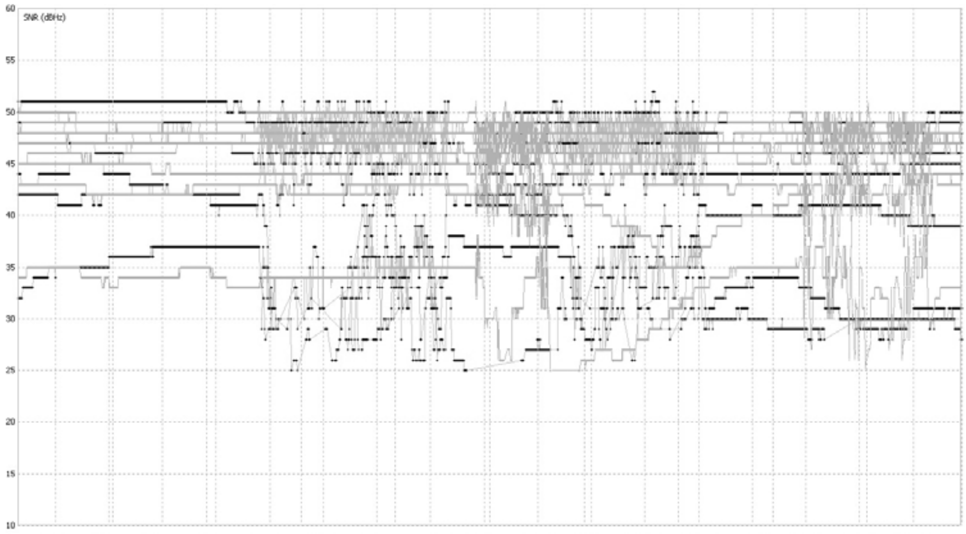

Figure 8 SNR for measurements during fog (black) and clear sky (gray) weather conditions

Figure 9 Large-scale measurements with VRS corrections

Apart from laboratory tests some field test were done with RTK positioning in kinematic mode. Because the tractor was used for rover larger velocities were achieved. This did not present any problems as 'fixed' solutions were calculated as before. The main difference was in transmission of corrections where GSM connection performed much better than WLAN. Even though the omnidirectional WLAN antennas should enable transmission in range of some hundred meters many corrections were lost and 'fixed' solutions were not consistently calculated. A possible reason for problematic WLAN operation may be placement of the antennas. The base station antenna was lower than the rover antenna which was located on the side of the tractor roof so occasionally the roof obstructed direct view between the antennas. Figure 9 presents a GPS track from a test drive. RTK positioning was done with corrections from VRS. Its position is marked with a white dot and was chosen close to the starting position. Distance between the extreme points of the track is 500 m.

CONCLUSIONS

A low-cost GNSS navigation system was build using a single-channel GPS receiver connected to a laptop computer. Precise positioning was based on RTK calculations and a centimeter-level accuracy was achieved for 'fixed' solutions. Positioning was done in static and kinematic mode with two sources of corrections. The first was from our own base station and the second was based on reference stations from Slovenian national GPS network SIGNAL. Permanent and virtual reference stations from SIGNAL were tested. All three types of reference stations showed comparably good results. Corrections were transmitted from a base station to the rover through ad-hoc WLAN network or through GSM network. GSM transmission showed some advantages over WLAN because it was less sensitive to obstructions and was not limited with range. Tests in different weather conditions showed no sensitivity of GPS on fog and only very little effect of protective netting on GPS signal strength while positioning remained precise.

Approximate price of the system was around 500 € as initially desired. It was possible to build such system because of low-cost GPS components and open-source programs used in it. Nevertheless, the desired functionality in terms of cm-accuracy, portability and autonomy was achieved. Further work in developing a truly useful system should be in terms of hardware directed towards replacement of the receiver from the kit with a dedicated receiver and with replacing a laptop computer with a smaller and simpler device. Considering software some applications intended for agricultural use should be implemented.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 543.42:632.95.02
Stručni rad
Expert paper

REMOTE SENSING APPLICATIONS TO IMPROVE EVALUATION METHODS OF VARIOUS PLANT AND SOIL PARAMETERS AND EFFICIENCY OF PEST CONTROL

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SUMMARY

Remote sensing technologies are intensively developing tools of new generation data acquisition which will revolutionarily change the information management in many scientific and industrial areas. The objective is to present the technological capabilities of remote sensing of our Institute and show some preliminary results of nutrient sensitive changes in winter wheat spectra, creation of thematic map of moisture content based on airborne and laboratory recors and finally a study that brings on the necessity of using high resolution devices to test spectral characteristics of insect luring or repelling illuminants.

Key words: *remote sensing, spectroscopy, wheat nutrition, soil moisture, pest control*

INTRODUCTION

In our modern civilization the growing demand for data and information is very important issue. The conventional measuring and sampling methods can no longer provide with the necessary information. These methods usually provide few or several discrete data which are relatively far from each other both in time and space. The modern imaging remote sensing technologies, however, have the potential to analyze large areas in a fast and precise way by providing thousands of simultaneously recorded data of land treatment units down to 1 m^2 scale.

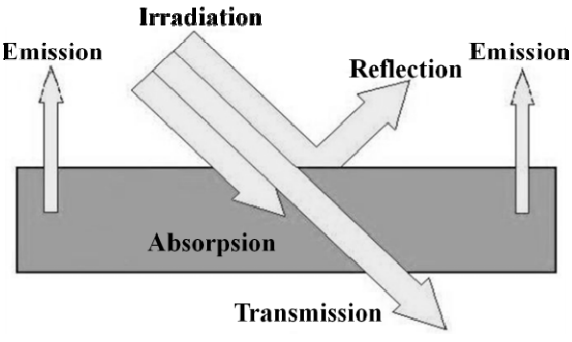


Figure 1 EM interactions (NOAA Coastal Service Center (2007) modified)

Remote sensing of Earth's surface includes several non-contact measurement techniques and evaluation methods. The only physical connection between the observer and the object is the electromagnetic radiation (EM). The incident EM interacts with the illuminated object. This interaction - based on the actual physical, chemical condition of the certain object and the energy, or rather the wavelength of the incident light - will result in the following phenomena above (Fig. 1).

The Hungarian Institue of Agricultural Engineering (HIEA) – hereafter referred as Institute – has been working and developing wide range of remote sensing application since the early 1980's. Airborne visible (VIS) and color infra red (CIR) images were taken where signs of formal soil compaction (Fig. 2) and fungal disease/perished trees are visible (Fig. 3).

Figure 2 VIS image of a land portion

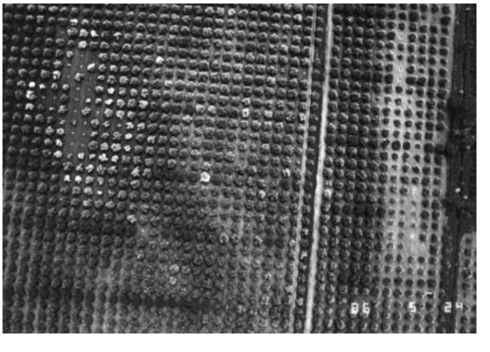


Figure 3 CIR image of orchard

Fig. 2 represents those situation where purely the visible region of the electromagnetic radiation is enough to detect changes or anomalies, but only from a certain height.

In the end of the 80's our Institute started working with thermal infra red (TIR) technology.

Figure 4 Thermal evaluation of maize

Figure 5 Thermovision assemlby on chopper

Figure 6 Thermovision under laboratory circumstances

Airborne (Fig. 4) ground-based (Fig. 5) and laboratory (Fig. 6.) applications were used and developed for examination and monitoring of various agricutural and mechanization processes.

Figure 7 FLIR ThermaCAM PM695

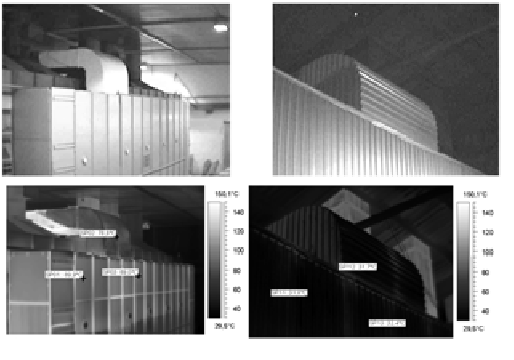


Figure 8 Studying dryers

From 2000, handheld thermal cameras (Fig. 7) are used to study the efficiency and thermal management of dryers (Fig. 8))and electric devices and several other agricultural and industrial application.

The dynamic development of different remote sensing technologies resulted in the hyperspectral imaging spectroscopy, which is one of the most advanced technologies in optical remote sensing. Since the year of 2006, together with the University of Debrecen, Department of Water and Environmental Management our Institute have been operating an AISA DUAL airborne twin-sensor system (Specim Ltd.).

The hyperspectral technology has greatly improved the efficiency of data utilization and created new perspective for modern information management in precision agricultural production. With the use of the hyperspectral remote sensing one can record the refletced flux radiation form the studied surface on hundreds of narrow, adjacent bands. Simoultaneously, gray-scale pictures are taken of these bands and recorded separately. This data recording method results in the so called data cube. In this high resolution of spectral information is assigned to all spatial pixel of the data cube, hence the spectral caracteristics of the surface can be mapped by high definition geometrical sampling method up to hundreds of adjacent spectral bands (Figure 9).

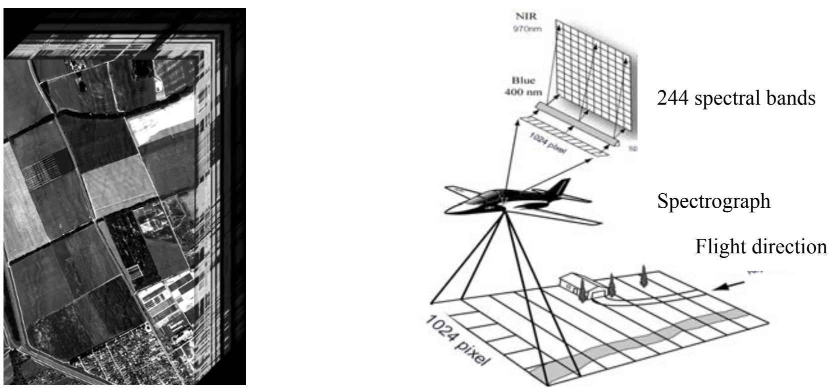


Figure 9 Hyperspectral imaging

In 2010 our Institute purchased an ASD FieldSpec 3 Max portable spectroradiometer in order to expand the available data acquisition system. The integration of in-field and laboratory spectroradiometric measurements is adequate to analyze large areas in a fast, precise and economic way. Data acquisition in the field and under laboratory conditions the spectral sampling results in one pixel, which contains the mean reflectance of the instantaneously scanned surface (Virág and Szőke 2011).

We introduce two systems which extend the range of the detectable (visible light) VIS (Lágymányosi and Szabó 2010, 2011) to NIR (near infrared) and the SWIR (shortwave infrared) that are able to operate in the full optical wavelength range of 400 to 2450 nm (AISA DUAL) and 350 to 2500 nm (ASD Fieldspec®3 MAX). Characteristic near infrared wavelengths can indicate changes in moisture content of vegetables (Kaszab et al. 2008).

Though, the processing of these images is a very complex procedure (Firtha et al. 2008). The coordinates of in-field experiments are recorded and the soil surface spectrum can be fitted to the adequate pixel of the hyperspectral airborne image that is an important element of the subsequent evaluation processes. The number and the quality of in-field measurements determine the final accuracy of the airborne images. Using this new generation data monitoring and sampling methods we can obtain quantitative relationships between the environmental and physiological parameters of the vegetation (Balla et al. 2011), soil quality parameters (Máthé et al. 2012, Tolner 2011) and different sources of soil contaminations, climate attributes (Erdélyi 2009a, 2009b, Tarnawa et al. 2011) and the features of reflectance spectra. The Department of Water and Environmental Management of the University of Debrecen, Centre for Agricultural and Applied Economic Sciences (Burai and Tamás 2005) and the Hungarian Institute of Agricultural Engineering (later Institute) operate the AISA DUAL sensor system of the Finnish Specim Spectral Imaging Ltd. In the year of 2010 the Institute bought an ASD Fieldspec®3 MAX field spectroradiometer to develop the available data acquisition system.

The Hyperspectral group of our Institute offers new generation of data acquisition methods. Beyond the scientific application of the technology our services are available to provide the client (Research Institute, Industrial or Private Companies) with the adequate hyperspectral methodologies to meet agricultural, industrial or other scientific needs.

MATERIALS AND METHODS

The AISA DUAL airborne twin-sensor (Fig. 11), which consist of the EAGLE (Fig 12.) and HAWK (Fig. 10) sensors, that has the potential for detecting the electromagnetic radiation in the wavelength range of 400 to 2450 nm with sub-meter level of spatial precision. During the flight the geographical coordinates and the position of the plane are recorded by Oxford RT-3000 GPS/INS system. Beside the DUAL mode both sensor can be operated depending on the aim of the experiment.

Figure 10 Eagle sensor

Figure 11 AISA DUAL twin-sensor

Figure 12 Hawk sensor

This equipment can be widely used for both in-field and under laboratory measurements. By using the spectroradiometer it is possible to correct and validate the airborne data with in-field and under laboratory measurements. For laboratory tests we constructed a light-isolated cabinet where disturbing environmental light is shielded. The ASD Field Spec®3 MAX portable spectroradiometer (Fig. 13) and the laboratory cabinet are presented in Figure 14.

Figure 13 ASD Field Spec®3 MAX

Figure 14 Laboratory cabinet

Figure 18 ProLamp light source

Figure 16 PlanProbe sensor-head

Two methods of data acquisition are possible according to the size and physical parameters of the object to be tested. ProLamp (Fig. 15) is used to illuminate the object from a distance of 30-70 cm. Measurements of small object areas can be carried out with PlantProbe. sensor-head (Fig 16) which has internal light source.

RESULTS AND DISCUSSION

Identifying different nutrition levels of wheat varieties

Experiments were carried out to identify spectral differences of winter wheat treated with various nutrient dozes. 'Alföld 90' winter wheat variety was tested on agronomic replicated blocks. Each replication had two variants: fertilized and unfertilized. Fertilized variants received 80 kg ha^{-1} nitrogen fertilizer. Samples were collected and analyzed in laboratory. Wheat ears were illuminated with ProLamp, kernel were tested with PlantProbe.

Processing steps were carried out with ENVI software. We used continuum removal to normalize spectra. This made possible to compare the absorption features according to the common baseline (ITTVIS ENVI). Mean reflectance spectra of treatments are presented by Figure 17.

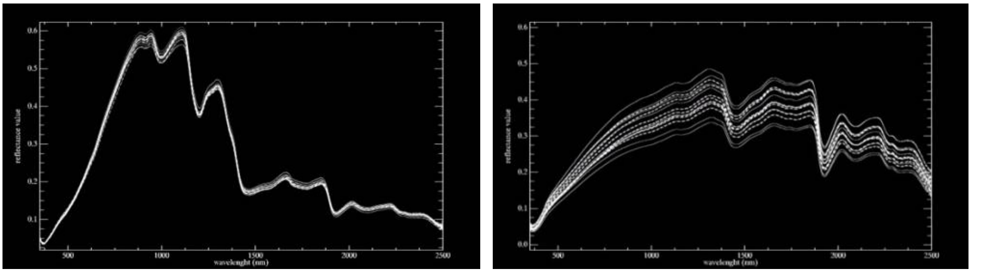


Figure 17 Normal reflectance curves of wheat ears (left) and kernels (right) with (80 kg dashed) and without fertilizer (0 kg - solid lines)

Normalized reflectance spectra with characteristic interval between 1700 nm and 1800 nm wavelength values were found in case of wheat ears and 500 to 800 nm at kernels (Fig 18.).

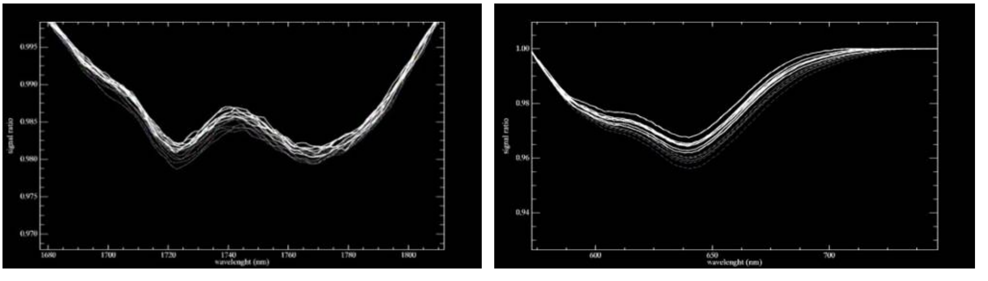


Figure 18 A decreasing trend is indicated in the spectra of nitrogen treated (80 kg - dashed) wheat ears (left) and kernels (right) compared to untreated ones (0 kg – solid lines)

The differences in nitrogen treatment generated changes in spectral features of wheat ears and kernels. After normalizing the spectra we found two characteristic intervals in the wavelength range of 500 to 800 nm for wheat kernel and 1650 nm to 1800 nm for wheat ear samples. Both treatments show the same trend. After evaluating the most important parameters of the winter wheat (yield, protein, wet gluten content) with conventional laboratory technology the interrelation between spectra and nutrition application rate can be determined. Through calibration and validation process spectral instruments can contribute to better description and traction of nutrient supply and plant up-take.

Prediction of soil parameters

Relationships between soil moisture content and reflectance spectra were measured. Partial Least Squares Regression (PLSR) was applied to build predictive models using reflectance spectra acquired under laboratory conditions, and to derive quantitative information on the moisture content of soils. The study area is situated near Mosonmagyaróvár. 200 samples were taken from the upper surface layer. FieldSpec 3 MAX with a Contact Probe attachment was used. During processing PLSR with leave-one-out cross validation (LOOCV) was used to calibrate the spectral data with the soil moisture content (measured in laboratory). The PLSR algorithm selects successive orthogonal factors that maximize the covariance between predictor (spectra) and response (laboratory) data. To determine the number of factors to retain in the calibration models LVOOCV was used. To select the optimal cross validated calibration model, root mean squared error (RMSE) of predictions was computed. The model with the lowest RMSE and highest R^2 was selected. The calibration models were independently validated against the soil data. This calibrated model was applied to a geometrically and atmospherically corrected airborne hyperspectral image using the ITTVIS ENVI and the HySoMa (Hyperspectral Soil Mapper) module. The laboratory analysis showed that the moisture content of the samples ranged from 13,91 to 21.29 %. The number of PLSR factors provided the lowest RMSE and highest R^2 was 9. The predictive capacity of reflectance spectroscopy and PLSR was good (R^2 = 0.744) for the soil moisture content. These results can be explained by the strong spectral activity of water. The accuracy of the model (RMSE = 0.84%), is very good (Fig. 19).

The model was applied to the hyperspectral image. Figure 20. shows the result of the procedure. The spatial distribution of soil moisture values indicates largely inhomogeneous topsoil.

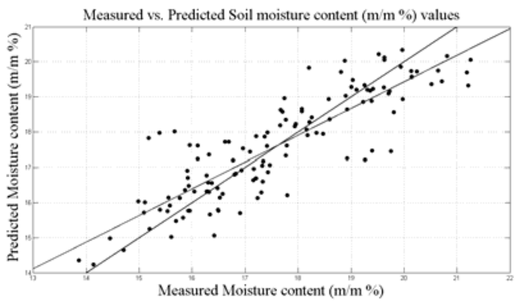


Figure 19 Cross plot of laboratory measured and model predicted values of soil moisture

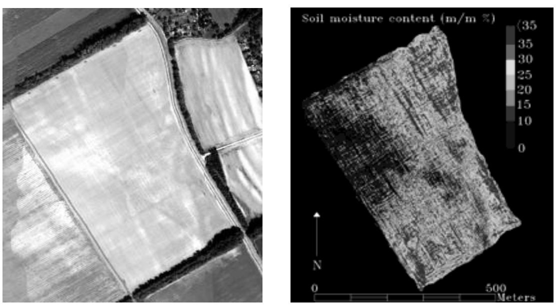


Figure 20 Hyperspectral image (left), extension of model with predicted soil moisture content (right)

Results demonstrated high potential of integrating reflectance spectroscopy and hyperspectral remote sensing by extending laboratory correlations into airborne scale.

Spectral evaluation of artificial illuminants

By the principle of pest's phototaxis and nocturnal habits the Shenzhen Fuwaysun Technology Co., Ltd. has developed a Solar Insect Killer (Fig. 21) - 1. solar cell, 2. power device with battery, 3. light bulb, 4. insect trap.

Figure 21 (FWS-SP05-12/2 type Solar Insect Killer at the MACFRUT 2011. exhibition)

Various illuminants are used to lure different insects into the trap. Very important elements of the system are the special light sources. There are two types, bulbs with wide and with narrow spectral characteristic. Nineteen narrow band illuminants are provided by the supplier. The aim of our project was to evaluate the spectral distribution of each bulb in the wavelength range of 350-2500 nm. In situ (Fig. 22) and ex situ measurements were made under laboratory circumstances (Fig. 23) - 1. light bub, 2. reference panel, 3. optical cable with 8° optic, 4. ASD FieldSpec 3 max - to determine the spectral feature of each illuminant.

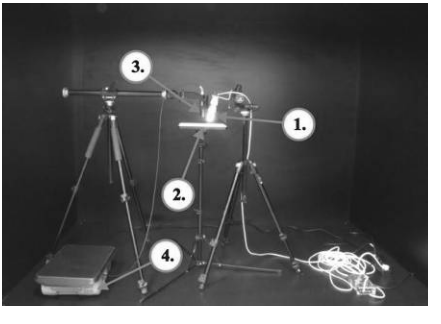
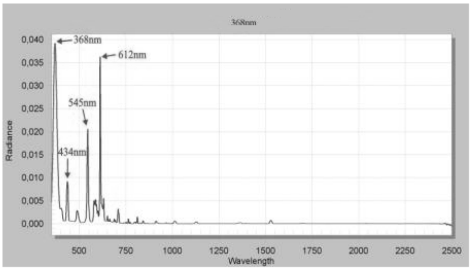


Figure 22 In situ measuring method

Figure 23 Measuring in laboratory cabinet

The results showed that even the narrow band illuminants have several spectral peaks in the visible region and some bulbs have peaks in NIR range as well (Fig. 24 and 25).



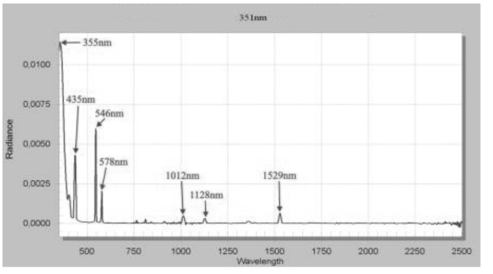


Figure 24 Narrow band illuminant 368 nm

Figure 25 Narrow band illuminant 351 nm

The high resolution spectroradimeter provides the opportunity to enhance the specification of light sources. As insects have very fine and special sensitivity to EM a more precise selection (ex- or inclusion) of relevant spectral peaks can improve the species specific luring or repelling effect.

CONCLUSIONS

The hyperspectral imaging spectroscopy is a promising future tool in the field of optical remote sensing and it creates new perspective for modern information management in site specific agricultural production. One can determine quantitative relationships between the environmental and physiological parameters of vegetation cover and the soil quality parameters as well as the features of the reflectance spectra by the new-generation data monitoring and sampling method. These reflectance spectra have characteristics of different crops and provide with the possibility of accurate classification and detection. Studies confirm the significance of combination of spectroscopic analyses with hyperspectral remotes sensing methods in environmental studies and modelling. Nevertheless, the sole application of the high resolution spectroradiometer has also wide range of utilisation possibilities.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 663/664
Prethodno priopćenje
Preliminary communication

THE DATABASE STRUCTURE FOR TECHNICAL EQUIPMENT FROM AGRICULTURE AND FOOD INDUSTRY

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SUMMARY

The paper presents the structure of a database with machines, technical equipment and installations designed to agriculture and food industry. The range of machines, technical equipment and installations designed to agriculture and food industry is extremely diversified. The information contained in elements that describe and characterize machines, technical equipment and installations designed to agriculture and food industry is complex and require a rigorous organization on various categories, based on specific criteria. Achieving a specific data collection with machines, technical equipment and installations and some data collection with elements common to several machines, groups of machines or agricultural machines in generally constitutes elements that allow different search criteria. The main goal consists in storing, updating and selecting information as decision making support. Database structure used allows easy retrieval and update of information.

Key words: *database structure, machines, agriculture, food industry*

INTRODUCTION

Scientific research, technological development and innovation in agricultural engineering and food industry field lead to achievement of new machines, technical equipment and installations with remarkable performance in labour productivity growth, agricultural production and environmental protection. Thus, application of the new technologies based on machines, technical equipment and installations constitutes special advantages both for users (farmers, agricultural companies, etc.) and environmental protection. Currently, the information on machines, technical equipment and installations designed to agriculture and food industry there is in electronic or printed catalogs and on the Internet, generally being organized in terms of marketing or is detailed presented by companies, without being able to achieve comparative analysis and quantitative, qualitative and economical reports for many suppliers, distributors, resellers, etc..

A database is a structured collection of data stored into electronic form that can be manipulated by a computer and software to easily find the desired information.

Database for technical equipment from agriculture and food industry takes into account the series products and the products in research - development stage, (design, experimental model, and prototype) from various research entities to facilitate the technological transfer and to know the state of the research in this field and also to information exchange. Thus, the database will allows farmers, machines, technical equipment and installations manufacturers and research entities to know the achievements in the field for a marketing and an efficient management [1].

The database structure with machines, technical equipment and installations designed to agriculture and food industry was designed according to the arborescent classification of agricultural machines and equipment, according to ISO 3339-0:1986 "Tractors and machines for agriculture and forestry - Classification and terminology - Part 0: Classification system" according to the destination of machines, technical equipment or installation.

The types of works (agricultural or from food industry) performed by the machines, technical equipment and installations included in database were also a criterion for the classification.

METHODS

Information that substantiates the database was collected from leaflets, presentations on printed catalogues or on web pages of the manufacturers of machines and technical equipment, manuals, brochures, specialized publications, etc. The main types of works executed by the machines and technical equipment classified in the database, starting from tillage, continued with harvesting agricultural products and finishing with the works from food industry, maintenance of green spaces and access roads have been analyzed [2],[3].

The soil works that cover all successive operations executed with mechanized tools starting from seedbed preparation and finishing with the sowing constitute a major chapter of the systematic approach of the information from the field of farm machinery.

The ploughing, the main work of soil is done with mouldboard or disk ploughs, with fixed or variable geometry with one or more coulters, single or reversible or in aggregate with energy sources.

The seeding, as mechanized working process, is characterized by the use of some wide range of mechanical or pneumatic seeders (precision) for cereals or hoes.

The maintaining crops represents the work that follows seeding, with serious consequences on the quality of the harvest, being placed as importance at a level of concern equal to that of crops establishment. Mechanization of all successive operations (weeding, cultivation, plant protection treatments, irrigation, and so on), represents the guaranty of making them in time and at an appropriate quality level.

The hoeing is done mechanically or chemically, with specialized machines and equipment, aggregate to energy sources adequate to worked surfaces, equipped with passive and active bodies.

The plant protection treatments are performed with a wide range of machines sizes, providing competitive performance for the benefit of users from all manufacturing sectors, from small and medium farms, to the large ones.

The crops irrigation is done using appropriate installations, stationary or mobile, equipped with automatic control systems and dosing water flow.

The harvesting of grain straw, corn, sunflower or technical and medicinal plants by mechanical means is made with a variety of sizes of self-propelled or towed harvesters with headers and interchangeable cleaning systems, depending on the harvested culture, with conventional battery system or on new principles, equipped with electronic adjustment systems and control of work quality.

The forage harvesting covers a comparable share to that designed to mechanize harvesting of grain products.

The mowing of forage mass cultivated on plain, hill, or mountain meadows**, the raking** in order to disarrangement or gathering hay in the swath is made using some equipment towed or carried on the tractor in the front, side or rear, mechanical or hydrostatic driven.

The works in fruit growing and viticulture, by their nature occupies a separate chapter, due to both climatic and relief particularities, the time when they are realized, and the great amount of needed work.

The cutting in green or dry of trees, especially in intensive orchards with cutting and contour shaped machine, then chopped dried or green branches fallen between rows and mowing grass in the same time with throwing vegetal mass on the row of trees in the form of mulch are only some examples of mechanical works.

The cutting green shoots of vines with a machine placed in front of the vineyard tractor, in the same time with soil preparation by a properly equipment placed in back (disc harrow, cultivator, etc..) provides the possibility to maintain permanently vineyards cultures in a state of optimal vegetation with special effects on grapes production.

The harvesting works of vegetable, potato and sugar beet with machines and technical equipment is still subject to research, because of the complexity of the processes resulted from the interaction between plant – machine and great diversity of physic-mechanical characteristics of useful product of each crop.

The baling with mechanized means of straw, hay or other vegetable products in order to their subsequent capitalization in different purposes (feed for animals, pulp industry, chemical industry, unconventional fuel, etc..), solves concomitant with the priority destination and a rapid release of the land, creating the possibility of starting soil works for the next crop.

The transport and handling of agricultural products and livestock are executed with respecting the regulations in force on public roads and exploitation of mechanized means used for this purpose, according to work safety rules.

The works mechanization in milling, silos and food industry are based on installations of cereals storage and preservation, milling combined installations of low capacity for wheat and maize, machines and installations for combustible oil extraction, equipment for liquids packed in cups or other types of packaging, complete sets of equipment for brewing industry, ovens and other equipment for bakery products etc.

The mechanization in small and medium farms includes, in fact, a very wide range of machines, technical equipment and installations that form a series of systems, grouped into different classes of power (usually up to 25 hp), fully covering the general requirements, or those specific to specialization of these units (cereal crops, horticulture, livestock, and so on).

The maintenance of green spaces and access roads designed public or private domain, through mechanization of all necessary works to be carried out practically throughout the year is done with a series of machines and equipment that are mounted on different universal motor cultivators of different powers or on the specialized energy sources.

DATABASE STRUCTURE

The structure of information in the database with machines, technical equipment and installations designed to agriculture and food industry has been made on levels in groups according to utilization domain (ISO 3339-0:1986):

1. Power and traction equipment for working the soil
2. Machines and equipment for prospecting, drilling, land reclamation, land clearing and forestry
3. Machines and equipment for working the soil
4. Machines and equipment for sowing and planting
5. Machines and equipment for applying fertilizers, soil conditioners and water
6. Machines and equipment for plant care and protection
7. Machines and equipment for harvesting
8. Post-harvesting machines and equipment
9. Machines and equipment for handling, transport and storage
10. Machines and equipment for livestock production
11. Miscellaneous farmstead equipment

The first level contains the group code and its name. In turn, this group contains one or more subgroups, which are located on the second level. Follow up to level 5 a particularization of subgroups. The code of the end of level symbolizes its end, case when the value is zero, or continue particularization for the value 1.

The following is presenting the particularization on levels of the main group (ISO 3339-0:1986):

Group 03: Machines and equipment for working the soil

03.1 Equipment for ploughing

03.2 Equipment for seedbed preparation

03.3 Equipment for working the soil between rows

03.4 Equipment for horticultural soil preparation

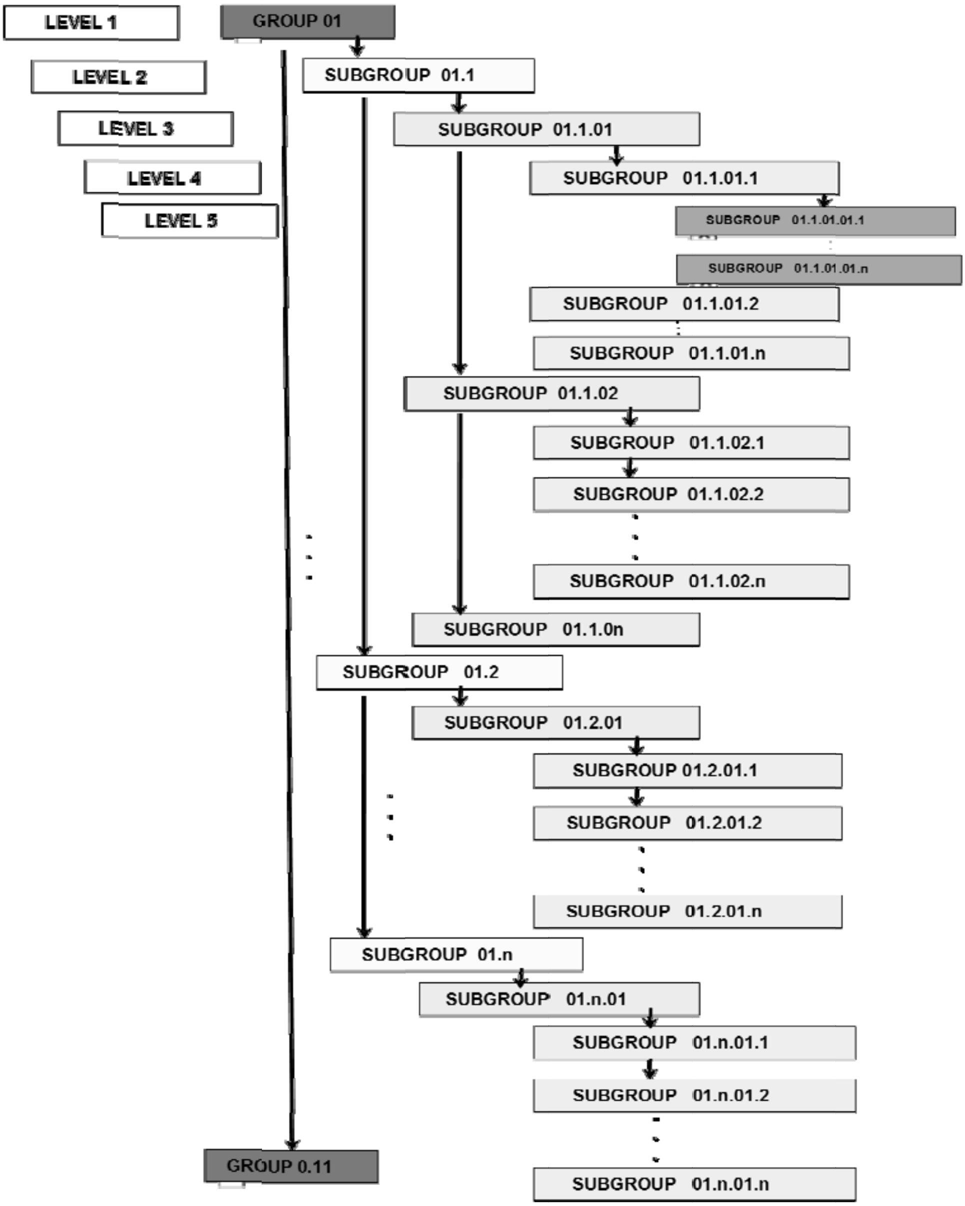

Figure 1 The information classification on levels, groups and subgroups

The next example presents the information structuring for the group 3 "Equipment for working the soil between rows» after the utilization domain at the level of groups and subgroups.

a) 03.1 Equipment for ploughing

03.1.04 Ploughs with shares (mouldboard)

03.1.04.2 Ploughs with shares (mouldboard) reversible

03.1.04.2.1 Ploughs with transverse rollover axis

03.1.04.2.2 Brabant plough

03.1.04.2.3 Ploughs with shares (mouldboard) ½ rev

03.1.04.2.4 Ploughs with shares (mouldboard) ¼ rev

03.1.04.2.5 Ploughs with shares (mouldboard) rotating

03.1.04.2.6 Ploughs with shares (mouldboard) for motorcultivator

b) 03.2 Equipment for seedbed preparation

03.02.03. Finishing harrows

03.2.03.1 Harrows with fixed fangs

03.2.03.1.1 with chain

03.2.03.1.1 without chain

From the structural point of view we can generalize the classification of information in figure 1.

RESULTS AND DISCUSSION

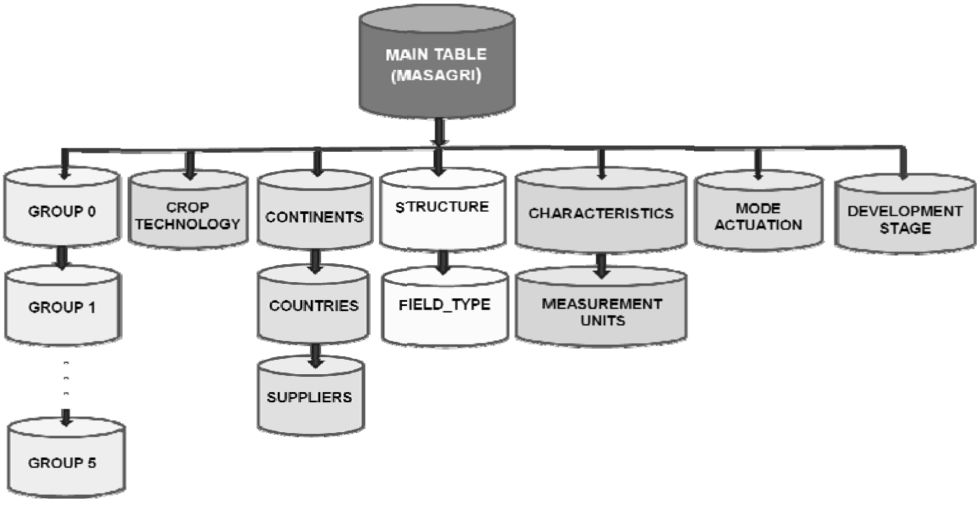

Figure 2 Database structure with all tables

The database structure was designed based on above classification and on all information necessary to describe all characteristics for the technical equipment from agriculture and food industry (figure 2).

The tree structure has many branches. Each branch has one to five levels. Connection between the branch level is based on the keys and codes indexed or not. It also connects the main database and other tables are similar.

All links were designed in a manner as simple and natural as possible. Implementing the structure were used programming facilities of a modern DBMS (DataBase Management System). Were widely used forms screen for entering and viewing data, vertical and horizontal menus, views and queries for data visualization and editing reports, etc.. There is a basis of predefined reports, but the user can achieve its report according to the information he wants to extract them from the database. All these things lead to an easy and friendly use and the database [4].

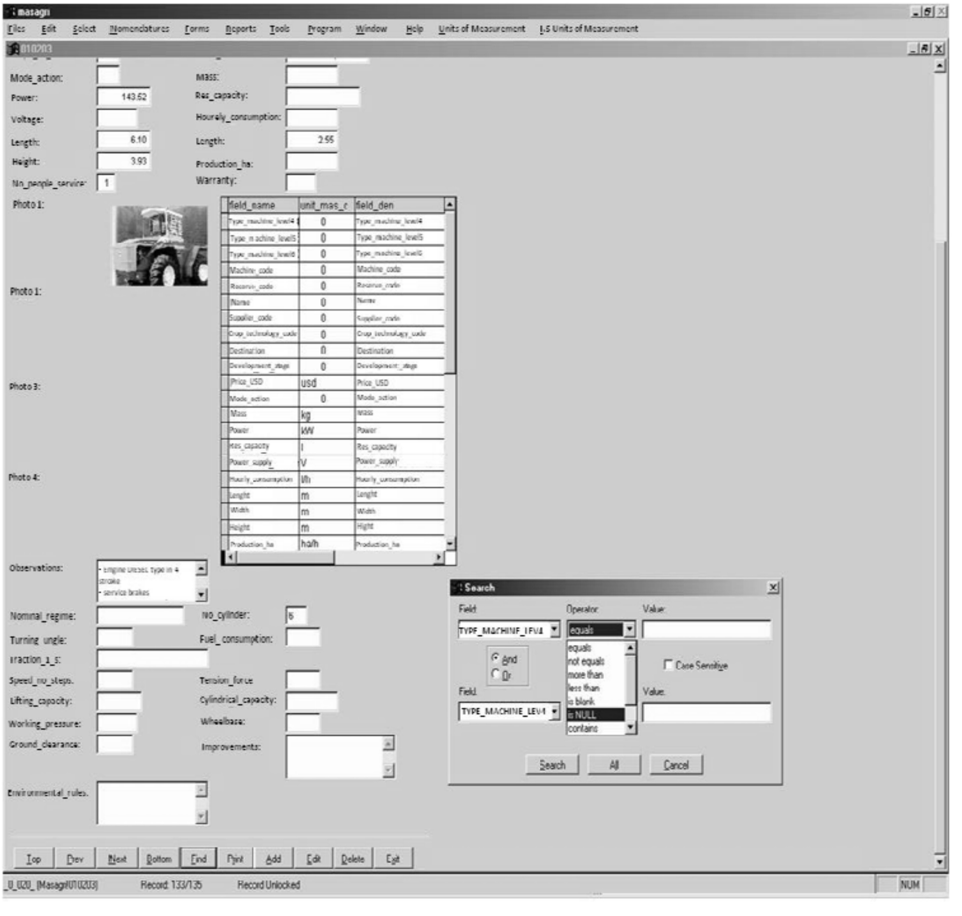

Figure 3 Search by logical operator between value fields

For example the database uses about 130 characteristics to describe all type of equipment. Some characteristics are common for a group of equipment or for all equipment (price, size, weight, etc.). Many characteristics have a unit of measurement. The system gives the possibility to use more measurement units and convert it to international system of measurement units.

The database together with operating software was implemented on a Windows platform using Visual FoxPro programming language.

The database is stored on a file server and is accessed by a network (client-server architecture). The server maintenance includes database maintenance to confirm that it work properly. This task will be performed automatically or by server administrator. The database administrator also will check the database for integrity and consistency from time to time (once on week at minimum). If there are any signs of corruption the administrator will rebuild the indexes, will remove duplicate records, etc.

Database can be implemented on the web in a similar structure using appropriate client-server architecture [5], [6]. In this way the number of users grows exponentially.

The next picture show screenshot depicting relevant issues during use the information system of database management (Figure 3).

CONCLUSIONS

1. Database structure used allows easy retrieval and update of information.
2. Database together with operating software and its use was implemented on Windows platform. Computers use programs in Visual FoxPro. The hardware requirements are common at a level of medium power office computer. The only special requirement refers to the storage space which depends largely on the number of machines introduced, to a number of the hundreds we need a space of hundreds of Mb order.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 628.2:631.223.2
Prethodno priopćenje
Preliminary communication

SPATIAL DISTRIBUTIONS OF AIR HUMIDITY IN A COWS BARN UNDER DIFFERENT RATES OF FORCED VENTILATION

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SUMMARY

Relative air humidity is important microclimate parameter of each livestock building. Increased air humidity affects the indoor air quality and, consequently, the animal and workers health. Among others, ventilation rate crucially controls the spatial distribution of air humidity in livestock buildings. This fact motivated authors of this paper to research the influence of air flow rate of under-roof axial fans on relative air humidity distribution over the tied cows house. During a series of performed experiments, six different air flow rates have been maintained in the range between 0 $m^3 \cdot h^{-1}$ *and 48000* $m^3 \cdot h^{-1}$*. Flow rate has been electronically controlled, providing six different rotation rates of two under-roof fans, including the neutral regime (natural ventilation only). Measurements have been performed at four typical height levels (0,5 m; 1,0 m; 1,5 m and 2,0 m), cross-over the three lateral and four longitudinal characteristic building sections. Therefore, the indoor space was adequately covered by 48 measuring points. Comparative analysis of air flow velocities and relative air humilities in certain measuring points showed that this fan setup may provide satisfactory microclimate conditions under adequate operational regime. Certain fan rotation rates are recommended for use, and the third rotation rate step, generating the airflow of 37300* $m^3 \cdot h^{-1}$ *or indoor air exchange level of approximately 25* h^{-1}*, is recommended as the most appropriate.*

Key words: *fan flow rate, airflow velocity, air humidity, livestock buildings, tied cows*

INTRODUCTION

Tie stall barns require a ventilation system that allows close control of air exchange, temperature and humidity. Appropriate air distribution is especially critical because the cows are restrained and cannot move out of drafts or poorly ventilated areas.

Environmental temperature, relative humidity and air speed determine the degree of heat stress (De Rensis and Scaramuzzi 2003). Heat stress can be defined as any combination of environmental factors leading to the deterioration of conditions in comparison to the optimum conditions prevailing in the thermal comfort of animals. Temperature-humidity index (THI), which incorporates ambient temperature and humidity is commonly used worldwide to determine the influence of heat stress on high yield cows (Fuquay 1981).

Mature cow will breathe out four gallons of water per day in the form of water vapor and produce almost 1000 watts of heat. When animals are confined in tie stall barns a ventilation system is needed to continuously exchange warm, moist indoor air for drier, cool outside air. Typically, Holstein cows can maintain high levels of productivity between -5°C and 25°C, as long as relative humidity is not allowed to go too high (Graves 1995).

Barns with only sidewall ventilation are a particular challenge. These barns exhaust warm moist air along both sidewalls. On still days this plume of warm moist air may flow into attic ventilation openings along the eaves. Large quantities of warm moist air diverted into attic spaces will condense or freeze on cold roof surfaces and subsequently cause damage to insulation and building components. It is important to have sufficient air exchanges to keep the barn air dry and fresh.

So far, a wide variety of research attempts related to enriching and verification of the available data bases and/or modeling the governing parameters of various production processes in animal husbandry have been made (Pearson and Sharples 1995, Petrović and Topisirović 1997, Petrović *et al*. 1998, Takai *et al*. 1998, Petrović *et al*. 1999, Jacobson *et al*. 2008, Topisirović and Djurić, 2008, Bartzanas *et al*. 2010). Following this practice, this study analyzes the influence of flow rate of multi-regime roof fans on the air relative humidity. On the base of performed experiments, recommendations on fan usage and settings are given.

METHODS

In this study are presented experimental results of researching the effect of De Laval ventilation system Multifan with control unit STD (Manual 8 A thermostatic controller T15 - WD and DF 1300 fans) on the spatial distribution of relative air humidity values.

This system can operate at six different rotation rate regimes. Three axial fans of indoor type, are located below the roof, but above the feeding alley. Maximum fan capacity is 48000 $m^3 \cdot h^{-1}$, at negligible pressure difference and the maximum rotation speed of 400 rpm.

Measurements in the experimental cows barn are carried out at 48 measurement points (Fig. 1). These points were arranged in three lateral sections, with 4 vertical rows in each section, and the four height levels (0,5 m; 1,0 m; 1,5 m and 2,0 m). Lateral measuring sections were placed in 3 distinctive parts, as it is presented in Fig.1.

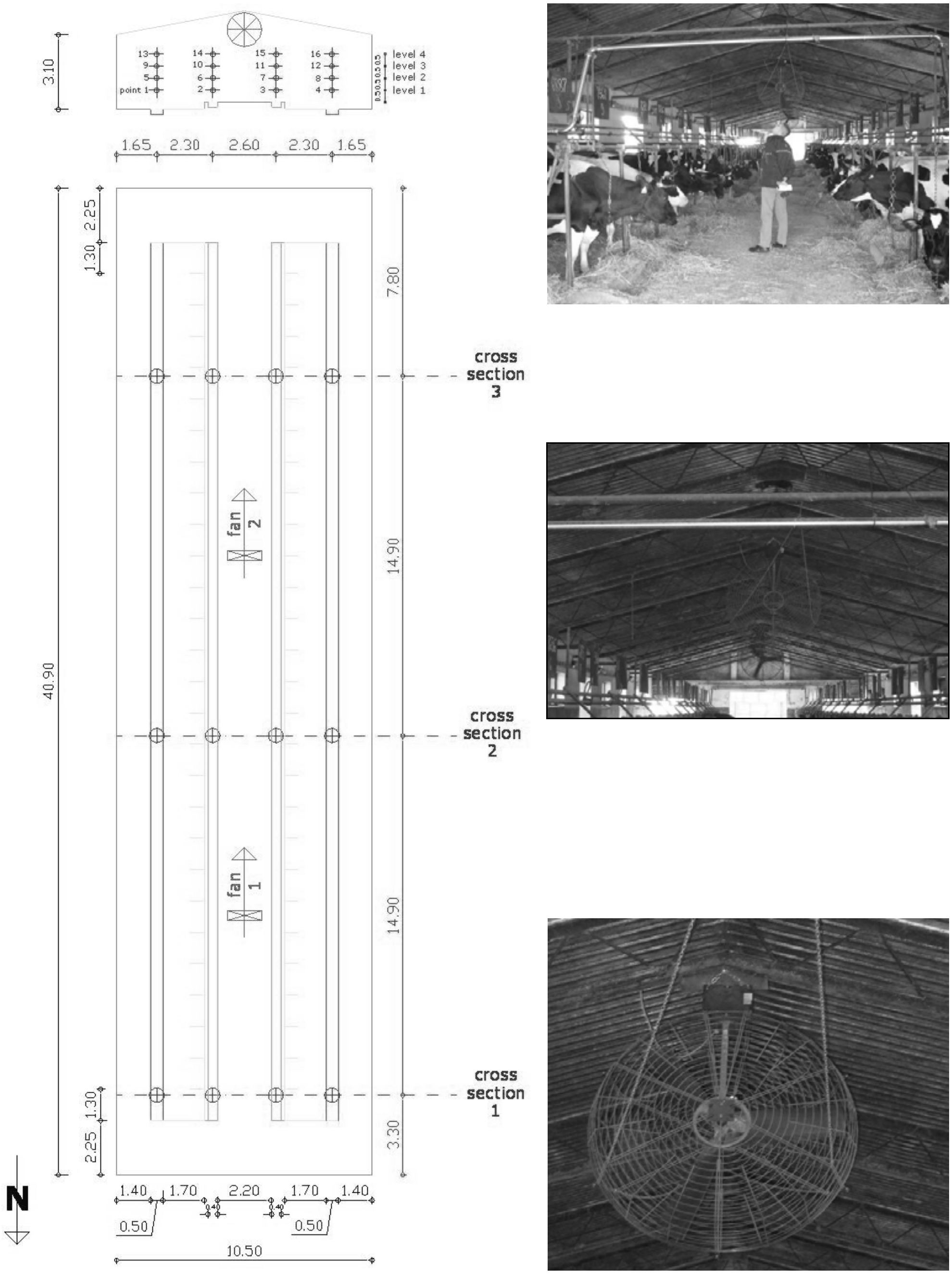

Figure 1 Building layout and map of measuring points locations (left), with photos of indoor ambient (right)

The first section was set at 3.30 m from the front door to the feeding alley on the north side, while the other two lateral sections were placed in a way to provide the distance of 14.90 m between any of two subsequent sections. This way, the fans influence zones are completely covered.

Vertical arrays are placed symmetrically, above the feeding places and manure channels (Curtis et al., 1996). Height levels are at 50, 100, 150 and 200 cm, with the same goal as in the previous case. Relative air humidity has been measured under carefully controlled indoor conditions. The measurements have been performed for five different fan operating regimes and neutral regime (natural ventilation).

During the whole experiment, a special care was taken in order to provide fairly stable values of outdoor air parameters. This way, during the all six measurement series temperature was in range t = 20.1 - 22.3°C, relative humidity varied between φ = 62 – 66,1% and intensity of air velocity was in range v = 0,15 – 0,4 $m \cdot s^{-1}$.

For measurements of air flow velocity, air temperature and relative air humidity were used:

- turbine type anemometer with measuring interval 0.8 - 15 m/sec (accuracy ±3%) and sensors for air temperature (-5ºC - 65ºC, accuracy ±1ºC) and relative air humidity (10% - 95%, accuracy ±3%),
- hot-wire anemometer with measuring interval 0 – 20 m/s (accuracy ±3%) and sensor for air temperature 0 – 80 °C (accuracy ±1ºC).

RESULTS AND DISCUSSION

During the first measurement series fans were switched off. In those conditions, relative air humidity values in different parts of the experimental cow barn depend on natural ventilation, i.e. on the natural air flow. Consequently, air humidity values were higher compared to corresponding measurement results when roof fans were switched on – operating at any flow rate (Figures 2a - 4a, respectively). Air humidity was fairly uniform over the object volume, which confirms stationary state of air velocity fields during the absence of forced ventilation. Some rare in-homogeneities of humidity field are caused by cows activity, different bedding composition, concentrated feeds distribution, etc.

The second series of measurements was performed under the controlled fans nominal air flow of 23750 $m^3 \cdot h^{-1}$. This operation regime resulted in the lowest air humidity values, with respect to all other operating regimes (Figures 2b to 4b, respectively). In this mode, fans provide adequate air exchange and acceptable air flow velocity. All those issues resulted in reduced air humidity in the stable, compared to other fans operating regimes - the average air humidity decreased from 62.8% (natural ventilation, Q = 0 $m^3 \cdot h^{-1}$ - Figs. 2a to 4a) to 53.1% (forced ventilation, Q = 23750 $m^3 \cdot h^{-1}$ - Figs. 2b to 4b).

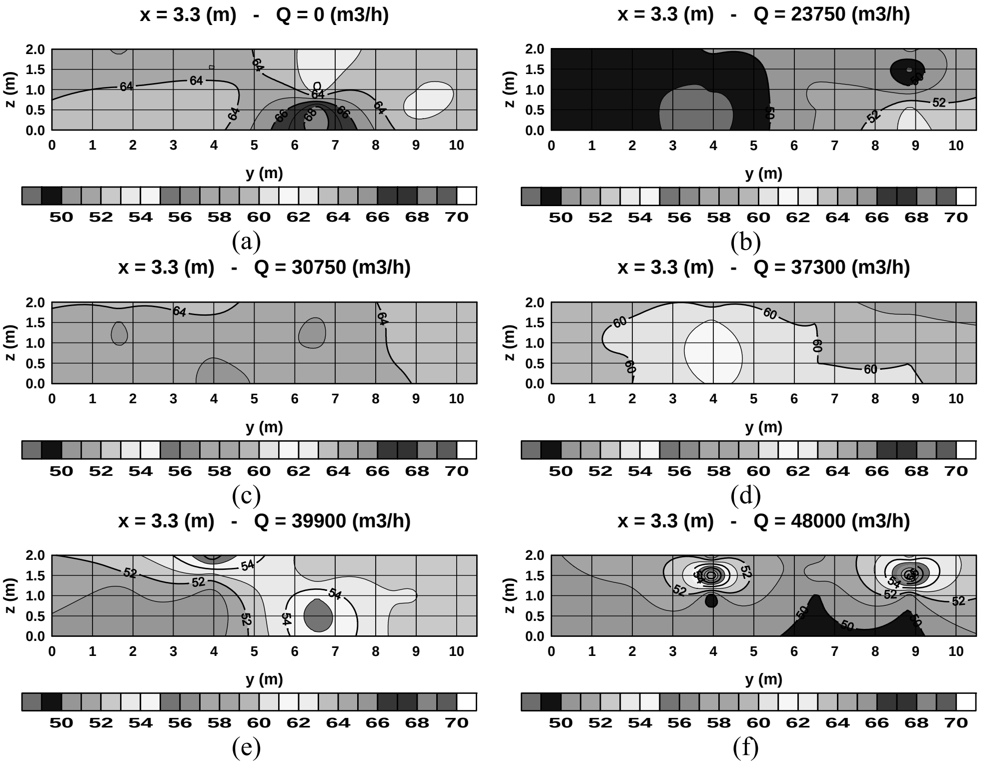

Figure 2 Distributions of relative air humidity across the first cross section at 3,3 m from the feeding alley entrance, under different operating regimes of roof fans

The third series of measurements comprehended 2nd fan operating regime with nominal air flow rate of 30750 $m^3 \cdot h^{-1}$. The highest air humidity values in the experimental facility were recorded (Figures 2c to 4c, respectively) in this regime, compared to all the other regimes (excluding switched-off fans). It can be expected that air humidity would additionally decrease after a longer fan operation.

During the fourth (Figures 2d to 4d, respectively) *and fifth* (Figures 2e to 4e, respectively) *series of measurements*, that included 3rd and 4th fan operating regime (respectively) with nominal flow rates of 37300 $m^3 \cdot h^{-1}$ and 39900 $m^3 \cdot h^{-1}$ (respectively), reduction of air moisture content was observed. Fairly uniform air humidity distribution was established in the barn. In these operating regimes, convective transport (exhaust) of moisture content exceeds moisture production from the animals and wet surfaces within the facility, and its introduction into the air flow.

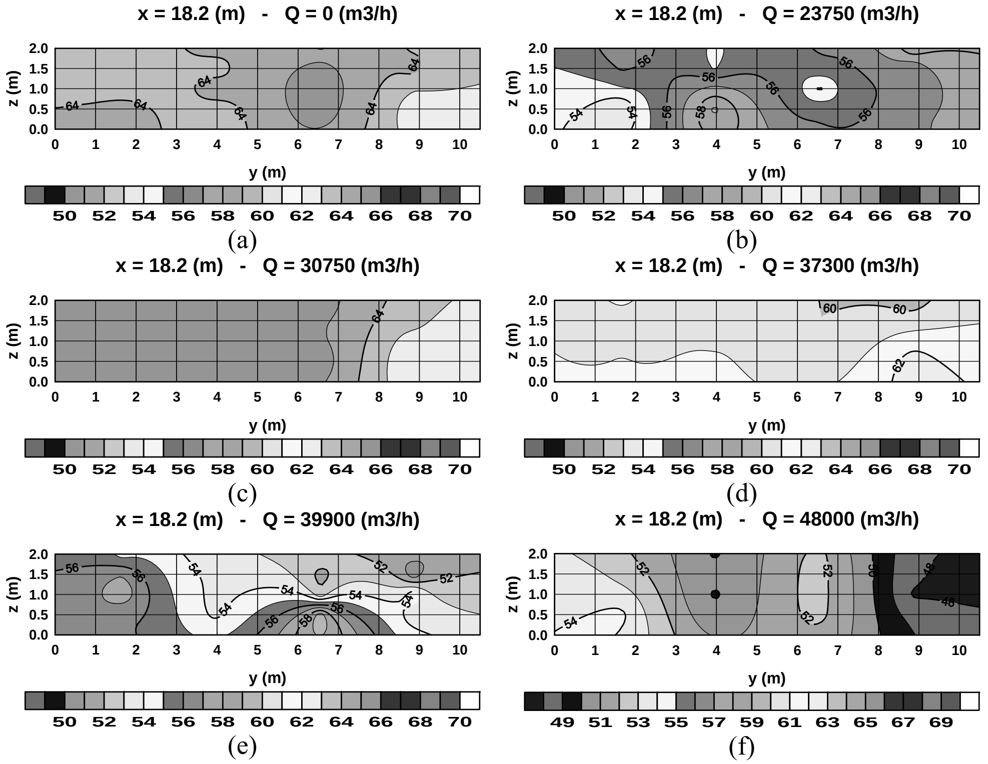

Figure 3 Distributions of relative air humidity across the first cross section at 18,2 m from the feeding alley entrance, under different operating regimes of roof fans

The last, sixth series of measurements included 5th fan operating regime with maximum air flow of 48000 $m^3 \cdot h^{-1}$. Relative air humidity continued further reduction (Figures 2f to 4f, respectively), as a result of intensive inlet of outside dry air, due to the increased airflow velocity in the house.

After comparison of air humidity under different fan operating regimes, as well as no ventilation/natural ventilation regime, it can be concluded that, for air exchange in summer conditions, the optimal operating regime is 2nd (30750 $m^3 \cdot h^{-1}$). Natural ventilation (no ventilation regime) had also acceptable results of relative air humidity in the barn, concerning optimal desired value of 60 – 80% (Topisirović and Tošić. 1992.). According to this criteria, in 2nd regime, along with optimal airflow velocities, the best effects of subjective feeling were achieved.

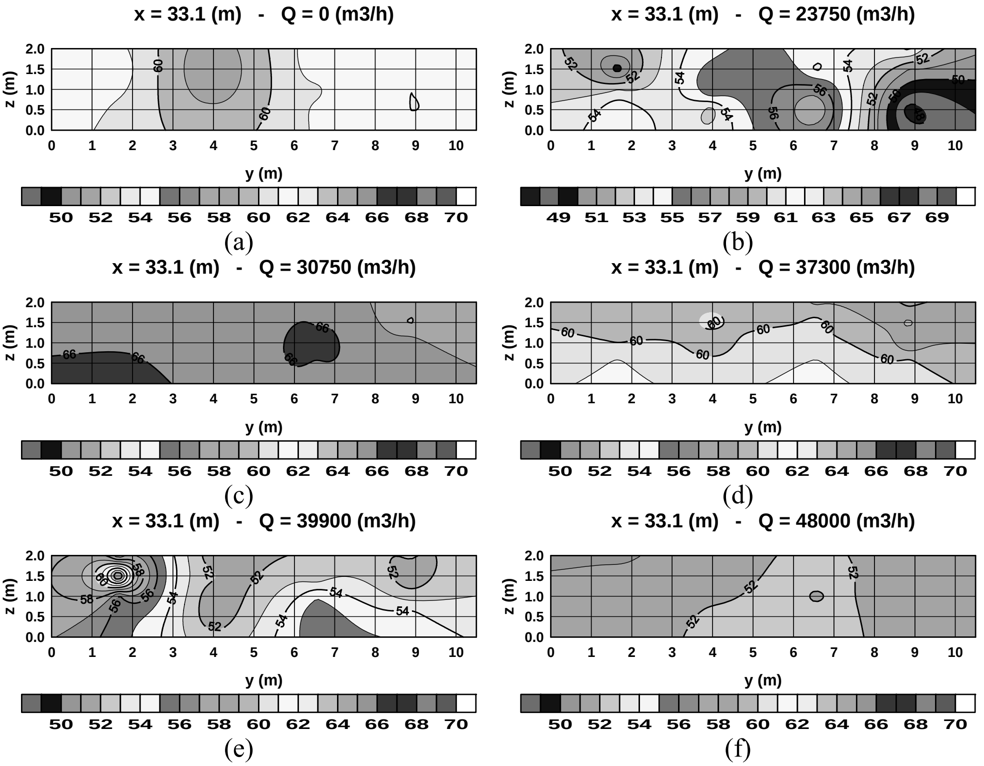

Figure 4 Distributions of relative air humidity across the first cross section at 33,1 m from the feeding alley entrance, under different operating regimes of roof fans

CONCLUSIONS

Careful and detailed analysis of measurement results of relative air humidity in the cows barn, with respect to the optimal fan airflow capacity requested in such buildings, it may be concluded that the best effect in relative humidity control was achieved by the lower fan rotation speed. The second operational regime (30750 m3·h-1) of the ventilation systems is particularly favorable, but also acceptable is no ventilation/natural ventilation regime. In those conditions very stable and effective air humidity control was achieved (60 – 80%), with airflow velocities that are within the optimal intervals for summer conditions (0.2 - 0.9 m·s-1).

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Optimization of technological procedures and zoo-technical resources on farms in purpose of milk production sustainability improvement (TR31086), Improvement of biotechnological procedures as a function of rational utilization of energy, agricultural products productivity and quality increase (TR 31051),

Improvement and development new technological procedures in production of animal products, to achieve high quality and safe competitive products in market (III46009).

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 664.71
Originalni znanstveni rad
Original scientific paper

STRUCTURAL MODEL FOR AN ACTUATION MECHANISM OF PLANSIFTERS IN WHEAT MILLS

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ABSTRACT

Plansifters for sifting and sorting the grist products in the facilities of wheat flour production must provide a plane circular translational motion to all the sieve frames.

Actuation of the equipments and their equilibration is performed often with mechanisms provided with centrifugal unbalanced masses into rotary motion, performing the circular movement of sieve frames at a range of the trajectory to an adjustable value.

Newest, there is sifting equipments with double the number of sieve blocks, mounted two by two, on the same frame support, in this situation the equilibration is easier to achieve.

The operating mechanism is, in this situation, a crankshaft, equipped with two eccentric for the two pairs of sifting blocks.

During the operation, the center of sieve block moves on a circle C1, of radius r1, equal to the eccentricity of the drive system. At one point inertial forces applied perpendicular to the axes of sieve blocks is equilibrating each other. Still, due to the eccentricity of the drive system, remains a twisting moment, in principal axle, equal to 2m·r_1·ω^2, where m is the mass of a cylinder. This moment may be compensated (equilibrated) by means of an elastic system plates mounted between the two support plates which stiffens the pairs of cylinders.

This paper presents a simplified mathematical model for calculating equlibration of the plansifter actuated by such a mechanism.

The results can be helpful to the designers and manufacturers of sifting and sorting equipments of the grist products in wheat mills.

Key words*: plansifter, action drive, kinematical structure, mechanism balancing*

INTRODUCTION AND LITERATURE REVIEW

Plansifters are the main sorting equipment by fraction of grist in milling units. In most cases, these have two bodies, each with one, two, three or four plansifter compartments, within which overlapping sifting frames are placed on packages. From each frames package are obtain at least a grist fraction which may be a groats (oversized), semolina, a dust, flour or bran.

Groats, semolina and dust are fractions that re-enter into the grinding and sorting by fractions process until the entire quantity of flour (for which the mill was regulated technologically) is extracted from the full content of cereal seed.

Generally, plansifters are actuated by actuator mechanisms which allow a movement plane-circular, each point on the sieve describing a circle of radius equal to the eccentricity of actuator mechanism [1,5,9].

Actuator mechanisms are extremely varied, but all are based on actuation with an eccentric shaft and equilibration via two centrifugal counterweights. On these equipments, equilibration is very important, often being very hard to do. An improper equilibration may decrease the lifetime of equipment and can seriously affect the efficiency of sifting.

M. Fiorini in [4] proposes the use of counterweights with height almost equal to the height of equipment to equilibrate the plansifter. This constructive solution leads to a better and easier equilibration performing, but has the disadvantage of weight gain and decrease of equipment life, [10,3].

Likewise, in paper [2] is highlights the fact that during startup of equipment, radius of the motion circle of plansifter in transitional regime increase perceptible until the revolution speed of the actuator mechanism passes by resonance zone and optimum revolution speed is reached. Thus, a heavy weight of equipment leads to a great start time and invariably to high energy consumption.

To decrease the starting time of the plansifter and to eliminate the retarded resonance during this staring period Qiu Ming [8] propose to attach to actuation systems of plansifter a self-adjustable inertial exciter. Having regard to the mechanical characteristic of three-phase asynchronous motor which put into operation the plansifter, as well as the friction torque of bearing he established the nonlinear dynamic model of the system consisting of the body of sifter, the suspenders and the exciter. Qiu Ming used the 4th order Runge-Kutta law to simulate the starting process in Matlab and the results have shown that, using self-adjustable inertial exciter, the maximum instantaneous amplitude and the starting time can be greatly shortened during starting period

Also Qiu Ming in paper [7], using the method described above show that, by using this self-adjustable exciter inertial, the resonant stresses in equipment and stopping time is reduced.

In paper [6], Qiu Ming subjected a plansifter to a finite element analysis revealing that the maximum stress point coincides with the point of rupture of plansifter. Breaking occurs to several factors such as weight of counterweights, improper revolution speed of equipment, inadequate equilibration as well as the size of frame support.

To cover some of these deficits, in the last time there appeared a new constructive solution [11], whose actuation mechanism is discussed in detail in this paper.

MATERIALS, METHODS AND PROCEDURES

A new actuation system of plansifter has been implemented by companies specialized in construction of equipments for milling (fig. 1). The system has four units of sieves, two by two being fixed diagonally opposite on each one frame (yoke) suspended on the ceiling through four elastic support of plastic reinforced with fiberglass. The two yokes that secure the four units of plansifter are connected in the intersection with four double-bearing in order to absorb the centrifugal forces. The two units are equilibrating each other in oscillating circular motion. Transmit of motion is performed by a drive shaft from a 1.5-2.2 kW electric motor.

Each plansifter compartment consists of a two-piece cylinder, closing a stack of square sieving frames. Between carcass and sieves stack can be arranged between 4-12 channels for the movement of grist products, and can thus obtain a variety of fraction.

Inside stack site, can be arranged in series or in parallel, forming interior scheme of the complex plane site that meets the technological process.

Fig. 1 Plansifter with circular bodies and its actuating mechanism (views)

RESULTS AND DISCUSION

A sieving battery consists of four interlocking cylinders, two by two on the diagonal of platforms I and II (fig. 2,a).

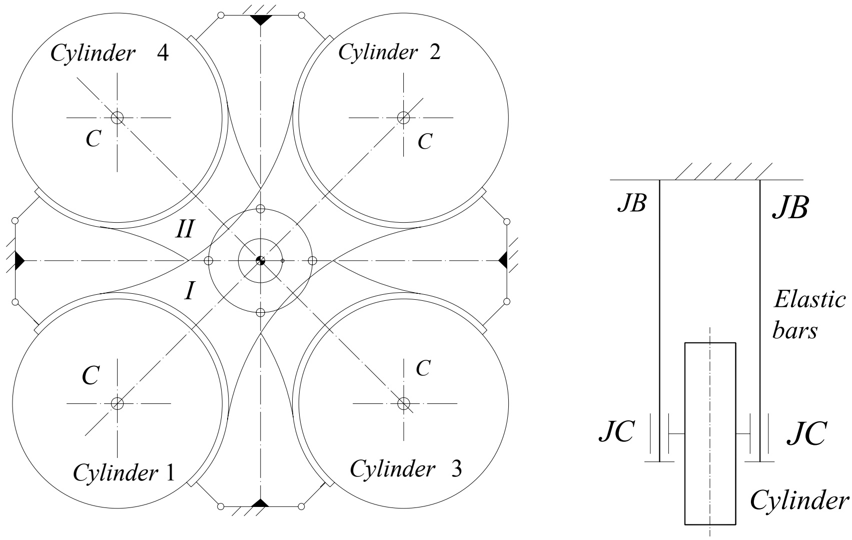

Fig. 2 Plansifter with four sifting units (a) and the suspend mode (b)

In initial position these cylinder occupy the corner of a square. Sifting cylinders are suspended of some steel beams through elastic bar, as it can be seen in fig.2,b. Cylinder oscillation movement is received from an electric motor through a belt transmission, a coupling with claws, a vertical shaft and two crankpin M1 and M2. Phase shift of the two crankpins is of 180° (fig.3).

Both platforms I and II are articulated with each other, thus forming a set of four parallelograms arranged at 90° to each other, as it can be seen in fig.5(a,b). This disposal of parallelograms is designed to overcome the dead spots, which occur when bars 1, 2 and 3 (or 1, 2 and 6) are overlapping.

Forces that appear at plansifter blocks actuation, show schematically in fig.4, are: G_1 – weight of the two plansifter bodies mounted on the upper yoke (framework), applied in its center of gravity (considered the center of upper crankpin bearing); G_2 – weight of the two plansifter bodies mounted on the lower yoke (framework), applied in its center of gravity (considered the center of lower crankpin bearing); P_1, P_2 – centrifugal forces of circular movement of plansifter for the two blocks of frames (fixed two by two on the same frame), that have expressions:

$$P_1 = \frac{G_1}{g} r_1 \omega^2 \qquad P_2 = \frac{G_2}{g} r_1 \omega^2 \tag{1}$$

where: ω is the angular velocity of the shaft with eccentric; r_1 – the radius of a eccentric (crankpin).

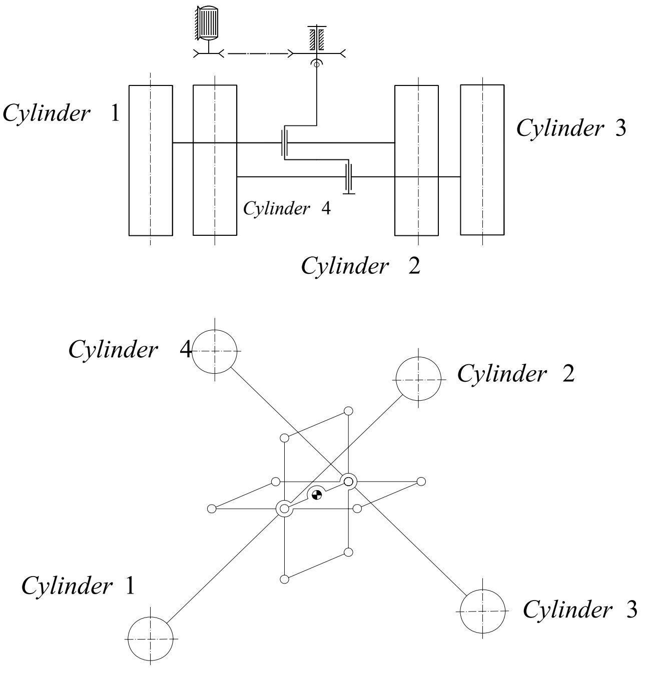

Fig. 3 Actuation system of plansifter and phase shift of the crankpin

To determine the plansifter equilibration is made also the hypothesis that the center of gravity of the entire equipment is located on the vertical that passes through main bearing of actuation shaft with two eccentric at halfway between the two yokes. According to fig.4, for static equilibration of equipment should be fulfilled relationship:

$$G_1 r_1 = G_2 r_1 \tag{2}$$

For the dynamic equilibration is necessary that centrifugal force to be equal, namely:

$$P_1 = P_2 \qquad \frac{G_1}{g} r_1 \omega^2 = \frac{G_2}{g} r_1 \omega^2 \tag{3}$$

from where results that the masses of the two plansifter units together with framework should be equal.

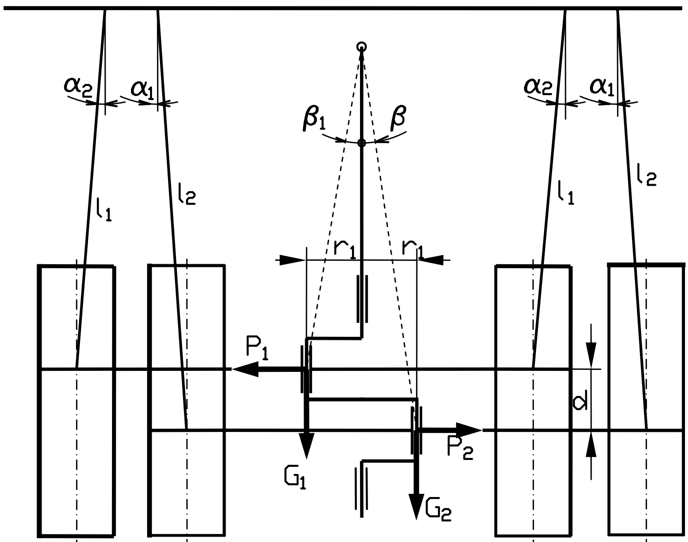

Fig. 4 Scheme for calculating the equilibration of plansifter actuated with a shaft with two eccentric

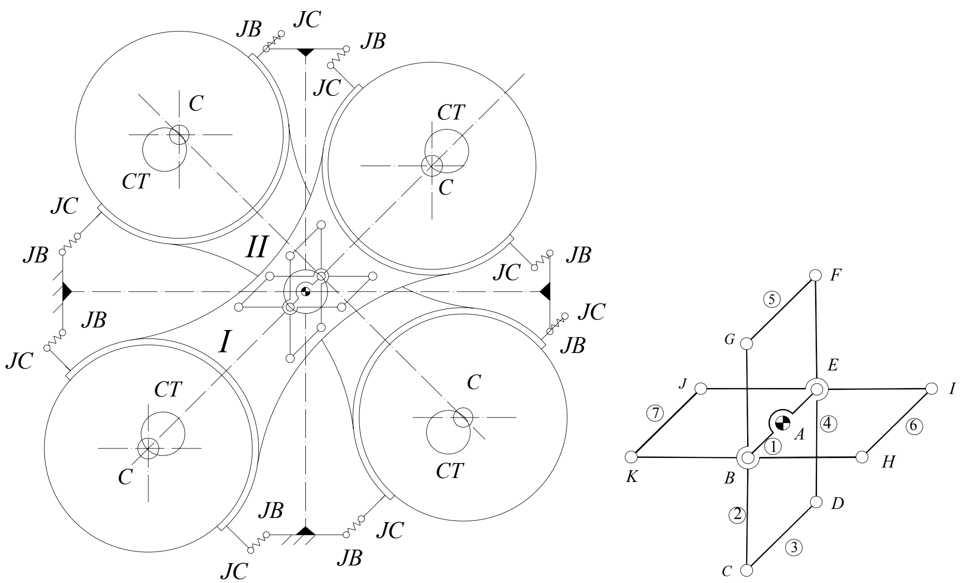

Fig. 5 Fixing platforms of the sifting units (a) and system of parallelograms of their articulation (b)

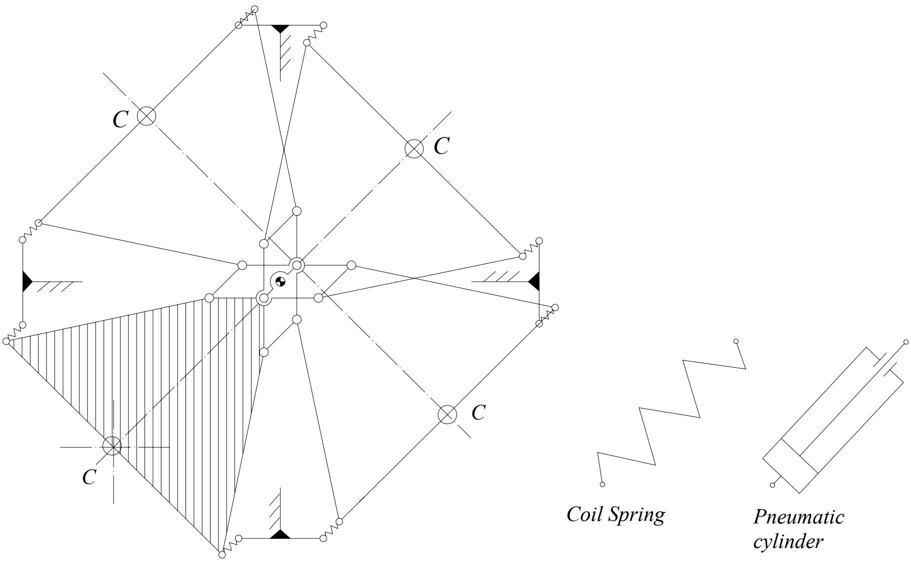

Fig. 6 Complete kinematic scheme of the actuation system (a) and manner of the equivalence of links with the vertical elastic supports ((b)

Considering that upper bearing of the actuation shaft is on the same horizontal with the points of fixation of the elastic support of each plansifter compartment(four on the equipment), then the following figure 4, can also be write:

$$G_1 r_1 = P_1 l_1 \qquad G_1 = P_1 \frac{l_1}{r_1} \tag{4}$$

$$G_2 r_1 = P_2 l_2 \qquad G_2 = P_2 \frac{l_2}{r_1} \tag{5}$$

If the masses of the two plansifter units G1 and G2 are equal, then from their equality is obtained:

$$P_1 l_1 = P_2 l_2 \tag{6}$$

Substituting the above expressions in relation of centrifugal forces, results the relation between the weights of the two units, in a situation where lengths of elastic support are different:

$$G_1 l_1 = G_2 l_2 \qquad G_1 = G_2 \frac{l_2}{l_1} \tag{7}$$

Symbolization of links at base of the two cylinders is schematized in fig.5 (elastic links. Complete kinematic scheme of the mechanism is shown in fig.6,a.

To determine the mobility degree of the mechanism, the elastic link can be equated with a pneumatic cylinder, as shown in fig.6,b.

Symbolization of links at base of these two cylinders is schematized in fig.3 (elastic links). Complete kinematic scheme of the mechanism is shown in fig.6,a.

For determining the degree of mobility of the mechanism, the elastic link can be equated with a pneumatic cylinder, as shown in fig.6,b.

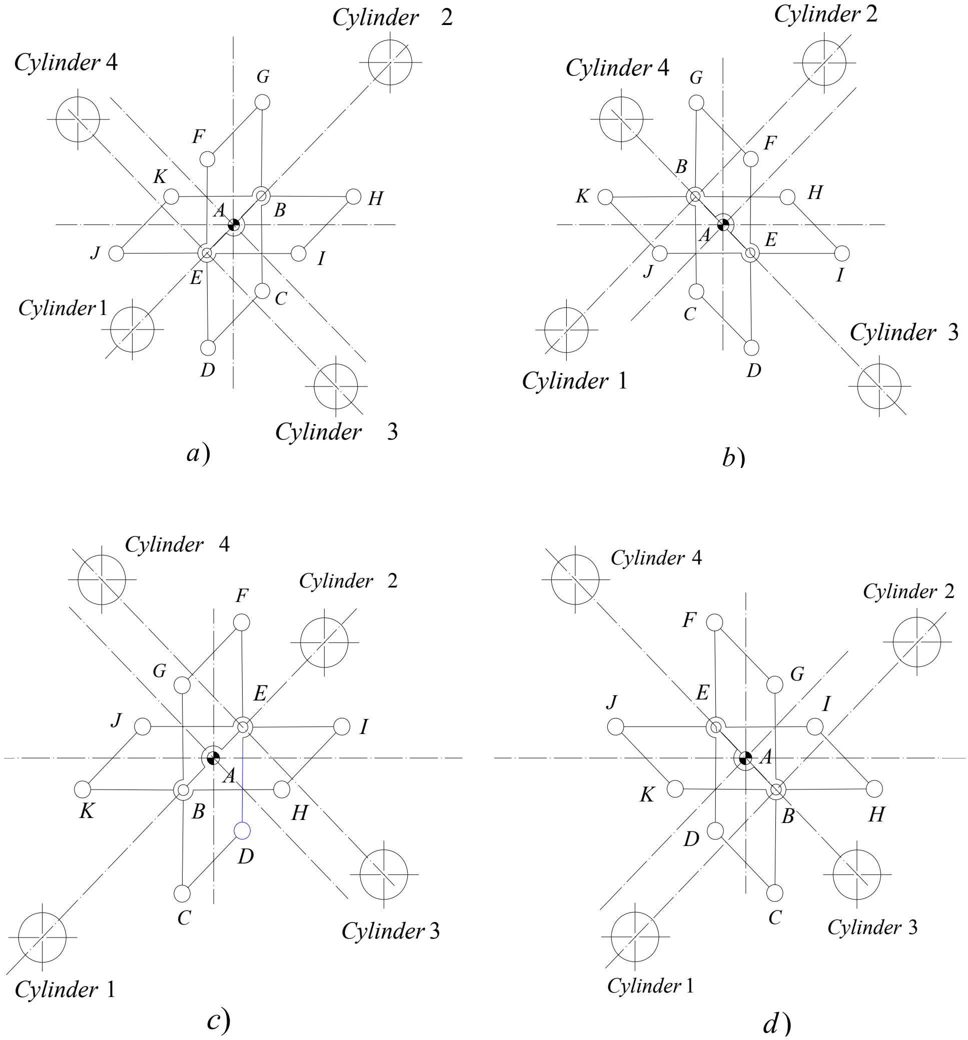

Fig. 7 Kinematic scheme of articulation parallelogram in four distinct positions

In fig.7 (a,b,c,d) are presented kinematics schemes of the actuation parallelogram in 4 different positions (B crankpin position at angles 45, 135, 225 and 315 degrees, compared to the positive direction of the axis Ox).

In fig.8,a is presented the kinematic scheme of the parallelogram into any position, to highlight the closeness of two parallelograms by death points and in fig.8,b is a presented the kinematic scheme of a battery with two cylinders placed on diagonal.

Having regard to the kinematic scheme of the mechanism from fig.8, b, results the degree of mobility M = 2. This means that the sifting cylinders have a motion assimilated with circular translational movement, centered on the circular trajectory CT (fig.5,a), of radius equal to the radius of the crank mechanism ($r = AB$),as well as a small oscillatory motion around the points B and E (fig.4,b), due to the elasticity of suspension bars (elastic supports).

If it is established the degree of mobility of the entire mechanism (fig. 6,a), is obtained the degree of mobility M = - 1, which means that the mechanism is over-constrained, this being false. The mechanism works because the cinematic elements 3, 5, 6 and 7 have equal lengths, and distances between points B - C, B - G, D - E, E - F, B - H, B - K, E - I, E - J are equal. These particularities lead to the formation of parallelograms mechanisms through the two yokes which support the plansifter bodies.

If not take into consideration the oscillation movement, of the two pairs of cylinders 1-2 and 3-4 around the points B and E, the mechanism is completely equilibrated (static and dynamic).

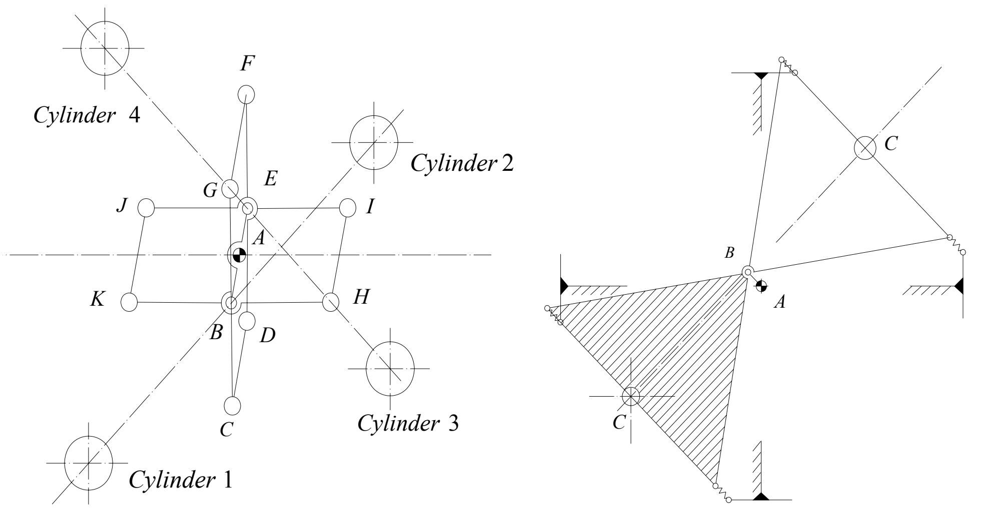

Fig. 8 Some positions of the parallelogram for joint (a) and the kinematic scheme of a single batteries of plansifter bodies (b)

CONCLUSIONS

Actuator mechanisms of the plansifters are, generally, of type with centrifugal counterweights with a relatively high weight, so that can set the pace to the equipment a circular trajectory approximately plane, horizontal. Difficult equilibration of the equipment and operation with a transitional regime with major disturbances on equipment framework and of it has led some milling equipment manufacturers (particularly, plansifters) to seek different solutions for actuation systems. Thus, were constructed and are already in exploatation in Germany plansifters with four units arranged two by two, diagonally opposite, on two platforms (yokes), linked together through elastic elements (double-berings). System actuation through a shaft with two eccentric of the actuation mechanism has simplified the construction and composition eliminated from the counterweights of the equipment that have been replaced by two plansifter bodies, thereby increasing the siefting surface of a single equipment (which has in construction four compartments).

By proper arrangement of fixing yokes of the sieve units and of elastic support those are equilibrating each other and functioning becomes more safer.

This paper presents a structural analysis of of the actuation mechanism that can help manufacturers and specialists in milling equipments.

AKNOWLEGEMENT

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Originalni znanstveni rad
Original scientific paper

MATHEMATICAL MODEL TO ESTIMATE THE ENERGY CONSUMPTION AT WHEAT GRINDING WITH ROLLER MILLS

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ABSTRACT

In the grain grinding process, energy consuming is influenced by several parameters, among which may be mentioned, on the one hand, the constructive and functional characteristics of the machine and its working parts, and, on the other hand, the physic-mechanical properties of grains.

Mathematical modeling of grinding process requires knowledge of the properties of material to be grinded, mainly seed breakage force required.

In the milling with the roller mills, the torque of grinding roll shaft can be estimated by calculation if known the forces resultant acting on the roll, the direction of this force and its point of application on the roll surface.

The paper presents a mathematical modeling for determining the torque of grinding roll shafts and some results of experimental researches on energy consumption of roller mills from technological flow of wheat flour plant with a capacity of 100 t / 24 h.

Also, energy consumption for a laboratory mill with fluted rolls was determined, for wheat seeds grinding with different moisture content. Results are presented in the paper.

Key words: energy consumption, wheat kernels, mathematical model, roller mill, breakage force

INTRODUCTION AND LITERATURE REVIEW

The grinding is one of the most expensive processes in the food industry, in terms of energy consumption.

In roller mills of milling industrial units, grinding of wheat seeds is achieved by action of compression and shear forces on the material between the two rotating rolls.

Energy consumption for grinding depends on geometrical and kinematic parameters of rolls (roll gap, roll disposition, differential), physical properties (particle size, moisture content, mass) and mechanical properties (hardness, resistance to crushing) of material to be grinded, [2,3,4,5,6,14].

From experiments made by Wiercioch M., Niemiec A. and Romański L. (2008), for grinding of three wheat varieties seeds (Elena, Kobra si Sarai) with a roller mill which has a diameter of rolls of 240 mm and roll gap of 0,4 mm, it was found that seed mass and hardness have significant influence on consumption energy during grinding process, [14].

Roll gap indirectly influence new created specific surface and energy consumption per unit mass (kJ/kg) and direct specific energy (kJ/m^2), [12].

The seeds with low moisture content (below 13%) have a reduced elastic characteritic to dynamic stresses, they are fragile and easily broken, requiring lower energy consumption for grinding, compared to with high moisture content, [1]. For moisture content within the limits 17-18%, the seeds behave as elastic bodies, particulary for bran, and therefore energy consumption for grinding is higher, [1,8].

Crushing resistance of wheat seeds increases with increasing moisture content and their vitreosity, requiring more intense grinding and hence higher energy consumption, [9,11].

In paper [2], C. Danciu and I. Danciu conducted experiments in order to identify the optimum disposition of roll flutes to achieve maximum efficiency of grist with minimum energy consumption for breakage phase in milling process of wheat seeds. The seeds grinded were Dropia, Romanian wheat variety (production 2009). Mill stand which the experiments were made was equipped with rolls of 60 mm length, 90 mm diameter, 0.8 mm roll gap, 7 flutes / cm, differential 2.5:1, flutes inclination 6% and flute angles 30^o/ 60^o (flute sharp angle / flute dull angle). Rolls have worked for all four rolls disposition: dull-to-dull (D/D), sharp-to-sharp (S/S), sharp-to-dull (S/D) and dull-to-sharp (D/S). Results obtained from these studies showed that the highest energy consumption was recorded for D/S roll disposition, followed by D/D, S/S and S/D roll disposition. The authors found that the S/S roll disposition is the most favorable regarding of energy consumption and material grinding index in breakage phase.

Q. Fang and al. (1998) [7] studied the energy requirements for size reduction of wheat seeds in a roller mill. Researches have been achieved on three wheat varieties: soft red winter wheat, hard red winter wheat and hard red spring wheat. To grinding of material were used rolls with fluted surface, their diameter was of 250 mm, length 100 mm and roll disposition were D/D. The power increased with increasing hardness of seeds and rolls feed rate. Seeds with high sizes required higher energy consumption, compared to the seeds smaller sizes. Rolls drive power was inversely proportional to roll gap. A small roll gap required a higher power drive. Energy increased with increasing differential and increasing moisture content of material. The seeds with small weight required higher energy consumption for creating a new unit surface area, [7].

The objective of this paper is to present a mathematical model that can be used to estimate the power for wheat seeds grinding in roller mills. Also, the paper presents some results of experimental researches on energy consumption of roller mills on the technological flow of S.C. Spicul Rosiori de Vede milling plant with capacity of 100 t/24 h, and energy consuming of laboratory mill (with fluted rolls) for grinding wheat seeds with different moisture content.

THEORETICAL ELEMENTS

To determine the resultant forces acting on a particle of material from passing through two rolls with smooth surface, the following assumptions were made, [10]:

- The two rolls have the same peripheral speed;
- Acting on material particle only one roll (other having supporting role);

The stresses along the processing route (grinding zone) $\overline{ab}$ (fig. 1) are distributed uniformly, meaning the value of particle relative deformation at different points is proportional to the particle grinding degree.

Under these conditions we can write:

$$\frac{d\sigma}{\sigma} = \frac{mc}{a^{`}b} \tag{1}$$

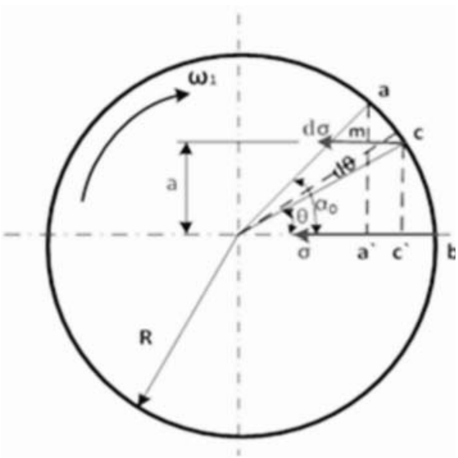

Fig. 1 Processing route

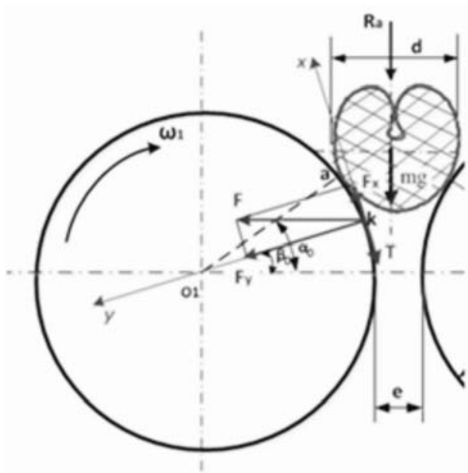

Fig. 2 Forces acting on wheat seeds when passing through rolls

where: *dσ* is crushing stress at a arbitrary point under angle θ positioned along the processing route and *σ* is the maximum stress corresponding to maximum strain directet to the centers line, [10].

According to fig. 1, *a'b* distance is given by:

$$a^{`}b = R(1 - \cos\alpha_o) = 2R\sin^2\frac{\alpha_o}{2} \tag{2}$$

where: α_o is catching angle of particle between rolls, and *R* is roll radius.

Elemental force *dF* along the roll on a local elementary strip of l_o length (*L* – roll length) and the angle dθ, can be calculated as follows:

$$dF = d\sigma \cdot l_o \cdot R \cdot \frac{sin^2\frac{\alpha_o}{2} - sin^2\frac{\theta}{2}}{sin^2\frac{\theta}{2}} d\theta \tag{3}$$

Total force *F* on the grinding roll, acting on the arc of the grinding zone is obtained by integrating the above expression (rel.3) and is equal to the sum of all pressure elements $d\sigma$:

$$F = \sigma l_o R \left(\alpha_o - \frac{\alpha_o - sin\alpha_o}{2sin^2\frac{\alpha_o}{2}}\right) \tag{4}$$

To determine the application point of the resultant force *F*, determine the forces moment acting on grinding roll on the arc $\overset{\frown}{ab}$. Thus, the resistant moment of elementary force *dF* is:

$$M = dF \cdot \overline{cc'}, \text{ unde } \overline{cc'} = Rsin\,\theta \tag{5}$$

$$M = \sigma \cdot l_o \cdot R^2 (\int_0^{\alpha_o} sin\theta d\theta - \int_0^{\alpha_o} \frac{sin\theta \cdot sin^2\frac{\theta}{2}}{sin^2\frac{\alpha_o}{2}} = \sigma \cdot l_o \cdot R^2 sin^2\frac{\alpha_o}{2} \tag{6}$$

Under these conditions, the coordinates of point k, who is the application point of resultant of all forces acting on particle in the grinding zone *ab*, meaning the value of distance *a* (fig. 2), is determined by the relationship:

$$a = \frac{M}{F} = \frac{\sigma \cdot l_o \cdot R^2 (1 - cos\alpha_o - sin^4\frac{\alpha_o}{2})}{\sigma \cdot l_o \cdot R(\alpha_o - \frac{\alpha_o - sin\alpha_o}{2sin^2\frac{\alpha_o}{2}})} = R\frac{(1 - cos\alpha_o - sin^4\frac{\alpha_o}{2}) \cdot 2sin^2\frac{\alpha_o}{2}}{2\alpha_o sin^2\frac{\alpha_o}{2} - \alpha_o + sin\alpha_o} = R2sin^4\frac{\alpha_o}{2} \tag{7}$$

Making calculations for values of α_o ranged between the limits $\frac{\pi}{2}$ and 0, results the values of a between 0,75·R (for $\alpha_o = \frac{\pi}{2}$) si 0. For $\alpha_o = \frac{\pi}{6}$, is obtained a = 0,64·R.

Also, the angle β_o, the positioning of the point of application of forces resultant acting on the milling roll, will have values between $\beta_o \approx 48^o$ for $\alpha_o = \frac{\pi}{2}$ and $\beta_o = 14{,}83^o$ for $\alpha_o = 20^o$.

The resultant *F*, which is directed parallel to the grinding rolls centre, can be decomposed as the normal (radial) and tangential direction, to the point k:

$$F_x = F\,sin\beta_o\,;\; F_y = F\,cos\beta_o \tag{8}$$

Next, one can neglect other forces acting on the particles of material (own weight *mg* and airflow resistance R_a, see fig.2) or may be taken into account for the calculation of energy consumption to particle passing through the work area between rolls.

If we neglect the forces mentioned [10], then the force necessary to pulling the particle in the area between rolls, directed on the tangential direction, is given by:

$$T = F(\mu - tg\beta_o) \tag{9}$$

where: μ is friction coefficient between particle and roll.

Substituting the expression of *F* in equation (4), we obtain:

$$T = \sigma \cdot l_o \cdot R\left(\alpha_o - \frac{\alpha_o - \sin\alpha_o}{2\sin^2\frac{\alpha_o}{2}}\right)(\mu - tg\beta_o) \tag{10}$$

The power required for the particle to passing through the grinding zone between two rolls, which rotate at different speeds v_r and v_l, can be determined by the relation:

$$P = 2T \cdot \frac{v_r + v_l}{2} = \sigma l R\left(\alpha_o - \frac{\alpha_o - \sin\alpha_o}{2\sin^2\frac{\alpha_o}{2}}\right)(\mu - tg\beta_o)(v_r + v_l) \tag{11}$$

Taking into account other forces (particles mass and airflow resistance), then the pulling force of material between grinding rolls is equal with forces projection resultant on vertical direction. Thus, the power required to pull the material through the rolls is determined by relationship:

$$P = \left[2T + m_c \cdot g + kS_p\frac{\rho(u-v)^2}{2}\right]\frac{v_r + v_l}{2} \tag{12}$$

where: m_c is mass of particles from the working zone of grinding rolls; g – gravity acceleration; k – resistance aerodynamic coefficient which depends on particle shape; S_p – particle projection surface on airflow direction; ρ – particle density; u – air absolute speed; v – particle absolute speed, equal with arithmetic mean of v_r and v_l.

Results:

$$P = \left[\sigma \cdot l_o \cdot R\left(\alpha_o - \frac{\alpha_o - \sin\alpha_o}{2\sin^2\frac{\alpha_o}{2}}\right)(\mu - tg\beta_o) + m_c \cdot g + kS_p\frac{\rho(u-v)^2}{2}\right]\frac{v_r + v_l}{2} \tag{13}$$

For wheat seeds, aerodynamic resistance coefficient has values k = 0.18 – 0.26, [10].

In working area, the wheat seed (material particle) becomes flattened, increasing its size from the initial value to a value that depends on the roll gap, the maximum pressure is on centres line (the direction perpendicular to it).

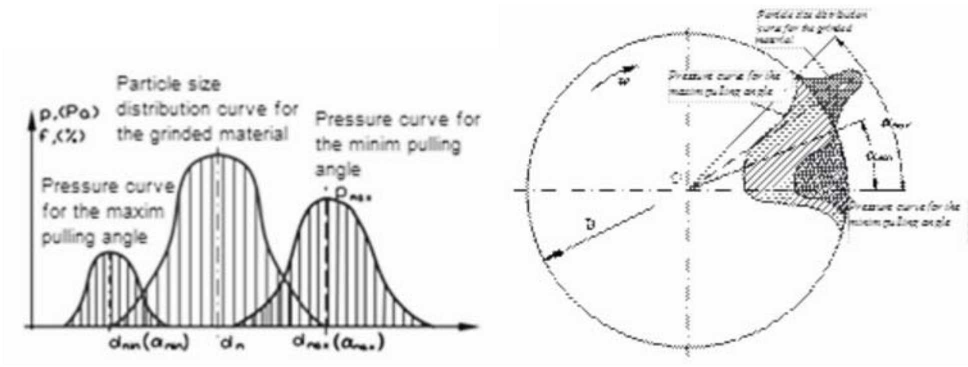

Fig. 3 Pressure distribution exerted by material on grinding rolls

Knowing the variation of power necessary to grinding can estimate the energy consumed for dividing of particles and transforming seeds (semolina) in flour.

MATERIALS, METHODS AND PROCEDURES

For the roller mills from breakage phase of milling plant S.C. Spicul Rosiori de Vede, Teleorman, Romania, with capacity of 100 t /24 h, measurements on energy consuming to grinding wheat seeds and grist obtained in breakage phase of milling plant were made. Grinding rolls characteristics from this technological phase are presented in table 1.

Working schemes and experiments based on the technological flow sheet of breake phase presented and described in the paper [13].

Measurements on energy consumption were made both under load (with roller mill feed material) and the no load (without material supply equipment).

For measurements without material, was stopped for a few seconds the feeding of mills by closing the flap on the feed conduct, using a ampermeter clamp on each phase of electric circuit.

Effective values of power were calculated with relationship:

$$P = \sqrt{3} \cdot U \cdot I \cdot cos\varphi \text{ (kW)}, \tag{14}$$

Electric power value U, was read on voltmeter from the control panel of entire mill plant and the power factor of electric motor (cos φ) used in calculation was that indicated on the electric motor.

Table 1 Characteristics of grinding rolls on breake technological phase

Characteristics of grinding rolls					
	Break1	Break 2	Break 3	Break 4	Break 5
Length (mm)	1000	1000	1000	1000	1000
Diameter (mm)	250	250	250	250	250
Flutes angle (α^o/β^o)	30/60	30/60	35/65	35/65	40/70
Flutes inclination (%)	6	6	8	10	10
Flutes number / cm circumference	3,8	6	7	8,9	10
Flutes disposition	S/S	S/S	S/S	S/S	S/S
Differential	1:2.5	1:2.5	1:2.5	1:2.5	1:2.5

Difference between the power to load and the power to without load is the power consumed to products grinding, the values obtained being presented in table 2.

To determine the specific grinding energy was determined the feed ratio to supply of each roller mill in working nominal regimen for 5 technological passages of phase. The relation for energy specific consumption is presented:

$$E = \frac{P}{Q} \text{ (kJ/kg)} \tag{15}$$

In the paper are presented some results of experimental measurements on energy consumption in grinding wheat seeds (Romanian wheat variety Dropia) on a laboratory stand with fluted rolls. The machine has the following technical characteristics: grinding rolls length L = 345 mm; rolls diameter D = 110 mm; differential 2.5:1; roll gap e = 1 mm; fluted number on cm roll circumference n_r = 310 rifluri / cm. Samples of wheat seeds from Dropia variety with different moisture content: 10%, 14%, 15%, 16%, 17% and 18%, were grinded.

RESULTS AND DISCUSSIONS

Results obtained from experiments were processed and in table 2 are presented the data obtained and measured. In fig.4 is graphically presented the variation of energy consumption for grinding in breakage phase of mill S.C. Spicul Rosiori De Vede, Romania.

From our measurements it was found that as the process were removed bran or particles with high content of bran, remains of grinded particle of endosperm (semolina), the power required for grinding increased, as well as the specific energy consumption. Specific energy consumption changed with characteristics of grinded material.

To the last passage (Break.5) are directed particles with higher bran content, which made both power consumption and specific energy consumption have lower values.

Table 2 Values obtained and calculated from measurements on technological flow of mill with capacity of 100 t/24 h

Break	Intensity I, (A)		Motor power, P_m (kW)	Rotational speed, n (rot/min)	cosφ	Calculated power, P (kW)		Specific energy, W (kJ/kg)
	No load	Load				No load	Load	
Break 1	19	45	30	960	0.83	10.408	24.651	22.624
Break 2	21	37	22	960	0.83	11.503	20.268	59.744
Break 3	23	32	18	975	0.82	12.447	17.318	69.454
Break 4	13	30	15	975	0.81	6.949	16.038	68.532
Break 5	13	17	11	960	0.79	6.778	8.863	22.944

Also, it was found that the first three break passages (Break1, Break 2 and Break 3) require the most power for grinding the material particles. On the other hand, electri motors load was not uniform, they worked about 55% to 65% of rate power and the mill did not work to the capacity for which it was designed, but only of 70% capacity.

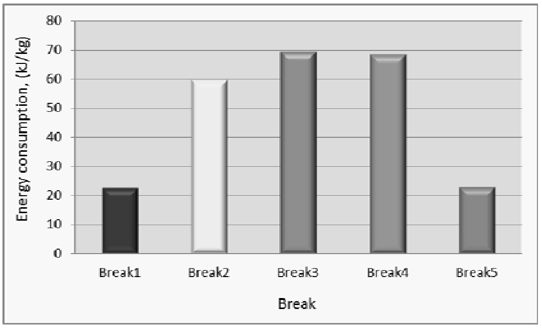

Fig. 4 Variation of energy consumption to grinding products in mill Roşiori de Vede, Romania

Our recommendation for mill specialists was increased working capacity and a judicious choice of acting motors.

As regards the researches made on laboratory mill, in the graph from fig.5 is presented the variation of mean diameter of material particles obtained from grinding with fluted roller mill, depending on moisture content.

In fig. 6 is presented the variation of energy consumption to grinding of six what seeds samples, depending on moisture content.

As shown in fig. 5 and the data presented in Table 2, the mean diameter of the particles increased as seed moisture content was higher. Thus, the mean diameter increased from 1.59 mm for seed moisture of 10 % to 2.61 mm for seeds with moisture content of 18 %.

The analysis of data obtained was found that when grinded seeds with low moisture content (10%), energy consumption showed the highest values, W = 188.47 kJ/kg, and the grinded particles had the lowest mean diameter (d_m = 1.59 mm).

Table 3 Results of experimental researches

Sample	Moisture content (%)	Grist mean diameter, d_m (mm)	Energy consumption, W (kJ/kg)
Sample 1	10	1.59	188.47
Sample 2	14	2.07	154.56
Sample 3	15	2.33	144.45
Sample 4	16	2.39	140.32
Sample 5	17	2.46	139.19
Sample 6	18	2.61	136.01

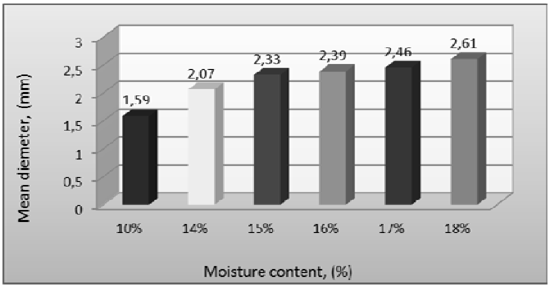

Fig. 5 Variation of mean diameter with moisture content

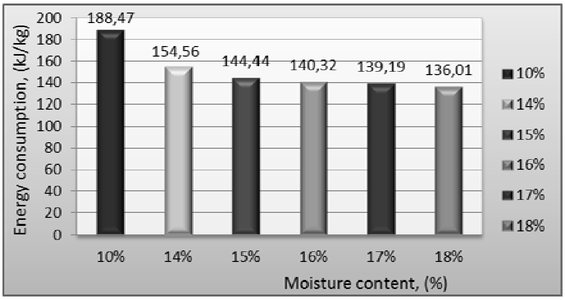

Fig. 6 Variation of energy specific consumption to grinding seeds with different moisture content

As the moisture content was increased, decreased energy consumption and mean diameter of particles was increasingly higher. This is explained by the fact that with increasing moisture content of seed the bran becomes soft, the endosperm is not brittle, and no breaks into small particles, seeds are especially compressed (flattened). Thus, in case of seeds with high moisture content (18%) resulted the largest size particles, d_m = 2,61 mm, for a energy consumption with the lowest value, W = 136.01 kJ/kg.

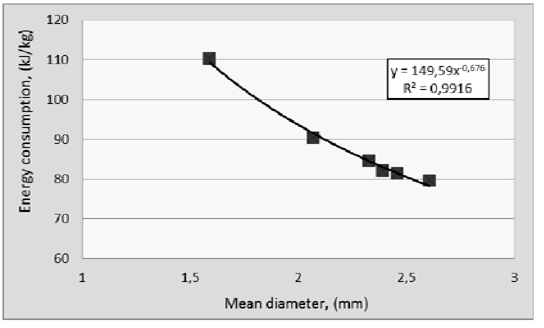

Fig. 7 Variation of energy specific consumption to grinding seeds depending on mean diameter of grinded particles

As the particle diameter, obtained from grinding wheat seed variety Dropia, was higher the energy consumption was lower (fig. 7). Therefore, it can be made that recommendation to establish from the beginning a correlation between specific energy consumption and the mean diameter of the particles of material, so not to perform an excessive grinding of the material, but no grinding too weak which would lead to a lower specific energy consumption. This correlation can be made according to engineering specifications and requirements of technological processes (grains, bread flour, semolina).

CONCLUSIONS

Energy consumption at the grinding with roller mill is determined by the variety of wheat (soft wheat of durum wheat), the moisture content of seeds and the geometrical characteristics of grinding rolls and operating mode of the equipment.

Specific energy consumption to grinding of wheat into a milling plant varies from from one break passage to another because in every passage entry material with different characteristics.

To the break passages where the endosperm particles are grinded (semolina), the energy consumption has relatively high (Break2 –, W = 59.74 kJ/kg; Break 3 –, W = 69.45 kJ/kg), while the passages through particles with higher content of bran (Break 5), energy consumption has lower values (W = 22.94 kJ/kg).

Is not recommended for grinding wheat seeds with low moisture content (10%), this resulting in high energy consumption and grinding exaggerated of bran. Grinding seeds with high moisture content (17%, 18%) not proceeding well (particles diameter is larger, the phenomenon of flattening appears, the endosperm is not crushed) and, also, is not recommended.

Between particle size and specific energy consumption is necessary to establish an appropriate correlation to the grinding degree to fit the technological recommendation.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

KINEMATIC STUDY OF A VIBRATING CONICAL SIEVE FOR SEPARATING IMPURITIES FROM SEED OF AGRICULTURAL CROPS

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ABSTRACT

A vibrating conical sieve, suspended with elastic cables both above and below, was used to separate impurities from canola seed, feeding being made centrally, by the top of the cone.

Actuation of the sieve being made eccentric with a coulisse oscillating mechanism in the point M (see fig.1) found on a bar cohesive with sieve, in the point N0.

Considering some simplifying hypotheses, was studied the movement of sieve in a horizontal plane and were determined differential equations of motion with Lagrange's equations.

Amplitude was determined on direction of connecting arm, as well as velocities of characteristic points using a simplified physical model of actuator.

Trajectory points were drawn graphic the characteristics of sieve and velocities hodograph of these points for different frequencies of oscillation of the sieve.

Sieve was used to separate impurities from canola seed harvested by combine.

In the paper is presented the mathematical model and calculation program for the study of sieve movement, as well as certain charts of separation curves of canola seed through circular holes of the sieve, for three frequencies of oscillation.

Key words*: conical sieve, circular oscillate movement, Lagrange equations, generalized coordinates, separation curves*

INTRODUCTION AND LITERATURE REVIEW

Process of separation on sieves with oscillatory motion is influenced by the amplitude and frequency of oscillations, providing relative movement of material on separating surfaces. Other parameters affecting the separation are: angle of the sieve, coefficient of internal friction of the material, external friction coefficient, size of the mesh aperture, average particle size, [2, 4, 7, 8]. Mechanical separation of seeds with sieves is not a complete separation, every time in a fraction being found 10-20% of other fractions particles, [1].

For sieves blocks with oscillating motion, oscillation parameters influence directly on process of separating impurities from the bulk grain, by moving imprinted on material particles. These need to move away from the feed point to the area where it performing the collection of particles larger than the mesh aperture. This outlined the two functions of sieve: function of separation for particles smaller than the aperture and transport function for larger particles, [3, 9].

Analysis of material movement on sieves, respectively the process of separating seeds or impurities, is done mostly through kinematic study of sieve actuator mechanism, based on simplifying assumptions, because the study is particularly complex especially when the sieve is suspended at several points. So can be determined the equations of motion of the sieve, velocities and accelerations of its characteristic points, oscillating amplitude of movement. Knowing these parameters can be estimated the material movement on the sieve, and the loss of seeds or impurities separated by sieve aperture.

MATERIALS, METHODS AND PROCEDURES

A conical sieve suspended with elastic yarns, operated tangential at a distance d, with coulisse oscillating mechanism, used to separate impurities from canola seed harvested by combine. This sieve is shown schematically in Figure 1.

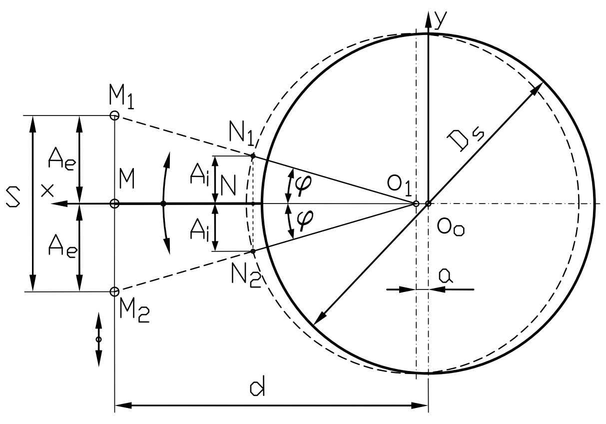

Fig. 1 Scheme for calculating the amplitude of oscillations of sieve, [7]

The paper presents the mathematical model for the study of sieve movement, based on simplifying hypotheses. Movement of sieve can be considered an alternative circular motion with very little movement on direction of arm and without taking into account any vertical movement of the sieve (movement that has been neglected due to its extremely low values).

For the dynamic study of vibrating machine with conical surface separation was designed schematic representation (Fig. 2) thereof.

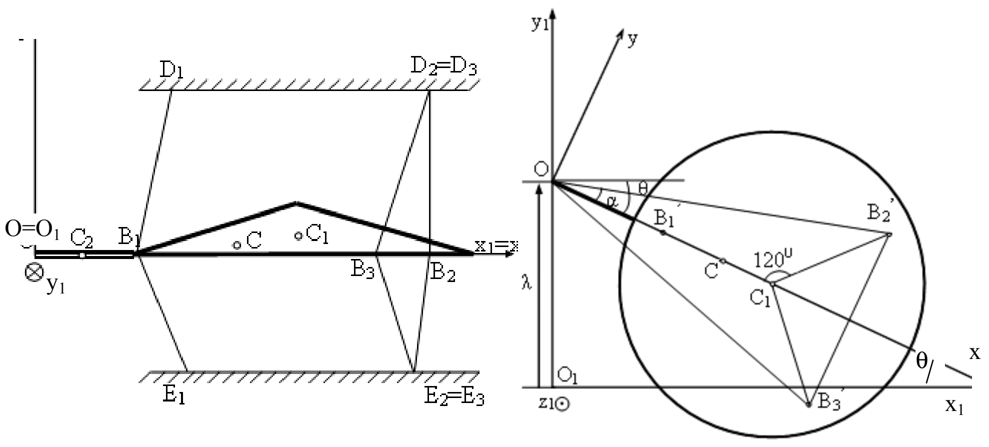

Fig. 2 Schematic representation of sieve into a current position

Simplifying assumptions used were:

- center of mass of the assembly conical sieve - arm connection with the actuator mechanism is always horizontal and on radial direction of connecting arm (we neglect the vertical movement of the sieve);
- movement of button of actuator system was considered a linear harmonic oscillatory motion leading to movement in two directions (in the horizontal plane) of conical sieve center and of the whole separation assembly;
- in those circumstances sieve movement is parallel-plane a movement defined by two parameters (the polar coordinate system);
- conical sieve separation surface was considered a flat surface, without taking into account the influence of aperture on the general movement of the sieve;
- has neglected the influence of air currents on separation assembly equipment;
- was considered a uniform elasticity of suspension cables by different elastic constants of cables at the top and bottom (to take account of their elongation at horizontal displacement of it).

Kinematic drive of sieve is calculated by imprinting rectilinear harmonic oscillations of articulation O.

Considering the simplifying hypotheses, was studied the movement of sieve horizontally and were determined differential equations of motion with Lagrange's equations (Equation 1).

$$\frac{d}{dt}\left(\frac{\partial E}{\partial \dot{q}_k}\right) - \frac{\partial E}{\partial q_k} = Q_k^C + Q_k^n, \qquad k = 1, 2, ..., n \tag{1}$$

where: E is the kinetic energy of the system consists of conical sieve and connecting arm (equation 2); q_k - generalized coordinates (λ and θ); $\dot{q}_k$ - generalized speeds; Q_k^n - non-conservative generalized forces (eq. 3); Q_k^C - conservative generalized forces (eq. 4);

$$E = \frac{1}{2} m\dot{\lambda}^2 + \frac{1}{2}\left(J_c + m\xi^2\right)\dot{\theta}^2 - m\xi\dot{\lambda}\dot{\theta}\cos\theta \tag{2}$$

$$Q_k^n = Q_\lambda = \frac{\delta L_\lambda}{\delta\lambda} = \frac{F_o \sin\Omega t \cdot \delta\lambda}{\delta\lambda} = F_o \sin\Omega t\,;\ Q_k^n = Q_\theta = 0 \tag{3}$$

Conservative generalized forces Q_k^c, comes from function of force:

$$U = -\frac{1}{2} k_1 \left[\left(\Delta\ell_{B_1D_1}\right)^2 + \left(\Delta\ell_{B_2D_2}\right)^2 + \left(\Delta\ell_{B_3D_3}\right)^2\right] - \frac{1}{2} k_2 \left[\left(\Delta\ell_{B_1E_1}\right)^2 + \left(\Delta\ell_{B_2E_2}\right)^2 + \left(\Delta\ell_{B_3E_3}\right)^2\right] \tag{4}$$

where: $\Delta\ell_{B_iD_i}$ – elongation of suspension cables at the top of the sieve; $\Delta\ell_{B_iE_i}$ – elongation of suspension cables at the bottom of the sieve; k_1 – rigidity of the suspension cables of the sieve on the top; k_2 – rigidity of the suspension cables of the sieve on the bottom.

To apply Lagrange's equation were considered different moments of inertia for arm connection and for conical sieve and were calculated moments of inertia for the entire oscillating assembly.

Were determined coordinates of the center of mass of the entire oscillating assembly necessary in establishing the kinetic energy equation of assembly and then used in applying the Lagrange equations.

It was considered that in articulation of connecting arm with the rod of the actuator mechanism, operating a force generating harmonic oscillator vibration with known amplitude, ($F = F_0 \sin\Omega t$).

Using Lagrange's equations and making necessary algebraic calculations were obtained differential equations of motion, (eq. 5, eq.6).

$$
\begin{aligned}
& m\ddot{\lambda} - m\xi\ddot{\theta}\cos\theta + m\xi\dot{\theta}^2\sin\theta = F_o\sin\Omega t - \\
& -\frac{1}{2}k_1[2\lambda - a_{13}\sin\theta - \frac{2\ell_1(2\lambda - a_{13}\sin\theta)}{2\sqrt{a_{11}+\lambda^2 - a_{12}\cos\theta - a_{13}\lambda\sin\theta}}] - \\
& -\frac{1}{2}k_1\{2\lambda - a_{24} - a_{25}\sin(\alpha-\theta) - \frac{2\ell_1[-a_{24} - a_{25}\sin(\alpha-\theta)]}{2\sqrt{a_{21}+a_{22}\cos(\alpha-\theta) - a_{23}\sin(\alpha-\theta) - \lambda a_{24} - a_{25}\lambda\sin(\alpha-\theta)}}\} - \\
& -\frac{1}{2}k_1\{2\lambda - a_{33} - a_{35}\sin(\alpha+\theta) - \frac{2\ell_1[-a_{34} - a_{35}\sin(\alpha+\theta)]}{2\sqrt{a_{31}+a_{32}\cos(\alpha+\theta) - a_{33}\sin(\alpha+\theta) - \lambda a_{34} - a_{35}\lambda\sin(\alpha+\theta)}}\} - \\
& -\frac{1}{2}k_2[2\lambda + b_{13}\sin\theta - \frac{2\ell_2(2\lambda + b_{13}\sin\theta)}{2\sqrt{b_{11}+\lambda^2 - b_{12}\cos\theta + b_{13}\lambda\sin\theta}}] - \\
& *\frac{1}{2}k_2\{2\lambda - b_{24} - b_{25}\sin(\alpha-\theta) - \frac{2\ell_2[-b_{24} - b_{25}\sin(\alpha-\theta)]}{2\sqrt{b_{21}+b_{22}\cos(\alpha-\theta) - b_{23}\sin(\alpha-\theta) - \lambda b_{24} - b_{25}\lambda\sin(\alpha-\theta)}}\} - \\
& -\frac{1}{2}k_2\{2\lambda - b_{34} - b_{35}\sin(\alpha+\theta) - \frac{2\ell_2[-b_{34} - b_{35}\sin(\alpha+\theta)]}{2\sqrt{b_{31}+b_{32}\cos(\alpha+\theta) - b_{33}\sin(\alpha+\theta) - \lambda b_{34} - b_{35}\lambda\sin(\alpha+\theta)}}\}.
\end{aligned} \tag{5}
$$

$$
\begin{aligned}
& \left(J_C + m\xi^2\right)\ddot{\theta} - m\xi\ddot{\lambda}\sin\theta - m\xi\dot{\lambda}\dot{\theta}\cos\theta - m\xi\dot{\lambda}\dot{\theta}\sin\theta = \\
& -\frac{1}{2}k_1\left[a_{12}\sin\theta - a_{13}\lambda\cos\theta - \frac{2\ell_1(a_{12}\sin\theta - a_{13}\lambda\cos\theta)}{2\sqrt{a_{11}+\lambda^2 - a_{12}\cos\theta - a_{13}\lambda\sin\theta}}\right] - \\
& -\frac{1}{2}k_1\left[\begin{array}{l} -a_{22}\sin(\alpha-\theta) + a_{23}\cos(\alpha-\theta) + a_{25}\lambda\cos(\alpha-\theta) - \\ -\dfrac{2\ell_1[a_{22}\sin(\alpha-\theta) + a_{23}\cos(\alpha-\theta) + a_{25}\lambda\cos(\alpha-\theta)]}{2\sqrt{a_{21}+a_{22}\cos(\alpha-\theta) - a_{23}\sin(\alpha-\theta) - \lambda a_{24} - a_{25}\lambda\sin(\alpha-\theta)}}\end{array}\right] - \\
& -\frac{1}{2}k_1\left[\begin{array}{l} a_{32}\sin(\theta+\alpha) + a_{33}\cos(\alpha+\theta) - a_{35}\lambda\cos(\alpha+\theta) - \\ -\dfrac{2\ell_1[a_{32}\sin(\alpha+\theta) - a_{33}\cos(\alpha+\theta) - a_{35}\lambda\cos(\alpha+\theta)]}{2\sqrt{a_{31}+a_{32}\cos(\alpha+\theta) - a_{33}\sin(\alpha+\theta) - \lambda a_{34} - a_{35}\lambda\sin(\alpha+\theta)}}\end{array}\right] - \\
& -\frac{1}{2}k_2\left[b_{12}\sin\theta + b_{13}\lambda\cos\theta - \frac{2\ell_2[b_{12}\sin\theta + b_{13}\lambda\cos\theta]}{2\sqrt{b_{11}+\lambda^2 - b_{12}\cos\theta + b_{13}\lambda\sin\theta}}\right] - \\
& -\frac{1}{2}k_2\left[\begin{array}{l} -b_{22}\sin(\alpha-\theta) + b_{23}\cos(\alpha-\theta) + \lambda b_{25}\cos(\alpha-\theta) - \\ -\dfrac{2\ell_2[b_{22}\sin(\alpha-\theta) + b_{23}\cos(\alpha-\theta) + b_{25}\lambda\sin(\alpha-\theta)]}{2\sqrt{b_{21}+b_{22}\cos(\alpha-\theta) - b_{23}\sin(\alpha-\theta) - \lambda b_{24} - b_{25}\lambda\sin(\alpha-\theta)}}\end{array}\right] - \\
& -\frac{1}{2}k_2\left[\begin{array}{l} b_{32}\sin(\theta+\alpha) + b_{33}\cos(\alpha+\theta) - \lambda b_{35}\cos(\alpha+\theta) - \\ -\dfrac{2\ell_2[-b_{32}\sin(\alpha+\theta) - b_{33}\cos(\alpha+\theta) - b_{35}\lambda\sin(\alpha+\theta)]}{2\sqrt{b_{31}+b_{32}\cos(\alpha+\theta) - b_{33}\sin(\alpha+\theta) - \lambda b_{34} - b_{35}\lambda\sin(\alpha+\theta)}}\end{array}\right]
\end{aligned} \tag{6}
$$

In equation (5 and 6) have used the following notations:

$a_{11} = 2(L-R)^2 + \ell_1^2$, $a_{12} = 2(L-R)^2$, $a_{13} = 2(L-R)$, $a_{21} = \left(L + \frac{R}{2}\right)^2 + 2OB_2^2 + \left(R\frac{\sqrt{3}}{2}\right)^2 + \ell_1^2$;

$$a_{22}=2\left(L+\frac{R}{2}\right)OB_2;\ a_{23}=2\left(R\frac{\sqrt{3}}{2}\right)OB_2;\ a_{24}=2R\frac{\sqrt{3}}{2};\ a_{25}=2OB_2$$

$$a_{31}=\left(L+\frac{R}{2}\right)^2+OB_3^2+\left(-R\frac{\sqrt{3}}{2}\right)^2+\ell_1^2;\ a_{32}=2\left(L+\frac{R}{2}\right)OB_3;\ a_{33}=2\left(-R\frac{\sqrt{3}}{2}\right)OB_3$$

$$a_{34}=2R\frac{\sqrt{3}}{2};\ a_{35}=2OB_3$$

$$b_{11}=2(L-R)^2+\ell_2^2;b_{12}=2(L-R)^2;\ b_{13}=2(L-R)$$

$$b_{21}=\left(L+\frac{R}{2}\right)^2+2OB_2^2+\left(R\frac{\sqrt{3}}{2}\right)^2+\ell_2^2;\ b_{22}=2\left(L+\frac{R}{2}\right)OB_2;\ b_{23}=2\left(R\frac{\sqrt{3}}{2}\right)OB_2$$

$$b_{24}=2R\frac{\sqrt{3}}{2};\ b_{25}=2OB_2;\ b_{31}=\left(L+\frac{R}{2}\right)^2+OB_3^2+\left(-R\frac{\sqrt{3}}{2}\right)^2+\ell_2^2;\ b_{32}=2\left(L+\frac{R}{2}\right)OB_3$$

$$b_{33}=2\left(-R\frac{\sqrt{3}}{2}\right)OB_3;\ b_{34}=2R\frac{\sqrt{3}}{2};\ \ b_{35}=2OB_3.$$

Geometrical and mass characteristics of the working element for the installation of fig.2, represented in position of static equilibrium, are: radius of the sieve generator circle R_o = 0.215 m; length of connecting arm $O_1A = l$ = 0.205 m; distance from actuation point to the projection of the gravity center C_1 of conical sieve on the plane $O_1x_1y_1$, $O_1C_1 = L = d$ = 0.420 m; the three suspension cables of the sieve are placed at 120^0 on a circle with the radius R= 0.2 m; height of the sieve cone h = 0.015 m; mass of sieve cone m_1 = 0,8 kg; mass of connecting arm m_2 = 0,4 kg.

Equations that express the differential equations of motion (eq. 5) have a complex form and can be integrated only by suitable numerical methods.

Regarding the motion of material particle on the surface of conical sieve with oscillating motion is necessary to know the forces acting on the particle of material in order of mathematical modeling of motion.

Considering particles of material as isolated material points which do not interact with each other, in contact with the sieve and neglecting the aerodynamic forces that could act on the material was developed a mathematical model that has led to the differential equations of motion of the material on the sieve (eq. 5, eq. 6).

As we have seen, conical sieve is suspended in three equidistant points on the circumference, both the top and at bottom. Assuming a certain elasticity of metallic suspension cables, displacement of sieve during the oscillation movement is a complex movement, uncontrolled.

It may be, however, considered, a circular alternative motion, because of its tangential actuation at a distance d from the center C (from fig.1), if we neglect the displacement of center of the sieve on direction *Ox* to be very small (of the order of hundredths of millimeters).

Assuming that sieve center moves only on Ox axis (fig.1), then we can calculate the displacement on Oy axis of the sieve points. It is recognized that sieve amplitude is the maximum displacement of the point N on its circumference up to (N_1, N_2), corresponding to angle φ, on both sides of the Ox axis, which it make the connecting arm with the actuator mechanism during oscillation sieve.

Given the geometric characteristics of suspended conical sieve and those of actuator mechanism, for a distance d (of actuation) known (fixed but adjustable), was calculated displacement A_i (on the assumption considered). By construction, race of actuator mechanism button is $S = 2A_e = 16$ mm, and amplitude (displacement) of motion of the actuator mechanism button M is $A_e = 8$ mm, for the characteristics mentioned above.

In the experimental measurements, the distance d (length of connecting arm of sieve with the actuator mechanism to) was set successively at four values, through the proper movement of the mechanism, idle by changing the direction Ox of point position M.

For known values of the connecting arm of sieve D and race $S = 16$ mm = constant, the eccentric of the actuator mechanism, displacements of characteristic positions of the sieve O and N (OO_1, NN_1, NN_2) are those in Table 1.

Table 1 The amplitude values A_i for four lengths of the arm of sieve

d (mm)	φ (°)	a (mm)	A_i (mm)
480	0.955	0.067	3.58
460	0.966	0.070	3.74
440	1.042	0.073	3.91
420	1.091	0.076	4.10

In figure 3 is shown the actuator mechanism of the sieve considering that the center sieve have displacement only on *Ox* axis.

Using the calculation elements from the theory of mechanisms, presented mechanism has a rotating drive element AB, which is represented in real mechanism by a spiral wheel and its eccentric button and two dyads, one RTT, represented by points BCD in equivalent mechanism and a dyad RRT, represented by points EFG, in which the point G is the center of sieve (with translational motion), see fig. 4.

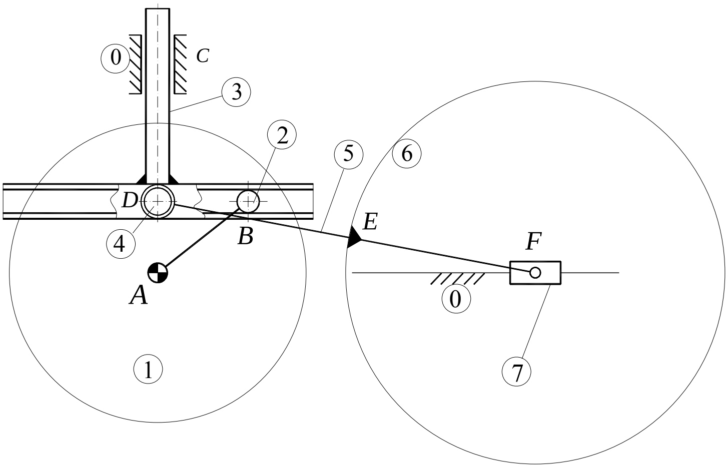

Fig. 3 Constructive - cinematic scheme of the actuator mechanism of conical sieve
1-spiral wheel; 2-crank button; 3-guided rod; 4-bolt; 5-connecting arm; 6-conical sieve suspended; 7-guide path

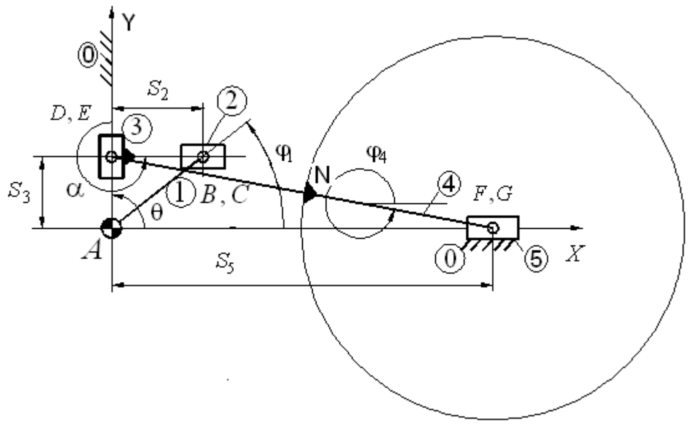

Fig 4 Scheme for equivalent mechanism

The elements CD, represents the rod of the actuator mechanism, while the item EF is represented by connecting arm of the sieve with its center. In order to achieve cinematic scheme of fig.3, has been proceeded, first at equivalence of upper couple from point B, couple that turned into an element and two lower couple.

Doing synthesis of mechanism and writing the characteristic equations in calculation program Turbo Pascal were determined the displacements of points E, on the rod of actuation, identical with point M (M_1, M_2 din fig.4), as well as moving of point N (N_1, N_2 from the same figure) on direction Oy, considered in the paper as the oscillation amplitude of sieve.

Preparation of calculation program for the determination of kinematic parameters of the mechanism elements was performed considering 360 equidistant positions of the element 1 (fig.3 – from degree to degree).

From the calculation program resulted a set of values that were processed in Microsoft Excel, on which were drawn graphs of variation of displacements and velocities of sieve characteristic points, in fig. 5 these being represented only for point N.

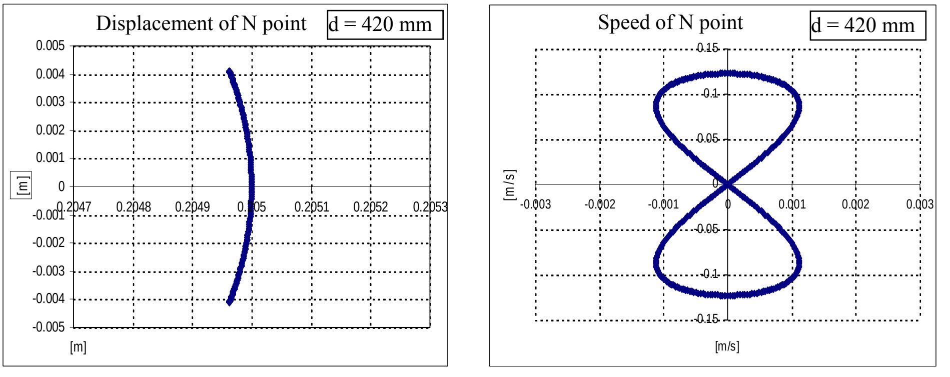

Fig. 5 Variation graphs of displacements and velocities of point N for connecting arm d = 420 mm and oscillating frequency F = 250 osc/min

To estimate the frequency of oscillation influence on the process of separating the seed on sieve was performed regression analysis of experimental data (in %) with normal distribution function in Microcal Origin 6.0, using the relation:

$$p_x(\%) = a \cdot e^{-b(x-c)^2} \tag{7}$$

where: $p_x(\%)$represents the proportion of material separated on an length interval (radius) of sieve; a, b, c – regression coefficients which depend on parameters of operating mode and physical characteristics of the material processed.

Sieve oscillation frequency influence on the process of separation and eventually the loss of seeds that reach and go beyond the bottom of the sieve could be estimated by the maximum position of the separation curves towards peak of the sieve (where is madethe material feeding) presented in fig.6, in different working conditions. Separation curves were traced by regression analysis of experimental data obtained with normal distribution law. From the regression analysis were obtained equation coefficients, respectively media, and standard deviation of values of percentage seed separated by sieve apertures.

For feeding flow rate $Q_2 \approx 0.033$ kg/s and and oscillation amplitude of the sieve A_1 = 3.58 mm, is observed that with increasing frequency from F_1 = 250 osc/min to F_2=520osc/min the maximum position of distribution curve of the material separately on the sieve generatrix (expressed by the coefficient c in equation 7) is moving on radius (generatrix) of the sieve from inside to outside of its (idle from feeding to evacuation), from c = 0.066 m to c= 0.087 m, then again approaching by the feeding point (c= 0.067 m) at frequency F_3 = 790 osc/min, uneven.

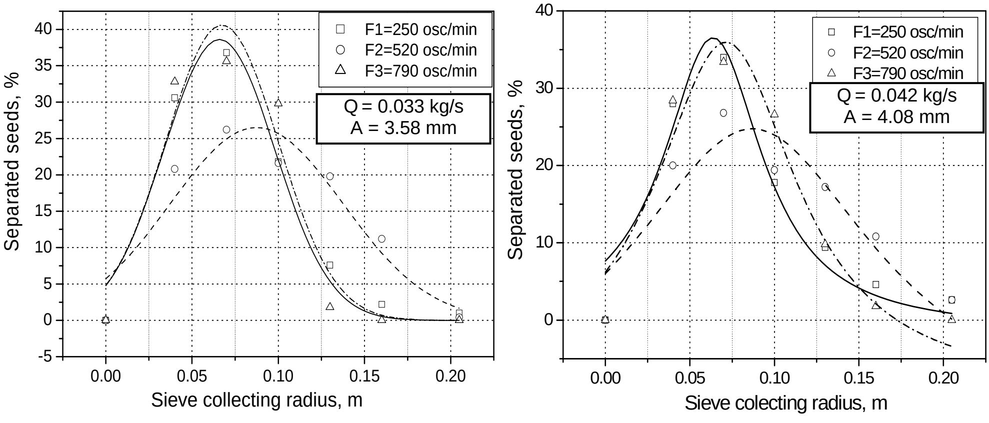

Fig. 6 Separation curves of seeds on generatrix of conical sieve for two feed flow rate and three frequencies of oscillation

CONCLUSIONS

Regarding the material particle motion on the surface of conical sieve with oscillating circular motion is necessary to know the forces acting on the material particle for mathematical modeling of the movement.

To achieving the mathematical model for kinematic study of the sieve were introduced some simplifying hypotheses presented in the paper and were determined differential equations of motion sieve.

The integration of these differential equations was performed numerically using a computer program written in Turbo Pascal, using fourth-order Runge Kutta method to known values related to geometric and functional characteristics of sieve.

Using a simplified physical model assuming a rectilinear displacement of the sieve center based on its geometric characteristics and of connecting rod, knowing the actuator mechanism race was determined amplitude of oscillation of sieve as being displacement on direction of the sieve actuator mechanism rod (in the link point between the sieve and his arm).

This value was determined for four positions of the actuator mechanism button and was used on the vibration sieve analysis as well as the analysis of working process of its.

From the experimental research has shown that efficient separation of seeds through sieve aperture occurs at a frequency of oscillation between 250 to 520 osc / min, at average amplitudes of displacement of the sieve on direction of the actuator mechanism rod.

AKNOWLEGEMENT

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.459.3:633.11:633.34:636.085.533
Prethodno priopćenje
Preliminary communication

UBRANE I NA POLJU PREOSTALE KOLIČINE ŽETVENIH OSTATAKA PŠENICE I SOJE

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SAŽETAK

Sprovedeno je istraživanje, koje je za cilj imalo da odredi količinu slame pšenice i soje, koja može da se ubere i nadzemnih žetvenih ostataka, koji ostaju na polju. Merenja su obavljena 2011. godine, koja po uslovima vlažnosti može da se oceni kao prosečna i 2012. godine, koja je bila izrazito sušna.

Prikupljeni su uzorci nadzemne mase osam najzastupljenijih sorti pšenice i šest sorti soje 2011. godine i sedam sorti pšenice i pet sorti soje 2012. godine, sa tri lokacije u Vojvodini. Uzorci pšenice razvrstani su na sledeće kategorije: zrno, pleva (sa vretenima klasja), stabljika i list, a soje: zrno, stabljika, granje/lišće i mahune. Određen je žetveni indeks, prinos i relativni prinos pojedinih kategorija žetvenih ostataka. Stabljike su podeljene na segmente, merena njihova masa, te definisane promene zbirnih masenih udela po visini, kako bi mogli da se utvrde ostaci na strnjištu u zavisnosti od visine reza kosionog aparata. Za uobičajeni postupak ubiranja slame presovanjem ocenjena je količina žetvenih ostataka, koja može da se ubere. Na osnovu količine žetvenih ostataka, koji ostaju na polju ocenjena je mogućnost ostvarenja zaštite od eolske erozije.

Za visinu reza kosionog aparata, pri žetvi pšenice, 15 cm, u proseku bi na strnjištu ostajalo oko 26 i 33 % stabljika u sezoni 2011, odnosno 2012. Pri žetvi soje bi na strnjištu, u sezoni 2011, u proseku ostalo 19 i 24 % stabljika, a u 2012. 25 i 31 %, za visinu reza 7,5 i 10 cm, respektivno. Prosečna količina ubrane slame je 2011. godine za pšenicu iznosila 3,8 Mg ha^{-1}*, što je značajno više nego 2,1 Mg ha*$^{-1}$*2012. godine. Za soju je 2011. godine bila 2,59 odnosno 2,46, a 2012 1,63 i 1,55 Mg ha*$^{-1}$*, za visine reza kosionog aparata 7,5 i 10 cm respektivno. Smanjenje količine žetvenih ostataka pšenice, u sezoni 2012. u odnosu na 2011. za slamu iznosi oko 45 %, a za žetvene ostatke na polju oko 18 %. Za soju je to smanjenje za slamu iznosilo oko 37 %, a za žetvene ostatke na polju oko 20 %. Količina žetvenih ostataka na polju nakon ubiranja slame pšenice i soje dovoljna je za zaštitu od eoloske erozije tokom zime i primene obrade zemljišta bez prevrtanja.*

Bilo bi poželjno da se merenja nastave i u narednim godinama, pri drugim agroklimatskim uslovima, kako bi se dobili što pouzdaniji podaci za višegodišnje procenjivanje raspoloživog potencijala slame pšenice i soje, ali i planiranja održivog upravljanja biljnim ostacima.

Ključne reči: *žetveni ostaci, slama, pšenica, soja, prinos slame, eolska erozija*

UVOD

U skladu sa svetskim i evropskim trendovima, posebno definisanim u Direktivi 2009/28/EC, biljni ostaci pšenice i soje, slama, smatraju se važnim resursom obnovljive energije. Martinov et al. (2011) ocenjuju potencijal slame pšenice i soje u Vojvodini na oko 530.000, odnosno 280.000 Mg godišnje.

Odnošenjem slame sa polja uklanja se i deo organske materije, što utiče na strukturu i plodnost zemljišta. Powlson (2006), autor modela za očuvanje organske materije u zemljištu (SOM – *Soil Organic Matter*), navodi da je vrednost biljnih ostataka, sa tog stanovišta, 8 do 80 €/ha godišnje. Saffih-Hdadi i Mary (2008) predlažu model uticaja unošenja ili odnošenja biljnih ostataka nekoliko biljnih vrsta na sadržaj organskog ugljenika u zemljištu (SOC – *Soil Organic Carbon*). Korišćeni su podaci višegodišnjih eksperimenata (18 do 35 godina), sprovedenih na osam lokacija u Evropi i jednoj lokaciju na Tajlandu. U istom radu je pokazano da unošenje biljnih ostataka, čak i svake druge godine, doprinosi povećanju SOC.

Rozentrater et al. (2009) pokušali su da sagledaju kompleksnost problema ubiranja biljnih ostataka u ratarskoj proizvodnji za njihovu energetsku primenu. Razmatran je realan ubrani prinos slame, kao i uticaj odnošenja biljnih ostataka, na plodnost zemljišta. Ipak, u radu nedostaju jednoznačni zaključci, ali se iscrpno ukazuje na kompleksnost problema. Daje se gruba procena da odnošenje oko jedne trećine biljnih ostataka ne bi prouzrokovalo negativne efekte na plodnost zemljišta. Sekulić et al. (2010) takođe su obradili ovaj problem, pa navode da biljni ostaci ne bi trebalo da se odnose sa parcela na kojima je nizak sadržaj humusa. Njihovi zaključci nisu dovoljno kvantifikovani da bi našli praktičnu primenu, što još jednom ukazuje na složenost problema.

Prinos pšenice i soje, kao i drugih biljnih vrsta, zavisi od mnogih faktora, a pre svega agroklimatskih i agropedoloških uslova. To se odnosi i na količinu žetvenih ostataka na polju i količine biomase, slame, koja može da se ubere. Stoga je potrebno da se sprovedu višegodišnja merenja, kako bi se ocenila promena prinosa i stvaranjem rezervi biomase obezbedila sigurnost snabdevanja energetskih postrojenja.

Osnovni zadatak ovog istraživanja bio je da se kvantifikuju količine slame pšenice i soje, koje mogu da se uberu, što je osnova za procenu realnih količina biomase, kojima se raspolaže. Vezano sa time, zadatak je bio da se utvrde količine biljnih ostataka, koje nakon ubiranja slame ostaju na polju, u zavisnosti od visine reza kosionog aparata. Takođe, zadatak je bio da se utvrdi u kojoj meri preostala količina žetvenih ostataka na polju može da obezbedi zaštitu od eolske erozije.

MATERIJALI I METODE

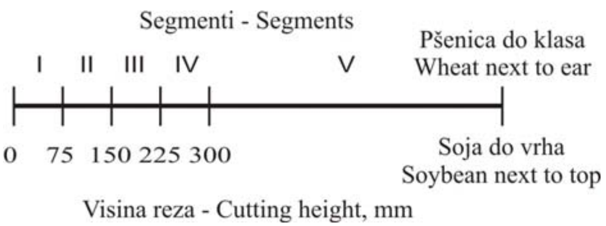
U radu je korišćena sledeća terminologija: ukupna nadzemna masa – cela biljka iznad zemlje; ukupni nadzemni žetveni ostaci – dobijaju se oduzimanjem mase zrna od ukupne nadzemne mase; slama – ukupna količina žetvenih ostataka koji se mogu prikupiti; žetveni ostaci na polju – dobijaju se oduzimanjem slame od ukupnih nadzemnih žetvenih ostataka. Ukupni nadzemni žetveni ostaci pšenice sastoje se od: stabljike, lišća i pleve, a soje od: stabljika, granja/lišća i mahuna.

Merenja su obavljena 2011. i 2012., na tri lokacije i za najzastupljenije sorte. Sa svake parcele uzeto je po pet uzoraka sa jednog kvadratnog metra, tokom žetve, pri čemu je zrno bilo u punoj tehnološkoj zrelosti. Mesta uzimanja uzoraka bila su približno ravnomerno raspoređena na celoj parceli, ali nisu uzimani uzorci na rubovima parcela. Stabljike su odsecane do zemlje. Uzorci su pakovani u vreće i transportovani do Laboratorije za inženjerstvo biosistema Fakulteta tehničkih nauka u Novom Sadu.

Sa stabljika pšenice je odsecano klasje, te odvajano lišće. Nakon toga je obavljen vršaj zrna i odvajanje pleve i vretena klasja u vertikalnom cik-cak separatoru. Dobijene su četiri kategorije materijala: zrno, pleva (sa vretenima klasja), stabljika i list.

Svaki uzorak soje, slično kao i kod pšenice, obrađen je i podeljen na sledeće delove: zrno, stabljika, granje/lišće i mahune.

Nadalje je stabljika deljena na segmente, sl. 1.



Sl. 1 Segmenti slame pšenice i soje

Fig. 1 Wheat and soybean straw segments

Vagom tačnosti 0,1 g merena je masa svakog dela biljke, a u slučaju stabljike meren je posebno svaki segment, prema sl. 1. Nakon toga je meren sadržaj vlage svih delova. Uzorci svih delova istovremeno su sušeni u sušnici, postupkom opisanim u Anonim (2004).

Na osnovu izmerenih vrednosti sadržaja vlage određeni su prinosi svakog dela, svedeni na suvu materiju. U slučaju stabljike izrađeni su dijagrami zbirnog masenog udela stabljike, računajući od tla. Oni su korišćeni za određivanje ostatka mase na strnjištu, u zavisnosti od visine reza kosionog aparata.

Količina ubrane slame pšenice obuhvata ubrane stabljike, odnosno masu koja se dobija oduzimanjem količine koja ostaje na strnjištu i 30 % mase lišća. Količina urbane slame soje obuhvata ubrane stabljike, bez one koja, kao u prethodnom slučaju, ostaje na strnjištu i 30

% granja/lišća (usvojeno je da 70 % lišća, odnosno granja/lišća soje otpada pri presovanju slame i ostaje na parceli).

Pretpostavljeno je da su gubici prese za baliranje 10 %.

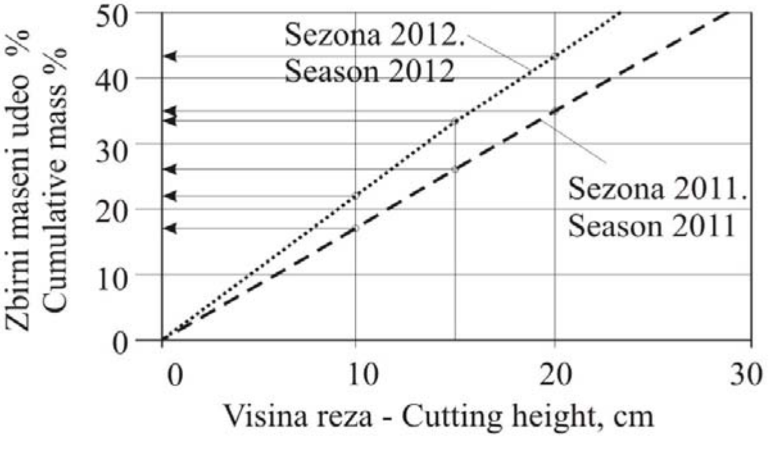
Minimalna količina žetvenih ostataka na polju, neophodna da bi se obezbedila adekvatna zaštita od eolske erozije, ekvivalentna je vrednosti 1.100 kg ha^{-1} SGe (*small grain equivalent*) (Anonim, 2009). Vrednosti SGe za ostatke pšenice i soje utvrđene su prema uputima, koja su definisali Hickman i Schoenberger (1989a, 1989b).

REZULTATI I DISKUSIJA

Pšenica

Rezultati merenja prinosa različitih delova biljke pšenice 2011. i 2012. godine prikazani su u tab. 1. Pri prosečnom prinosu zrna 6,85 i 5,11 Mg ha^{-1}, uz žetveni indeks 0,48 i 0,49, ukupan prosečan prinos nadzemnih žetvenih ostataka iznosio je 7,60 i 5,19 Mg ha^{-1}, respektivno za navedene godine obavljanja merenja.

Na sl. 2 prikazan je zbirni maseni udeo stabljike slame u funkciji visine, srednje vrednosti svih merenja, na osnovu kojeg može da se odredi količina stabljika, koja ostaje na strnjištu, u zavisnosti od visine reza kosionog aparata. Naznačeni su primeri za nisku, srednju i visoku visinu reza, 10, 15 i 20 cm respektivno. Najniža vrednost ostatka na strnjištu bila je 2011. godine 17, a 2012. godine 22 %. Najviša vrednost bila je 2011. godine 35, a 2012. godine 43 %.



Sl. 2 Zbirni maseni udeo stabljika pšenice po visini, srednja vrednost svih merenja

Fig. 2 Cumulative mass of wheat stalks by height, average values for all meassurements

Tab. 1 Prinosi nadzemnih delova pšenice 2011. i 2012.

Tab. 1 Yield of above-ground parts of wheat plants, seasons 2011 and 2012

Sorta Variety	Zrno - Grain				Stabljika - Stalk			
	Prinos - Yield, Mg ha^{-1}		ŽI*		Prinos - Yield, Mg ha^{-1}		Udeo mase prema zrnu - Yield relative to grain, %	
	2011.	2012.	2011.	2012.	2011.	2012.	2011.	2012.
Pobeda	6,60	5,01	0.49	0,49	5,15	3,1	76,2	61,9
Renesansa	6,36	7,29	0,51	0,50	4,37	4,34	69,4	59,6
NS 40S	7,10	4,04	0,50	0,49	5,26	2,31	74,7	57,2
Renata	6,22	3,66	0,48	0,39	5,14	2,95	81,7	80,8
Balaton	7,04	4,74	0,52	0,52	4,72	2,43	67,2	51,2
Apache	6,74	4,63	0,46	0,51	6,09	2,49	90,4	53,7
Dragana	7,92	NP*	0,42	NP	7,81	NP	98,3	NP
Ljiljana	6,79	NP	0,44	NP	6,07	NP	88,9	NP
Simonida	NP	6,43	NP	0,55	NP	2,75	NP	42,8
Prosečna vrednost Average	6,85	5,11	0,48	0,49	5,58	2,91	80,7	58,14
SD*	0,49	1,20	0,03	0,05	1,01	0,64	10,24	10,85
Sorta Variety	Lišće - Leaves				Pleva - Chaff			
	Prinos - Yield, Mg ha^{-1}		Udeo mase prema zrnu - Yield relative to grain, %		Prinos - Yield, Mg ha^{-1}		Udeo mase prema zrnu - Yield relative to grain, %	
	2011.	2012.	2011.	2012.	2011.	2012.	2011.	2012.
Pobeda	0,16	0,81	2,4	16,3	1,47	1,31	22,3	26,2
Renesansa	0,25	1,22	4,0	16,7	1,51	1,7	23,9	23,3
NS 40S	0,22	0,72	3,1	17,8	1,66	1,1	23,9	27,3
Renata	0,18	1,28	2,9	35,0	1,39	1,43	22,4	38,9
Balaton	0,27	0,8	3,8	16,9	1,47	1,14	20,9	24,1
Apache	0,31	0,72	4,7	15,5	1,66	1,17	24,7	25,3
Dragana	0,62	NP	7,8	NP	2,48	NP	31,3	NP
Ljiljana	0,61	NP	9,0	NP	1,85	NP	28,3	NP
Simonida	NP	0,77	NP	12,0	NP	1,81	NP	28,1
Prosečna vrednost Average	0,33	0,90	4,7	18,6	1,69	1,38	24,7	27,6
SD	0,17	0,22	2,25	6,9	0,33	0,26	3,2	4,9

*) ŽI – žetveni indeks, NP – nema podataka, SD – standardno odstupanje.
*) ŽI – harvest index, NP – no data, SD – standard deviation.

Nadalje će se za proračun količine ubrane slame koristiti vrednost visine reza kosionog aparata 15 cm. Ostaci stabljika na strnjištu su 2011. bili 26 %, a 2012. 33 %. U tab. 2 prikazani su najznačajniji rezultati za 2011. i 2012..

Tab. 2 Razultati za pšenicu, 2011. i 2012., prosečne vrednosti za sva merenja, visina sečenja kosionog aparata 15 cm

Tab. 2 Results for wheat, seasons 2011 and 2012, average values for all measurements, cutting bar height 15 cm

Parametar – Parameter	2011.	2012.
Prinos zrna - Yield, Mg ha^{-1}	6,9	5,1
Žetveni indeks - Harvest index	0,48	0,49
Masa nadzemnih žetvenih ostataka - Mass of aboveground harvest residue, Mg ha^{-1}	7,6	5,2
Srednja visina stabljika - Average height of stalks, cm	75	58
Udeo stabljika u ukupnoj masi nadzemnih žetvenih ostataka - Percentage of stalks in total aboveground residual mass, %	74	56
Masa ubrane slame* - Mass of harvested straw*, Mg ha^{-1}	3,8	2,1
Procenat ubrane slame u odnosu na masu zrna* - Percentage of harvested straw in comparison with mass of grain*, %	55,5	40,0
Udeo ubrane slame u nadzemnim žetvenim ostacima - Percentage of harvested straw in total aboveground residual mass, %	50,0	39,3
Masa žetvenih ostataka na polju - Mass of residues remaining on-field, Mg ha^{-1}	3,8	3,1
Procenat žetvenih ostataka na polju u odnosu na masu zrna* - Percentage of residues remaining on-field in comparison with mass of grain*, %	55,5	62,0
Udeo žetvenih ostataka na polju u ukupnim nadzemnim žetvenim ostacima* - Percentage of residues remaining on-field in total aboveground residual mass, %	50,0*	60,7

*pri gubicima prese 10 %, 10 % baler losses

U tabelama se uočava da se rezultati značajno razlikuju, što je, pre svega, posledica drugačijih agroklimatskih uslova. Prema podacima Republičkog hidrometeorološkog zavoda Srbije (www.hidmet.gov.rs, pristup sajtu oktobar 2012), ocena uslova vlažnosti je u vegetacionom periodu 2012. bila niža za dva nivoa nego za isti period 2011.. Za 2011., ocene uslova vlažnosti su bile – *umerena i jaka suša* (zavisno od lokacije uzorkovanja), a 2012.– *ekstremna i izuzetna suša*, što su ujedno i najlošije ocene uslova vlažnosti.

U 2012. prinos slame bio je značajno niži u odnosu na 2011., 2,1 prema 3,8 Mg ha^{-1}, a udeo ubrane slame u odnosu na ukupnu nadzemnu masu žetvenih ostataka, 39,3 prema 50,0 %. Količina žetvenih ostataka na polju nije značajno smanjena, 3,1 prema 3,8 Mg ha^{-1}.

U tab. 3 prikazani su podaci merenja na osnovu kojih se može zaključiti da smanjenje količine biomase u sezoni 2012. u odnosu na 2011. za slamu iznosi oko 45 %, a za žetvene ostatke na polju 18 %.

Masa stojećih, odnosno poleglih žetvenih ostataka pšenice na polju, koja iznosi 280 i 580 kg ha^{-1}, prema Hickman i Schoenbergr (1989a), ekvivalentna je 1.100 kg ha^{-1} SGe. Isti izvor daje podatke o smanjenju količine biljnog materijala nakon nekih operacija i vremenskih uslova. Na primer, tokom zime, masa koja pokriva polje smanjuje se za 10 %. Količine žetvenih ostataka na polju dovoljne su da se spreči eolska erozija u toku zimskog perioda i pri sprovođenju operacija obrade zemljišta bez prevtanja.

Tab. 3 Ubrana i na polju preostala količina žetvenih ostataka pšenice u 2011. i 2012., za visinu reza kosionog aparata 15 cm, prosečne vrednosti za sva merenja

Tab. 3 Harvestable and remaining mass of wheat crop residues in 2011 and 2012, for height of cutting bar 15 cm, average values for all measurements

2011.	Slama - Harvestable biomass, Mg ha^{-1}	3,8
	Udeo u ukupnim žetvenim ostacima - Share in total crop residues, %	50,0
	Žetveni ostaci na polju - Remaining biomass, Mg ha^{-1}	3,8
2012.	Slama - Harvestable biomass, Mg ha^{-1}	2,1
	Udeo u ukupnim žetvenim ostacima - Share in total crop residues, %	40,0
	Žetveni ostaci na polju - Remaining biomass, Mg ha^{-1}	3,1

Soja

Rezultati merenja 2011. i 2012. godine prikazani su u tab. 4. Pri prosečnom prinosu zrna 4,7 i 2,7 Mg ha^{-1}, uz žetveni indeks 0,47 i 0,41, ukupan prosečan prinos nadzemnih žetvenih ostataka iznosio je 5,3 i 3,8 Mg ha^{-1}, respektivno, za navedene godine obavljanja merenja.

Svi uzorci prikupljeni su na gazdinstvima sa naprednom tehnologijom proizvodnje soje, što je u sezoni 2011. rezultiralo relativno visokim prosečnim prinosom zrna 4,7 Mg ha^{-1} suve materije. Međutim 2012. godine prosečan prinos zrna približno je prepolovljen i iznosio je svega 2,7 Mg ha^{-1} suve materije, što je posledica ekstremne suše.

Prosečan žetveni indeks sezone 2011. iznosio je 0,47, što je tipično za visok prinos zrna, ali i za visok prinos žetvenih ostataka 5,3 Mg ha^{-1} suve materije. U sezoni 2012. prosečan žetveni indeks je smanjen na vrednost 0,41, što je, pre svega, posledica smanjenja prinosa zrna, ali i smanjenja prinosa žetvenih ostataka.

Pri žetvi soje primenjuje se mala visina reza kosionog aparata da bi se smanjili gubici, pa su ovde razmotrene visine 7,5 i 10 cm. Udeo mase stabljika na strnjištu iznosio je, u sezoni 2011, u proseku 24 % za visinu reza 7,5 cm i 19 % za visinu reza 10 cm, a u 2012. godini 31 % i 25 %, sl. 3.

To znači da je sezone 2011, za visinu reza 7,5 i 10 cm, na raspolaganju za ubiranje bilo 2,04 i 1,90 Mg ha^{-1} mase suve materije, respektivno, a sezone 2012. 1,12 i 1,03 Mg ha^{-1}, respektivno. Većina granja/lišća i mahuna pada na zemlju, ali dolazi i do mešanja sa odsečenim stabljikama. Ako je učešće ovih delova 30 %, to je u sezoni 2011. značilo dodatnih 0,84 Mg ha^{-1}, a u sezoni 2012. 0,69 Mg ha^{-1}. Gubici prese, odnosno *pick-up* uređaja, su u proseku oko 10 %. U sezoni 2011. količina biomase, koja je mogla da se ubere, slame, iznosila je, za visinu sečenja 7,5 i 10 cm, 2,59 i 2,46 Mg ha^{-1}, respektivno, a u sezoni 2012. 1,63 i 1,55 Mg ha^{-1}, respektivno. Žetveni ostaci na polju u sezoni 2011. iznosili su 2,71 i 2,84 Mg ha^{-1} suve materije, respektivno za visine sečenja 7,5 i 10 cm, a u sezoni 2012. 2,17 i 2,25 Mg ha^{-1}.

Tab. 4. Prinosi nadzemnih delova soje (vrednosti mase su date za suvu materiju) u sezoni 2011. i 2012.

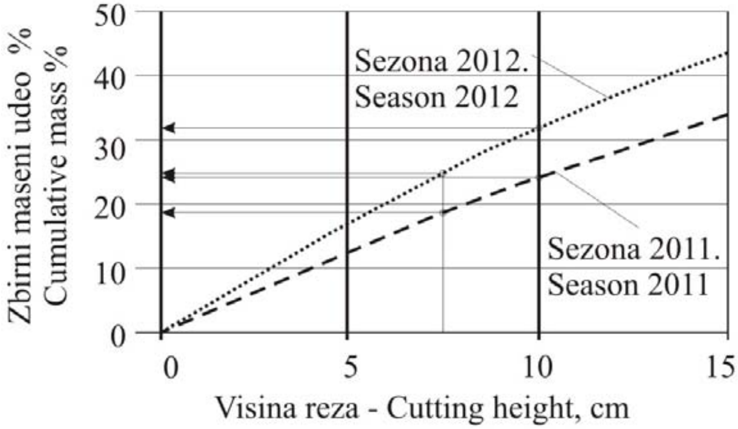
Tab. 4 Yield of the above-ground parts of soybean (mass for dry matter), season 2011 and 2012

Sorta Variety	Zrno - Grain				Stabljika - Stalk			
	Prinos - Yield, Mg ha^{-1}		ŽI*, -		Prinos - Yield, Mg ha^{-1}		Udeo mase prema zrnu - Yield relative to grain, %	
	2011.	2012.	2011.	2012.	2011.	2012.	2011.	2012.
Venera	3,0	1,9	0,43	0,34	2,1	1,5	68,8	79,4
Sava	7,0	NP*	0,54	NP	3,1	NP	44,7	NP
Balkan	5,9	3,9	0,44	0,51	2,7	1,6	48,1	41,2
Galeb	3,4	2,7	0,51	0,38	1,7	1,5	51,6	52,8
Gorštak	2,7	NP	0,45	NP	1,6	NP	60,2	NP
Dukat	NP	3,2	NP	0,48	NP	1,3	NP	39,6
Vojvođanka	6,5	1,8	0,45	0,34	3,6	1,5	55,4	84,6
Prosečna vrednost Average	4,7	2,7	0,47	0,41	2,5	1,5	54,8	59,5
SD*	1,7	0,8	0,04	0,07	0,7	0,1	8,0	19,0

Sorta Variety	Granje/lišće - Branches/leaves				Mahune - Hulls			
	Prinos - Yield, Mg ha^{-1}		Udeo mase prema zrnu - Yield relative to grain, %		Prinos - Yield, Mg ha^{-1}		Udeo mase prema zrnu - Yield relative to grain, %	
	2011.	2012.	2011.	2012.	2011.	2012.	2011.	2012.
Venera	0,4	1,2	13,1	60.0	1,5	1,0	51,0	50,9
Sava	0,8	NP	12,2	NP	2,0	NP	28,9	NP
Balkan	2,5	0,6	42,9	16,2	2,2	1,4	38,4	36,7
Galeb	0,3	1,6	7,8	59,2	1,3	1,3	37,7	49,1
Gorštak	0,5	NP	20,7	NP	1,0	NP	39,2	NP
Dukat	NP	0,8	NP	23,8	NP	1,5	NP	45,5
Vojvođanka	2,1	1,1	32,7	63,9	2,1	0,8	32,9	44,6
Prosečna vrednost Average	1,1	1,1	21,6	44,6	1,7	1,2	38,0	45,4
SD*	0,9	0,3	12,4	20,3	0,4	0,3	6,8	4,9

*) ŽI – žetveni indeks, NP – nema podataka, SD – standardno odstupanje.

*) ŽI – harvest index, NP – no data, SD – standard deviation.



Sl. 3 Uporedni prikaz zbirnih masenih udela stabljika soje

Fig. 3 Comparative review of the cumulative mass of soybean stalks

U tab. 5 prikazani su najznačajniji podaci za merenja 2011. i 2012.. Na osnovu tih podataka može da se zaključi da smanjenje količine biomase, u sezoni 2012. u odnosu na sezonu 2011, za slamu iznosi 37 %, za obe visine sečenja kosionog aparata 7,5 i 10 cm, a za žetvene ostatke na polju 20 %, takođe za obe visine sečenja.

Tab. 5 Ubrana i na polju preostala količina žetvenih ostataka soje u 2011. i 2012., za visine reza kosionog aparata, prosečne vrednosti za sva merenja

Tab. 5 Harvestable and remaining mass of soybean crop residues in 2011 and 2012, for two heights of cutting bar, average values for all measurements

		7,5 cm	10 cm
2011.	Slama - Harvestable biomass, Mg ha^{-1}	2,59	2,46
	Udeo u ukupnim žetvenim ostacima, Share in total crop residues, %	48,8	46,4
	Žetveni ostaci na polju - Remaining biomass, Mg ha^{-1}	2,71	2,84
2012.	Slama - Harvestable biomass, Mg ha^{-1}	1,63	1,55
	Udeo u ukupnim žetvenim ostacima, Share in total crop residues, %	42,9	40,8
	Žetveni ostaci na polju - Remaining biomass, Mg ha^{-1}	2,17	2,25

Masa stojećih i poleglih žetvenih ostataka soje, koja odgovara 1.100 kg ha^{-1} SGe, prema Hickman i Schoenberger (1989b), je 1.300 i 1.700 kg ha^{-1} respektivno. Na osnovu toga može da se zaključi da su preostali biljni ostaci soje dovoljni da se spreči eolska erozija, ali ne u svim slučajevima meteoroloških uticaja tokom zime i pri sprovođenju operacija obrade zemljišta bez prevrtanja.

ZAKLJUČCI

Pri korišćenju žetvenih ostataka, kao izvora energije, bitno je da se zna količina biomase kojom se raspolaže. Takođe, upravljanje žetvenim ostacima useva trebalo bi da se sprovodi na održiv način, kako bi se sprečila degradacija i smanjenje plodnosti zemljišta. Jedna od relevantnih informacija je količina žetvenih ostataka slame. Te količine zavise od mnogih uticaja, a najznačajniji su klimatski uslovi.

Prosečna vrednost žetvenog indeksa pšenice 2011. godine bila je 0,48, a 2012. 0,49, a za soju 0,47 i 0,41, respektivno.

Prosečna vrednost žetvenog indeksa pšenice za merenja 2011. godine bila je 0,48, a 2012. 0,49, a za soju 0,47 i 0,41, respektivno.

Za visinu reza kosionog aparata pri žetvi pšenice 15 cm u proseku bi na strnjištu ostajalo oko 26 i 33 % stabljika, u sezoni 2011, odnosno 2012. Pri žetvi soje bi na strnjištu, u sezoni 2011, u proseku ostalo 19 i 24 % stabljika, a u 2012. 25 i 31 % za visinu reza 7,5 i 10 cm, respektivno. Prosečna količina ubrane slame je u 2012. godini za pšenicu, iznosila 2,1 Mg ha^{-1}, što je značajno manje nego u 2011, 3,8 Mg ha^{-1}. Za soju je ta vrednost 2011. iznosila 2,59 odnosno 2,46, a 2012. 1,63 i 1,55 Mg ha^{-1}, za visine reza kosionog aparata 7,5 i 10 cm respektivno. Smanjenje količine žetvenih ostataka pšenice u sezoni 2012. u odnosu na 2011. za slamu iznosi oko 45 %, a za žetvene ostatke na polju oko 18 %. Kod soje to smanjenje za slamu iznosilo je oko 37 %, za obe visine sečenja kosionog aparata 7,5 i 10 cm, a za žetvene ostatke na polju 20 %, takođe za obe visine.

Količina žetvenih ostataka na polju nakon ubiranja slame pšenice i soje dovoljna je za zaštitu od eoloske erozije tokom zime i sprovođenja operacija obrade zemljišta bez prevrtanja.

Dobijeni rezultati mogu dobro da posluže za planiranje količine slame, koja stoji na raspolaganju, te da budu podloga za definisanje održivog upravljanja biljnim ostacima. U budućnosti bi trebalo da se merenja nastave, kako bi se dobili podaci za duži vremenski period i različite agroklimatske uslove, te da se obavi istraživanje o vrednostima hranljivih materija u biljnim ostacima, kako bi se i to uzelo u obzir pri formiranju cene slame.

Količina slame, koja se ubira, zavisi od pretpostavki o gubicima prese i stepenu ubiranja lišća, pa je poželjno sprovesti istraživanje, koje bi rezultiralo tačnijim vrednostima gubitaka prese.

Takođe bi bilo poželjno da se ovakva istraživanja nastave i u narednim godinama, za drugačije agroklimatske uslove, kako bi se dobili što pouzdaniji podaci za višegodišnje planiranje korišćenja slame pšenice i soje kao goriva, ali i planiranja i ostvarenja održivog upravljanja biljnim ostacima i očuvanja plodnosti zemljišta.

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HARVESTABLE AND ON-FIELD REMAINING CROP RESIDUES OF WHEAT AND SOYBEAN

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ABSTRACT

Objective of investigation was to determine the amount of harvestable wheat and soybeans straw and crop residues that remain on the field. Measurements were done in season 2011, which according to weather conditions can be assessed as an average, and in season 2012, when conditions were extremely dry.

Eight and six samples of most common wheat and soybean varieties, respectively, were collected in season 2011. The seven wheat and five soybean varieties in season 2012, from three locations in Vojvodina, agricultural region of Serbia. Wheat samples were classified in the following categories: grain, chaff (with spindles), stalks and leaves, and soybean: grain, stalks, branches/leaves and hulls. Harvest index, yield and relative yield of categories were determined. Stalks were cut into segments and their masses were measured. Based on it the diagrams of cumulative stalks mass were created, which enabled estimation of stalks remaining on stubble, depending on the cutting bar height. For the common straw harvesting procedures were estimated amounts of harvestable crop residue – straw. Based on amount of on-field remaining crop residues were assessed possibilities of achieving protection again wind erosion.

For 15 cm cutting bar height for wheat harvest the stalks remained on the field, in average, were around 26 and 33 % for the season 2011 and 2012, respectively. During soybean harvest, in the season 2011, in average, 19 and 24 % of stalks, and in the season 2012 25 and 31 % of stalks remained on the field for the cutting bar heights 7.5 and 10 cm, respectively. The average amount of harvested straw in season 2011 for the wheat was 3.8 Mg ha^{-1}, which is significantly more than 2.1 Mg ha^{-1} in the season 2012. For soybeans it was 2.59 and 2.46; 1.63 and 1.55 Mg ha^{-1} in season 2011 and the season 2012, for 7.5 and 10 cm cutting height bar, respectively. Due to worst climatic condition reduction of the amount of harvestable straw of wheat, comparing season 2012 and 2011 was about 45 %, whereby the reduction of the amount of on-field remaining harvest residues was about 18 %. For soybeans, reduction of the straw was about 37 %, and on-field remaining harvest residues about 20 %. The amount of crop residues remaining on the field after harvesting wheat and soybean straw is sufficient for protection of wind erosion, during winter period and if the tillage without plowing is performed.

It would be desirable to continue with measurements in the following years, under different agro climatic conditions in order to obtain the more reliable data for long-term assessment of the wheat and soybean straw potential, but planning of sustainable management of plant residues as well.

Key words: *crop residues, straw, wheat, soybeans, wind erosion*

41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.1:621.182.3:662.756](497.4)
Stručni rad
Expert paper

MOŽNOSTI MANJŠE PORABE GORIVA V SLOVENSKEM KMETIJSTVU

TOMAŽ POJE

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IZVLEČEK

Manjša poraba goriva za kmetijsko pridelavo pomeni na državni oziroma evropski ravni prispevek k manjšemu ogljičnemu odtisu in usmeritev v nizko ogljično družbo, kar je tudi eden od ciljev Slovenije. Poleg okoljskih prednosti pa ima manjša poraba goriva lahko velik vpliv tudi na ekonomsko uspešnost posamezne kmetije. Na osnovi modelnih kalkulacij Kmetijskega inštituta Slovenije predstavlja strošek goriva 39 % stroškov vseh strojnih storitev pri pridelavi koruze za zrnje. V letu 2011 je bilo 25.893 fizičnim osebam (kmetom) povrnjen del trošarine za 54 milijonov litrov porabljenega goriva v kmetijstvu. Pri delu s traktorji in drugimi kmetijskimi stroji obstaja veliko načinov za varčnejšo rabo goriva. V okviru IEE projekta Efficient 20 so bili trenutno doseženi največji prihranki goriva s pravilnejšo nastavitvijo priključkov in z uporabo varčne priključne gredi traktorja. Oranje je eden največjih porabnikov energije v kmetijski pridelavi; z manjšo globino oranja lahko porabo goriva občutno znižamo. Varčevalne ukrepe pa lahko v praksi uporablja le tozadevno strokovno izobražen kmet, ki se mora o tem neprestano strokovno izpopolnjevati.

Ključne besede: *kmetijstvo, manjša poraba goriva, traktor, varčni načini dela, Efficient 20*

UVOD

Slovenija se je zavezala, da bo postala nizkoogljična družba. Zato mora zmanjšati izpuste toplogrednih plinov. Toplogredni plini nastajajo v naravnih procesih, povzroča pa jih tudi človek s svojo dejavnostjo. Najpomembnejši toplogredni plin je ogljikov dioksid, ki nastaja tudi (ali predvsem) zaradi zgorevanja goriv. Kmetijstvo s svojo dejavnostjo prispeva k izpustom toplogrednih plinov in ogljičnemu odtisu. Pri ogljičnem odtisu kmetije se upošteva direktne komponente (kot je poraba dizelskega goriva, bencina, elektrike, itd.) in indirektne komponente (energija potrebna za izdelavo mineralnih gnojil, pesticidov, strojev itd.). Ogljični odtis na kmetiji lahko zmanjšamo z različnimi ukrepi, eden izmed njih je tudi manjša poraba goriva pri delu na kmetiji. V Sloveniji so se s porabo goriva in celotne energije v slovenskem kmetijstvu ukvarjali na Kmetijskem inštitutu Slovenije (Jejčič in Poje 1993, Poje in Jejčič, 2007, Jejčič, Poje in Cunder, 2003). Za porabo goriva v slovenskem kmetijstvu so uporabili različne metode izračunavanja. Agencija Republike Slovenije za okolje (ARSO) v svojih Slovenskih poročilih o emisijah toplogrednih plinov (TGP), navaja tudi emisije, ki jih povzroča uporaba kmetijske mehanizacije. Izračun emisij s kmetijsko mehanizacijo pa temelji na študijah Kmetijskega inštituta Slovenije oziroma na številu hektarov kmetijskih zemljišč in povprečni porabi goriva na hektar (Mekinda 2012).

Po Popisu kmetijstva iz leta 2010 imamo v Sloveniji 101.756 traktorjev. Manjša poraba goriva v kmetijstvu pa poleg okoljskih plusov prinaša tudi boljše ekonomske rezultate na kmetiji. Goscianska (2011) piše o potrebi po bolj učinkoviti izrabi energije v Evropski uniji tudi v kmetijstvu. Za to pa je potrebno tudi večje znanje končnih porabnikov energije – kmetov. Namen prispevka je prikazati nekatere možnosti za manjšo rabo goriv v kmetijstvu.

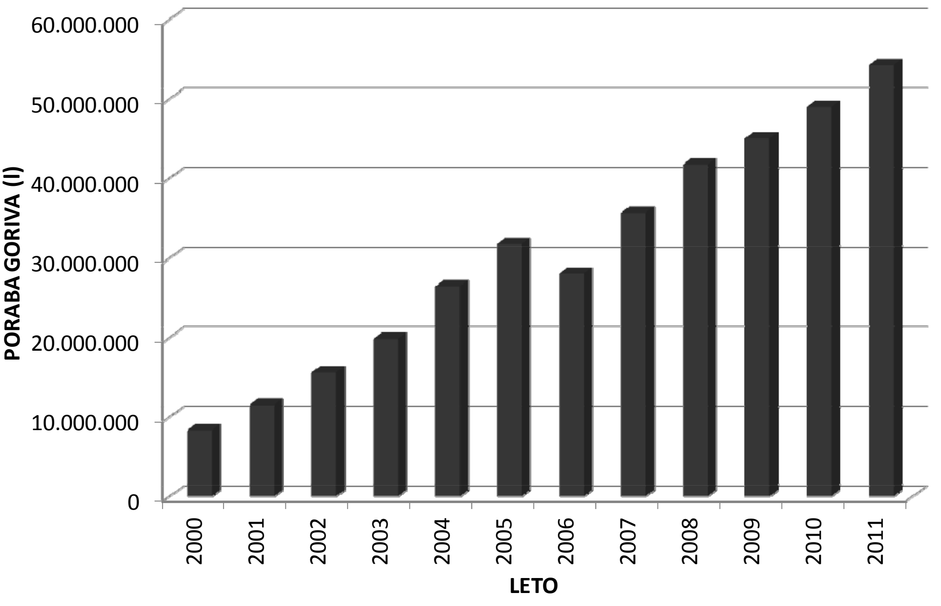
MATERIAL IN METODE DELA

Stroški goriva za pridelavo izbranih poljščin so izračunani po metodiki Modelnih kalkulacij Kmetijskega inštituta Slovenije. Zahtevki za vračilo trošarine za gorivo porabljeno v kmetijstvu so analizirani iz podatkovne baze Generalne carinske uprave RS. Iz podatkov skupne evropske baze projekta Efficient 20 smo analizirali rezultate meritev porabe goriva in dosežene prihranke. Meritve porabe goriva pri oranju smo izvedli na peščenih tleh. Uporabili smo traktor Fendt 714 Vario, nazivne moči 110 kW. Na traktor je bil pripet štiri brazdni obračalni plug Kverneland 180-9, MOD F. Pri oranju smo spreminjali globino dela, ostali delovni parametri pa so bili enaki. Poraba goriva je bila merjena na volumetrični način. Dobljene rezultate meritev smo statistično obdelali z opisnimi statistikami.

REZULTATI Z DISKUSIJO

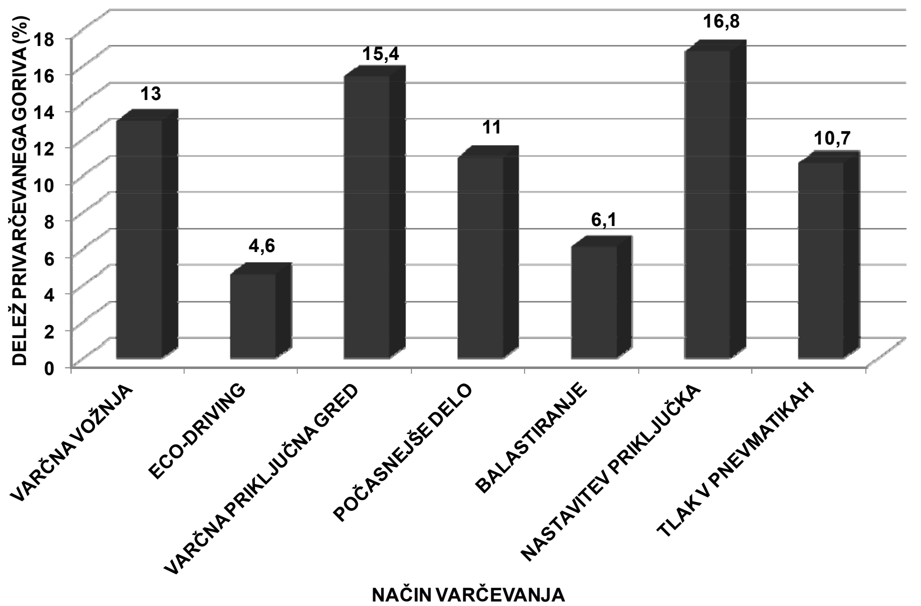
Iz analize Modelnih kalkulacij Kmetijskega inštituta Slovenije (2012) ugotavljamo, da je pri pšenici s pridelkom 5,3 t/ha delež stroškov goriva 11 % v skupnih stroških pridelave ter 38 % v stroških strojnih storitev (v strošek strojnih storitev ni vštet strošek dela traktorista oziroma kombajnista). Pri koruzi za zrnje s pridelkom 9 t/ha pa stroški za gorivo predstavljajo 9 % stroškov v skupnih stroških pridelave ter 36 % stroškov goriva v stroških strojnih storitev (v strošek strojnih storitev ni vštet strošek dela traktorista oz. kombajnista).

Delež goriva v strukturi stroškov pa se veča tudi zaradi vedno večjih cen goriva. Drobno prodajna cena dizelskega goriva je sestavljena iz prodajne cene goriva brez dajatev, takse CO_2, dodatka za zagotavljanje prihrankov energije, trošarine in DDV. Na podlagi 9. odstavka 54. člena Zakona o trošarinah za energente, ki se porabijo za pogon kmetijske in gozdarske mehanizacije lahko upravičenci zahtevajo vračilo 70 % trošarine, ki je predpisana za pogonski namen. Upravičenci morajo imeti v uporabi toliko gozda in kmetijskih zemljišč po posameznih vrstah dejanske rabe, da skupna normativna poraba znaša vsaj 540 litrov. Znesek vračila trošarine za pogonsko gorivo, porabljeno v letu 2011 za kmetijsko in gozdarsko mehanizacijo s strani fizičnih oseb, je 250,845 EUR za 1000 litrov goriva. Analiza zahtevkov za vračilo trošarine kaže na porast števila zahtevkov obravnavanem časovnem obdobju 2000 do 2011. V izhodnem letu 2000 je vračilo trošarine zahtevalo 6692 fizičnih oseb. V letu 2011 (ko so zadnji dostopni podatki) pa je vrnitev trošarine zahtevalo 25.893 fizičnih oseb. Te fizične osebe so v letu 2011 zahtevale nazaj del trošarine za dobrih 54 milijonov litrov goriva. Vsem skupaj je bilo nazaj vrnjeno 13,5 milijona EUR. Tudi pravne osebe iz kmetijstva lahko zahtevajo vračilo trošarine. V letu 2011 so zahtevale trošarino za dobrih 5,3 milijona litrov goriva. Popis kmetijstva 2010 ugotavlja, da je v Sloveniji dobrih 64 tisoč kmetijskih gospodarstev. Glede na to koliko upravičencev vlaga zahtevo za vračilo dela trošarine, ugotavljamo, da veliko kmetov tega še vedno ne stori. To si lahko razlagamo s tem, da nekateri ne dosegajo minimalne normativne porabe 540 litrov na leto glede na vrsto rabe kmetijskega zemljišča. Drugi spet ne zbirajo računov za gorivo ali pa v vračilu trošarine še ne vidijo smisla oziroma ekonomske koristi.



Slika 1 Količina goriva za katerega so fizične osebe zahtevale vračilo dela trošarine za pogonsko gorivo porabljeno za kmetijsko mehanizacijo

Najbolj enostavna možnost za zniževanje stroškov kmetijske pridelave in stroškov goriva je vlaganje zahtevkov za vračilo trošarine. Kmetje pa lahko stroške povezane s porabo goriva zmanjšajo na številne načine, med drugim tudi z bolj varčnim delom pri uporabi traktorjev in drugih kmetijskih strojev. O bolj varčnem delu s kmetijskimi stroji in traktorji se v Sloveniji do pridobitve projekta Efficient 20 dejansko ni veliko govorilo. V Sloveniji je sicer nekaj večjih kmetijskih posestev, kjer že zaradi velikosti kmetijskih zemljišč, razmišljajo in izvajajo energetsko manj potratne delovne postopke. Prihranki energije so na velikih površinah lahko zelo veliki. Ta velika posestva imajo zaposlene tudi tehnologe, ki skrbijo za to področje. Kmetje pa so bili za bolj varčno delo iz stališča porabe goriva prepuščeni sami sebi. Kmetijska svetovalna služba v Sloveniji za področje mehanizacije nima veliko specialistov, njihova dejavnost pa tudi ni bila usmerjena v bolj varčno delo s traktorji. Varčevanje z gorivom pri delu s traktorji in drugo kmetijsko mehanizacijo pa postaja ob vedno ostrejših ekonomskih razmerah na kmetijah vedno bolj aktualno. Že pri nakupu oziroma izboru traktorja mora biti kmet pozoren na tehnične lastnosti traktorja povezane s porabo goriva. Poraba goriva je v veliki meri odvisna tudi od samega traktorista – od njegovega načina vožnje in dela s traktorjem. Ravno on s svojim ravnanjem dela varčno ali pa bolj razsipno. Za porabo goriva je pomembno skrbno vzdrževanje traktorja (hladilni sistem, sistem za dovod zraka, itd.), nadalje ravnanje z gorivom (skladiščenje, vzdrževanje sistema za dovod goriva itd.). Velik vpliv na porabo goriva ima tudi ustrezen tlak v pnevmatikah in usklajenost velikosti in moči traktorja ter priključka.



Slika 2 Izmerjeni prihranki goriva pri pilotnih kmetijah včlanjenih v EFFICIENT 20

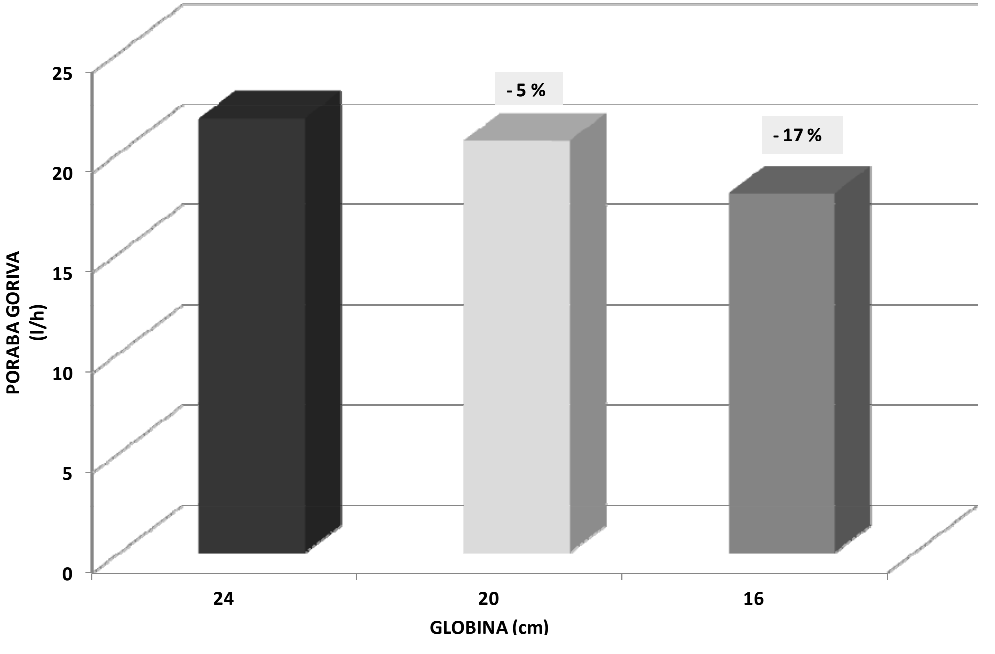
Evropski program Intelligent Energy Europe (IEE) poleg drugega promovira tudi učinkovito rabo energije. V letih 2010 do 2013 sofinancira projekt Efficient 20, ki ima za cilj zmanjšati porabo goriva v kmetijstvu. V ta projekt je vključena tudi Slovenija. V okviru projekta se izvajajo aktivnosti za manjšo porabo goriva na lokalnih ravneh v 9 evropskih državah, ki sodelujejo v projektu. Cilj projekta je doseči 20 % zmanjšanje porabe goriva tekom projekta pri pilotnih skupinah, vzpostaviti spletno bazo podatkov z rezultati preizkusov na terenu pred in po vzpostavitvi ukrepov za zmanjšanje porabe goriva in z rezultati meritev, ki jih izvajajo institucije itd. V meritve porabe goriva je vključenih 74 pilotnih skupin, 121 kmetijskih gospodarstev oziroma 235 članov. Do decembra 2012 je v podatkovni bazi izmerjena poraba goriva za 1833 delovnih operacij. V Sloveniji imamo dve pilotni skupini s skupno 12 člani. Člani pilotnih skupin merijo svojo porabo goriva pri delu na kmetiji. Izmerjena poraba goriva se vnaša v podatkovno bazo projekta. Članom pilotnih kmetij strokovnjaki svetujemo možne načine, kako lahko zmanjšajo svojo porabo goriva. Po upoštevanju teh nasvetov se meritve ponovijo. V podatkovni bazi so meritve, ki jih izvajajo kmetje. V podatkovno bazo pa so vključene tudi ekspertne meritve, ki jih opravljajo institucije (inštituti, testne postaje, ipd.). Rezultati meritev do decembra 2012 so prikazani na sliki 2 in nam kažejo začasno dosežene prihranke goriva glede na različne načine varčevanja z gorivom.

Iz slike 2 je razvidno, da se je največ prihranjenega goriva doseglo s pravilnejšo nastavitvijo priključka in z uporabo varčne priključne gredi. Podatkovna baza teh meritev se stalno dopolnjuje, zato se tudi ti prihranki spreminjajo. Spreminjajo pa se tudi najbolj uspešni načini varčevanja z gorivom. Dokončni rezultati bodo znani ob koncu projekta Efficient 20.

V okviru projekta Efficient 20 smo sodelavci Oddelka za kmetijsko tehniko izvedli več ekspertnih meritev povezanih z oranjem in manjšo rabo goriva. Te in ostale meritve porabe goriva so koristni primeri zlasti za promocijo bolj varčnega dela s kmetijskimi stroji. V okviru projekta so bila v Sloveniji v zadnjih dveh letih izvedena številna predavanja o možnostih bolj varčnega dela v kmetijstvu. Izvedeni so bili tudi celodnevni tečaji varčnega dela s traktorji. Ta promocija je bila namenjena tako kmetom kot neposrednim izvajalcem kot tudi kmetijskim svetovalcem in učiteljem iz srednjih biotehniških šol, ki potem to novo zanje posredujejo naprej.

Kljub temu, da se veliko govori o nekonvencionalnih načinih obdelave tal, plug ostaja osnovno orodje pri obdelavi tal. Poraba goriva pri oranju je lahko zelo velika in je lahko od 15 pa tja do 40 litrov goriva na hektar tal v odvisnosti od vrste in stanja tal. Za manjšo porabo goriva pri oranju so številne možnosti, našteli jih bomo le nekaj. Ena izmed možnosti, da zmanjšamo porabo goriva v celotni obdelavi tal je tudi tako imenovana „zimska brazda“, ki jo načeloma kmetje dobro poznajo in kar v veliki meri uporabljajo. Poleg potencialne akumulacije vode (če so padavine), pa so konec jeseni oziroma na začetku zime preorana tla, čez zimo izpostavljena velikim temperaturnim razlikam kar pomeni izmenjavanje zmrzovanja in odtajevanja, vlaženja in sušenja. Zaradi tega se velike talne grude drobijo v manjše strukturne talne agregate in to po naravnih razpokah. Dopolnilna – sekundarna ali predsetvena obdelava takih tal pa zahteva manj energije – manj goriva. Včasih je dovolj samo en spomladanski prehod z vlačo. Gnojenje s hlevskim gnojem ima številne pozitivne lastnosti na sama tla. Organska snov veže lahko do 5 krat več vode kot pa je njena lastna masa, kar je pomembno zlasti za peščena tla oziroma za vsa tla, kadar nastopijo suše. Če njivske površine redno in več let gnojimo z uležanim hlevskim gnojem je potrebna vlečna sila za vleko pluga do 38 % manjša kot na tleh gnojenih s mineralnimi gnojili. Hlevski gnoj (organska snov) izboljšuje strukturo tal, zaradi katere je potem manjši specifični odpor tal ob vleki pluga (manjša poraba goriva). Na porabo goriva pri oranju ima velik vpliv tudi konstrukcija pluga. Večina „boljših“ proizvajalcev ponuja deske različnih oblik primernih za taka ali drugačna tla. Poleg oblike plužne deske je pomemben tudi material iz katerega je izdelana.

Eden izmed možnih način varčevanja z gorivom pri oranju je prikazan na sliki 3. Količina prihranjenega goriva je seveda odvisna tudi še od drugih vplivov (delovne razmere – vrsta tal, vlažnost tal, zbitost tal, nastavitve pluga, ostrine delovnih elementov pluga, tlaka v pnevmatikah traktorja itd). S to sliko je dejansko prikazan samo princip možnega zmanjšanja porabe goriva pri oranju.



Slika 3 Vpliv globine oranja na porabo goriva pri oranju

Analiza slike 3 pokaže velik vpliv globine oranja na porabo goriva pri oranju. Osnovno globina oranja je bila 24 cm, nato pa smo zmanjšali globino oranja na 20 cm in na 16 cm. Vsi ostali delovni parametri so bili enaki. Sicer je bila širina oranja 2 m, vozna hitrost traktorja pa 8,3 km/h. Pri globini oranja 20 cm smo tako dosegli 5 % prihranek goriva, pri globini oranja 16 cm pa je izmerjen prihranek 17 %.

SKLEPI

Stroški za porabo goriva predstavljajo v kmetijski pridelavi velik delež. Kljub temu da obstaja veliko tehničnih možnosti za manjšo rabo goriva pa je traktorist ključen dejavnik, da bo dejanska poraba goriva tudi manjša. Ozaveščanje kmetov o pomenu varčnega dela je dolgotrajen proces in se mora ponavljati. Kmetje morajo poznati priporočila, možnosti in navodila za manjšo porabo goriva. Seveda pa se mora tudi vsak kmet oziroma traktorist odločiti, ali bo vse te nasvete tudi začel uporabljati v praksi. Rezultati IEE projekta Efficient 20 dokazujejo, da je varčevanje možno in nujno potrebno.

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POSSIBILITIES OF FUEL SAVINGS IN SLOVENIAN AGRICULTURE

TOMAŽ POJE

SUMMARY

Reduced fuel consumption of agricultural production means on the state or European level contribution to a smaller carbon footprint and focus on low-carbon society, which is also one of the objectives of Slovenia. In addition to environmental benefits, however, reduced fuel consumption can be a major influence on the economic success of the individual farms. On the basis of model calculations of the Agricultural Institute of Slovenia, the costs of fuel represent 39% of the cost of all mechanical services for the production of corn for grain. In 2011, 25,893 farmers have got a part of excise duty on 54 million litre of fuel used in agriculture. When working with tractors and other agricultural machinery, there are many ways for saving fuels consumption. In the frame of IEE project Efficient 20 were currently achieved maximum fuel savings with the more correct settings of implements and using the economical tractor PTO. Ploughing is one of the largest consumers of energy in agricultural production. Fuel consumption at ploughing can be reduced also with shallow depth of ploughing. Only a skilled driver can put these fuel-saving measures into practice and that it is subject to continuous professional training.

Key words: *agriculture, reduced fuel consumption, tractor, efficient ways of working, EFFICIENT 20*

41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 621.892:665.637.6:665.765
Stručni rad
Expert paper

EMISIJE CO_2 PRI DECENTRALIZIRANI PROIZVODNJI RASTLINSKEGA OLJA ZA ENERGETSKE NAMENE

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IZVLEČEK

Proizvodnja rastlinskih olj, ki predstavljajo gorivo ali osnovno surovino za proizvodnjo biodizla danes poteka na osnovi ekstrakcije olj s pomočjo mehanskega iztiskanja semen ali s pomočjo topil (ekološko sporno, uporablja se v velikih industrijskih obratih). Mehansko iztiskanje semena se opravlja z mehanskimi kontinuiranimi stiskalnicami vijačnega tipa. Za ugotavljanje porabe energije in emisij CO_2 v decentralizirani proizvodnji olja smo uporabili mehansko stiskalnico vijačnega tipa. Stiskalnica opravlja kontinuirano hladno stiskanje semena oljnic (za proces delovanja ni potrebno dovajanje posebne toplote za segrevanje semena ali samega stroja). Ugotovili smo da se pri enofaznem stiskanju porabi od 7,2 do 10,1 kWh/t predelanega semena (za decentralizirano proizvodnjo olja se porabi bistveno manj energije, kot pri industrijski proizvodnji olja). V drugi fazi stiskanja pa se porabi od 7,1 do 8,1 kWh/t predelanega semena. Seštevek prve in druge faze stiskanja nam da porabo energije za dvofazno stiskanje, ki se giblje od 14,3 do 18,2 kWh/t predelanega semena. Emisije CO_2 pri decentralizirani proizvodnji olja so tudi nizke, znašajo od 2,592 do 3,924 g CO_2/kg olja v eni fazi stiskanja. Zaradi boljšega izkoristka se uporablja dvofazno stiskanje, tako da celotne emisije CO_2 (seštevek prve in druge faze) znašajo od 5,148 do 6,84 g CO_2/kg olja.

Ključne besede: *oljna ogrščica,mehanska ekstrakcija rastlinskega olja, mehanska stiskalnica kontinuiranega tipa, eno in dvo fazno stiskanje, emisije CO_2*

UVOD

Proizvodnja rastlinskih olj, ki predstavljajo gorivo ali osnovno surovino za proizvodnjo biodizla danes poteka na osnovi ekstrakcije olj s pomočjo mehanskega iztiskanja semen ali s pomočjo topil (ekološko sporno, uporablja se v velikih industrijskih obratih). Mehansko iztiskanje semena se opravlja z mehanskimi kontinuiranimi stiskalnicami vijačnega tipa. Glede temperature vhodne surovine razlikujemo hladen ali topel postopek stiskanja. Pri hladnem postopku je temperatura vhodne surovine do 25˚ C, pri toplem postopku stiskanja pa je temperatura vhodne surovine nad 25˚ C. Stiskanje semena oljnic se lahko opravi v eni ali dveh fazah. Pri dvofaznem iztiskanju (hladni postopek) lahko dosežemo da iz semena oljne ogrščice iztisnemo tudi do 35 % olja. Tako se da pri dobro delujoči stiskalnici pri dvofaznem stiskanju dobiti iz 1 kg semena oljne ogrščice, 0,35 kg olja in 0,65 kg oljne pogače ali peleta. Stranski produkt je namenjen za prehrano domačih živali.

Z decentralizirano proizvodnjo olja se lahko ukvarjajo kmetije, strojni krožki, mikro podjetja, kmetijsko živilske šole itn. Hladno stiskanje olja ima veliko prednost pred drugimi proizvodnimi postopki, ki danes obstajajo za proizvodnjo rastlinskega olja zaradi praktične dostopnosti postopka proizvodnje. Za hladno stiskanje olja niso potrebni izredno zahtevni in dragi stroji, ki se uporabljajo pri industrijski ekstrakciji olja (prevladuje kemična ektrakcija). Značilno je, da so postopki mehanskega stiskanja semena enostavni, kontinuirani, ne zahtevajo posebnega dolgotrajnega nadzora strojev in ne zahtevajo velike količine energije.

Osnovo male oljarne predstavlja mehanska stiskalnica (večinoma vijačnega tipa). Stiskalnica je namenjena za mehansko ekstrakcijo olja s pomočjo mehanskega stiskanja semena različnih oljnic. Stiskalnica opravlja kontinuirano hladno stiskanje semena oljnic (za proces delovanja ni potrebno dovajanje posebne toplote za segrevanje semena ali samega stroja). Pri stiskanju tudi ni potreben poseben nadzor stroja. Olje se iz stiskalnega dela med procesom stiskanja kontinuirano odstranjuje v poseben rezervoar za pred filtriranje, kjer se opravi grobo čiščenje olja od mehanskih delcev. Istočasno nastajajo, kot stranski produkt stiskanja tudi oljna pogača oziroma peleti. Za stiskanje se lahko uporabijo različne oljnice namenjene za proizvodnjo olja: olje za gorivo (ali estrifikacija rastlinskega olja v biodizel), zdravilne, farmacevtske ali prehrambene namene itn.

Slika 1 Primer mikro oljarne (Hocem) za proizvodnjo olja na decentralizirani način, seme oljne ogrščice se kontinuirano dovaja iz zalogovnika s transporterjem v vijačno stiskalnico s kontinuiranim delovanjem

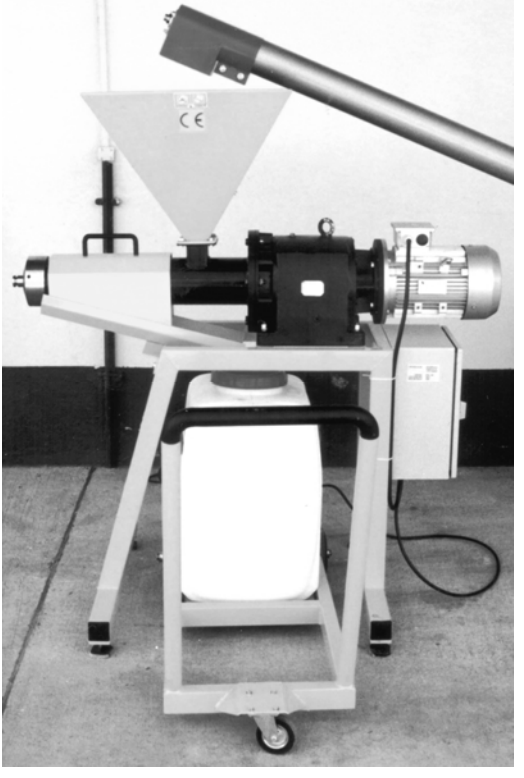
Za decentralizirano proizvodnjo olja gre takrat, ko enote za predelavo semena oljnic stisnejo od 0,1 do 5 t /dan (v nekaterih državah za proizvodno mejo imajo celo kapaciteto 25 t/dan, npr. Danska) semena. Decentralizirane proizvodne enote lahko ekonomsko in okolju prijazno obratujejo, ker je njihova tehnična oprema in delovni proces izredno enostaven ter povezan z nizko porabo energije. V povprečju se za decentralizirano proizvodnjo olja po podatkih literature porabi do 6 krat manj energije, kot pri industrijski proizvodnji olja. Proizvodnja olja na decentraliziran način ima še druge pomembne prednosti, kot so: odvija se poleg lokacij, kjer se odvija kmetijska proizvodnja, direktno ali indirektno je povezana s samo kmetijsko proizvodnjo (ni posrednikov), stroški investiranja v opremo so nizki, ni odpadnih vod, visoka fleksibilnost proizvodnje (hiter prehod na stiskanje drugih vrst oljnega semena, npr. za konzumno uporabo, kar poveča izkoriščenost stroja), krajše transportne poti (do 30 km od mesta proizvodnje) in s tem tudi manjši stroški, omogoča višjo dodatno vrednost kmetijstvu nekega območja, stranski produkt, ki nastane pri mehanski ekstrakciji olja je oljna pogača za živalsko krmo, ki ima visoko prehrambeno vrednost (vsebuje 12 – 17 % olja za razliko od industrijske pogače, ki vsebuje olja manj kot 1 %). Ekonomičnost takšne proizvodnje je pogojena s strukturo trga v smislu dobave surovine, kakor tudi možnosti sprejemanja produktov (olja in krmne pogače).

MATERIAL IN METODE DELA

Za ugotavljanje porabe energije v decentralizirani proizvodnji olja smo uporabili stiskalnico PHS 100, ki jo poganja elektro motor nazivne moči 2,2 kW. To je mehanska stiskalnica vijačnega tipa, namenjena za ekstrakcijo olja s pomočjo mehanskega stiskanja semena različnih oljnic. Stiskalnica opravlja kontinuirano hladno stiskanje semena oljnic (za proces delovanja ni potrebno dovajanje posebne toplote za segrevanje semena ali samega stroja). Pri stiskanju tudi ni potreben poseben nadzor stroja. Olje se iz stiskalnega dela med procesom stiskanja kontinuirano odstranjuje v poseben rezervoar za pred filtriranje, kjer se opravi grobo čiščenje olja od mehanskih delcev. Istočasno nastajajo, kot stranski produkt stiskanja peleti.

Učinek stiskalnice je odvisen od števila vrtljajev vijaka, premera stiskalne glave, premera izstopne šobe za pelete ter vrste semena. Pri višjih vrtljajih se učinek poveča, zmanjša se količina olja, ki ostane v oljni pogači oziroma peletu, vendar se poveča tudi poraba energije, kakovost olja pa se poslabša zaradi večje količine nečistoč v olju (fosoforja itn.).

Za stiskanje smo uporabili seme oljne ogrščice (Brassica napus) z vlažnostjo 8 %. V prvi fazi smo opravili stiskanje oljne ogrščice tako da smo spreminjali vrtljaje vijaka za stiskanje (20, 30 in 40 vrt./min.). Za določanje emisij CO_2, ki nastanejo pri uporabi električne energije za pogon elektromotorja stiskalnice je predpostavljeno da je električna energija pridobljena iz različnih energetskih virov (vodna energija, energija iz premoga, nuklearna energija in ostali viri energije npr. alternativni viri energije itn.). Različni viri električne energije ustvarjajo tudi različne emisije CO_2. Najvišje so emisije CO_2, ki nastanejo pri proizvodnji električne energije iz sežiganja premoga, najnižje pa iz vodne energije. Za izračun so vzete povprečne emisije 360 g CO_2/kwh$_e$



Slika 2 Stiskalnica kontinuiranega tipa PHS 100 (Hocem) uporabljena za ugotavljanje porabe energije pri hladnem stiskanju semena oljne ogrščice

Tabela 1 Izmerjene vrednosti za stiskanje oljne ogrščice v prvi fazi stiskanja s šobo premera 6 mm, temperatura semena na vhodu v stiskalnico je znašala 5,8 ºC, temperatura okolja 9 ºC

Učinek (kg semena /h)	76,9	113,4	145,4
Poraba energije (kWh/t) olja	7,2	8,5	10,9
Emisije g CO_2 /kg olja	2,592	3,060	3,924

Učinek stiskalnice se povečuje z naraščanjem števila vrtljajev polža. Poraba energije narašča z večanjem števila vrtljajev polža. Vidno je da zaradi večanja porabe energije naraščajo tudi emisije CO_2.

Tudi v drugi fazi stiskanja se učinek stiskalnice povečuje z naraščanjem števila vrtljajev polža. Poleg tega tudi poraba energije narašča z večanjem števila vrtljajev polža. Poraba energije je nekoliko nižja v primerjavi s prvo fazo stiskanja, ker peleti iz prve faze stiskanja vsebujejo manj olja. Zaradi porabe energije naraščajo tudi emisije CO_2 , vendar v manjši meri v primerjavi s prvo fazo stiskanja.

Tabela 2 Izmerjene vrednosti za stiskanje oljne ogrščice v drugi fazi stiskanja s šobo premera 6 mm, temperatura semena na vhodu v nasipnico je znašala 5,8 ºC, temperatura okolja 9 ºC

Učinek (kg semena /h)	64	97,6	125,2
Poraba energije (kWh/t) olja	7,1	7,8	8,1
Emisije g CO_2 /kg olja	2,556	2,808	2,916

ZAKLJUČEK

Decentralizirane proizvodne enote rastlinskega olja, lahko ekonomsko in okolju prijazno obratujejo, ker sta njihova tehnična oprema in delovni proces izredno enostavna ter povezana z nizko porabo energije. Ugotovili smo da se pri enofaznem stiskanju oljne ogrščice v prvi fazi porabi od 7,2 do 10,1 kWh/t predelanega semena (za decentralizirano proizvodnjo olja se porabi bistveno manj energije, kot pri industrijski proizvodnji olja). V drugi fazi stiskanja pa se porabi od 7,1 do 8,1 kWh/t predelanega semena. Seštevek prve in druge faze stiskanja nam da porabo energije za dvofazno stiskanje, ki se giblje od 14,3 do 18,2 kWh/t predelanega semena. Emisije CO_2 pri decentralizirani proizvodnji olja so tudi nizke, znašajo od 2,592 do 3,924 g CO_2/kg olja v eni fazi stiskanja. Zaradi boljšega izkoristka se uporablja dvofazno stiskanje, tako da celotne emisije CO_2 (seštevek prve in druge faze) znašajo od 5,148 do 6,84 g CO_2/kg olja.

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CO_2 EMISSION IN DECENTRALIZED PLANT OIL PRODUCTION

V. JEJČIČ, T. GODEŠA, A. OREŠEK

ABSTRACT

Production of pure plant oils for fuels or biodiesel production now is based on the extraction of oil with mechanical extraction of seeds or by using solvents (organic solvents used in large industrial plants). Mechanical extrusion of seeds is carried out by continuous mechanical screw type presses. To determine the energy consumption and CO_2 emissions in the decentralized production of oil we used mechanical screw press, which is designed for the extraction of oil by mechanical compression of various oil seeds. The machine performs continuous cold extraction of oil seeds (process does not need warming of oil seeds or single machine). We found that in single phase pressing of rape seeds, energy consumption is from 7.2 to 10.1 kWh/t of processed seeds (decentralized production of oil consumes significantly less energy than the production on industrial level). In the second stage of pressing, energy consumption is from 7,1 to 8,1 kWh /t of processed oil seeds. The sum of the first and second stage of pressing, gives energy for the two phase pressing. In mentioned case energy consumption is in range from 14,3 to 18,2 kWh /t of processed seeds. CO_2 emissions from decentralized pure plant oil production, are also low, in range from 2,592 to 3,924 g CO_2/kg oil at first stage of pressing. Due to the better efficiency of process, applied was two phase pressing, so that the total CO_2 emissions (sum of the first and second phase) ranging from 5,148 to 6,84 g CO_2/kg oil.

Key words: *rape seeds (Brasica napus), mechanical extraction of pure plant oil, mechanical screw press for mechanical oil extraction, one and two phase pressing of rape seeds*

41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Prethodno priopćenje
Preliminary communication

AN ENERGETIC AND EMISSION ANALYSIS OF A DIESEL ENGINE BASED MICRO COGENERATION UNIT USING DIFFERENT TYPES OF FUEL

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SUMMARY

On three-cylinder indirect-injection compression ignition engine based micro cogeneration unit (CHP) has been tested with mineral diesel fuel (D2), pure rapeseed oil (PPO) and biodiesel fuel (B100). The engine was upgraded with two tank system for PPO fuel preheating using engine cooling liquid through plate heat exchanger to ensure fuel temperature 72 °C. CHP unit was loaded through eight oil filled radiator heaters, which were turned off one by one to get changing load. Energetic balance and exhaust gasses analyses were done at different fuels and load rates. Based on results of measurements, type of fuel has no effect on produced electric energy and exhaust gasses heat, but usable heat and consequently lost energy are dependent on fuel type. Usable heat energy and exhaust gasses heat are almost independent of load rate of CHP. NO and black smoke emissions are the highest using D2 fuel at full CHP load.

Key words*: combined heat and power unit, bio fuels, efficiency, exhaust gasses emissions, rapeseed oil*

INTRODUCTION

The reduction of the pollutant emissions in the environment, produced by the industrial, energetic and the transportation sectors is one of the most important targets that are being taken into account in the most of the industrialized countries. It is necessary that all involved sectors prepare and accept strategies for the reduction of harmful impact on the environment.

In the last three decades, the world has been confronted with energy crises due to the decrease of fossil resources, with the increase of environment constraints, and the prices of oil. This situation brought as consequence the search of alternatives and renewable fuels, which have to be not only sustainable, but also friendly in respect to environment and techno-economically competitive (Coronado et al. 2010). Bio-fuels like ethanol, vegetable oil, biomass, biogas, synthetic fuels, biodiesel, etc.; are starting to be of high interest to the developed countries. Some of these fuels could be used in a direct form; however, others need some kind of modification to replace the conventional diesel fuel – gasification or digestion when the subject is bio-mass, and transesterification when it is biodiesel (Coronado et al. 2009). Many resources and work has been invested in the development of technologies, standards and legislation to reduce emissions in the transport sector. In the field of heat supply are set standards and legislative frameworks for fuels and flue gas emissions too. In larger systems, such as factories, public buildings or major cities is easier to achieve high efficiency and flue gas emission control, due to more uniform heating needs. For individual heating systems, it is difficult to provide high efficiency operation and control emissions. Recently, electrical and thermal energy cogeneration technology which could be used also for the individual buildings (houses, workshops, farms) progress much.

Combined Heat and Power (CHP), also known as co-generation, is the simultaneous generation of both usable heat and electrical power from the same source. As in a conventional boiler, the heat is used for space heating and hot water, but unlike in a conventional boiler, electricity is produced that can be used on site or exported to the national grid. These systems present many advantages for residential applications where they could contribute to the reduction of the primary energy consumption, the operating cost and the environmental impacts.

Technologies suitable for residential cogeneration systems include reciprocating internal combustion engine (ICE), micro-turbine, fuel cell, and reciprocating external combustion Stirling engine based cogeneration systems.

Presently reciprocating internal combustion engines (ICE) are the prime mover of choice for residential micro cogeneration applications because of their well-proven technology, robust nature, reliability, and reasonable cost (Onovwiona et al. 2007). To use bio-fuel, diesel engine for biodiesel or plant oil and gasoline engine for biogas are suitable.

Use of plant oil, when it is blended with fossil diesel or transesterified into biodiesel, generally does not require any engine modification. Modification is recommended, however, if the plant oil is used directly in neat form, mainly due to higher viscosity of the plant oils compared to fossil diesel which leads to incomplete combustion and coke formation inside the cylinder and in fuel supply systems including the injectors (Hossain and Davies 2012).

In this study we wanted to find out what is the impact of different types of fuel for micro cogeneration unit with diesel engine on electrical and thermal efficiency and exhaust emissions.

METHODS

The tested micro CHP unit consists of diesel engine, electric generator, exhaust gas heat exchanger and two tank system conversions, when rapeseed oil (PPO) is used as fuel.

The engine used in the tests is a Lombardini LDW 1503 with the specifications given below in table 1. It is a three cylinder, four-stroke, indirect-injection, water-cooled engine with a governor to maintain a constant speed. Through the crankshaft, also cooling liquid pump, fan and alternator are driven. There were no changes or adjustments done on fuel delivery system (like ignition timing and valves control).

Table 1 Technical data of used engine

Make	LOMBARDINI	Compression ratio	22:1
Type	LDW1503	Nominal frequency	3000 rpm
Cylinders	3	Nominal power	26.4 kW (ISO 1885)
Displacement	1551 cm^3	Nominal 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 engine was just upgraded with two tank system for PPO fuel preheating. To start the engine, mineral diesel fuel (D2) or biodiesel (B100) was used and when the engine warms up, automatic control module switched the electromagnetic valves to change fuel supply from D2 or B100 to PPO. The PPO was heated in the heat exchanger, which was connected to the engine cooling system to ensure PPO temperature 72°C. The energy for PPO heating is assumed as lost energy. For the experiment, cold pressed rapeseed oil (PPO), mineral diesel fuel (D2) and biodiesel (methyl ester of rapeseed oil, B100) were used as fuel. Main characteristics of used fuels are in table 2.

Table 2 Main fuels characteristics

Parameter	Unit	PPO	D2	B100
Lower heat of combustion	MJ/kg	39.69	42.96	40.06
	MJ/lit.	36.55	35.79	35.37
Spec. Density at 20°C	kg/dm^3	0.921	0.833	0.883
Viscosity at 20°C	mm^2/s	32	2-3	3.5-5
Flame point	°C	>220	74	>100

Two poles synchronous self regulated alternator SINCRO FT2MBS, 50 Hz, 3 Ph., 16 kVA, 400V was directly connected to the engine flywheel. As load we used eight oil filled radiator heaters of nominal power 2000W each, which were divided on three groups and connected as Y (star) type of connection to the alternator. Engine was working at about 2350 rpm because of minimal specific fuel consumption at this engine rotational frequency. So also voltage and frequency of alternator was lower as nominal and was measured at each treatment and used at power calculation. During measurements, heaters were disconnected one by one to change the load and so we got nine load treatments.

On engine exhaust manifold a heat exchanger was mounted and through another two connectors linked to engine cooling system. On such way the part of exhaust gasses heat, which is usually lost, was converted to heat energy, which can be used.

On CHP unit were measured:

- Coolant temperature at the outlet of the cylinder head, at inlet and outlet of the exhaust gas heat exchanger and at the outlet of engine cooling radiator.
- Exhaust gas temperature at the inlet to exhaust gas heat exchanger and at the exit from it.
- Ambient, fuel and engine oil temperature.
- Volume of coolant that has streamed in the time of one measurement cycle.
- Exhaust gas flow via Pitot tube.
- Electric current and voltage on each phase and thus electric power.
- Mass of fuel, burned during testing time.
- Engine crankshaft rotational speed
- Exhaust gasses composition and particulate emission expressed as adsorption coefficient.

For exhaust gas measurements the BOSCH BEA 350 device was used with additional module for NO emission and RTM 430 module for measuring particulate emissions.

Table 3 Measuring range and resolution of extended BEA 350 device

Component	Measuring range	Resolution
CO	0.000 – 10.00 %vol	0.001 %vol
CO_2	0.00 – 18.00 %vol	0.01 %vol
HC	0 – 9999 ppm vol	1 ppm vol
O_2	0.00 – 22.00 %vol	0.01 %vol
NO	0 – 5000 ppm vol	< =1 ppm vol
Absorption coefficient k	0 – 9.99 min^{-1}	0.01 min^{-1}
Oil temperature	-20 – +150 °C	0.16 °C
Engine speed BDM (B+/B–)	600 – 6000 min^{-1}	10 min^{-1}

Based on measurements of exhaust gases we wanted to determine the impact of load and fuel type on emissions of CHP engine. Particulate emissions measurements and measurements of exhaust gas composition were performed three times during each treatment and averages were calculated and used for analyses.

RESULTS

When using different fuels, the shares of new forms of energy change. Fig. 1 shows the percentage of each form of energy derived from fuel energy at full load, when all 8 oil radiators were connected. Usable heat represents the heat that is gained in the engine cooling system and heat that is transferred from the exhaust gas heat exchanger.

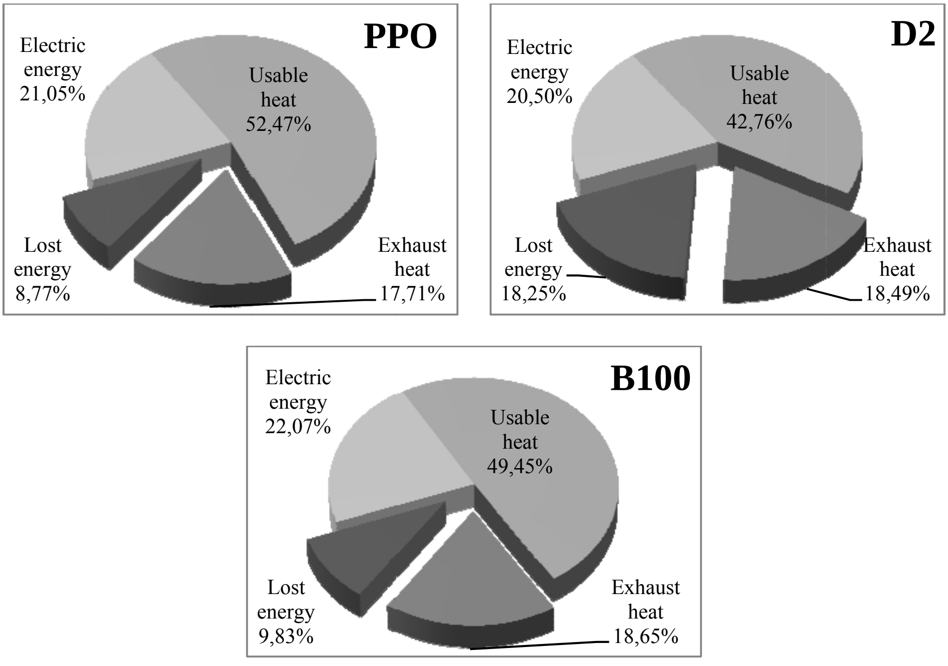

Fig. 1 Proportions of different fuels energy conversion at full load

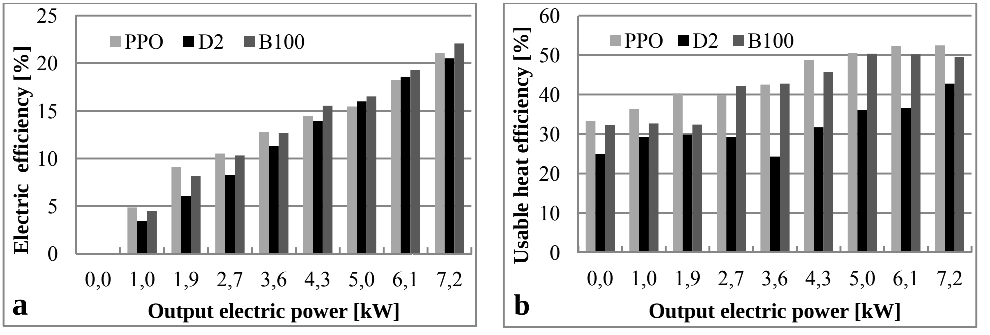

Fig. 2 Electric and usable heat efficiency in dependence on output electric power

The percentages of electric energy are almost at same level, little more than 20%, when using all three types of fuel. Usable heat differ more, especially at D2 fuel where is about 10% lower than at PPO and 7% lower than at using B100. Reverse difference is in lost energy, which is energy to power devices on the engine and mechanical, electrical and heat losses in the CHP unit. While CHP unit was same for all three fuels, heat looses probably contribute mostly to different percentage of lost energy. One of certain causes is higher engine working temperatures when using D2 fuel and thus higher heat and radiation emissions from engine surface. Energy, lost through exhaust is also at same level, about 18%, for all three fuels. The proportions of usable energy (electric and heat) and lost energy (losses and exhaust heat) differ in dependence of load level.

The electrical efficiency of the unit (fig. 2a), which is defined as the ratio of the electrical load to the fuel energy input, increases with rising load (electric power). Efficiency at full load is a little over 20% which is within the interval of average electrical efficiency (20% - 25%) obtained from the literature for the CHP units (De Paepe et al. 2006; Krishna et al. 2010). B100 gives higher percentages of electric energy at all loads compared to D2. Efficiency of usable heat (proportion of usable heat energy from the fuel energy) also increases by the rising load, but not so uniformly (fig. 2b). Especially at higher loads, bio-fuels give greater percentage of usable heat compared to D2 fuel. Usable heat efficiency at full load is around 50% which is also normal value for small CHP units.

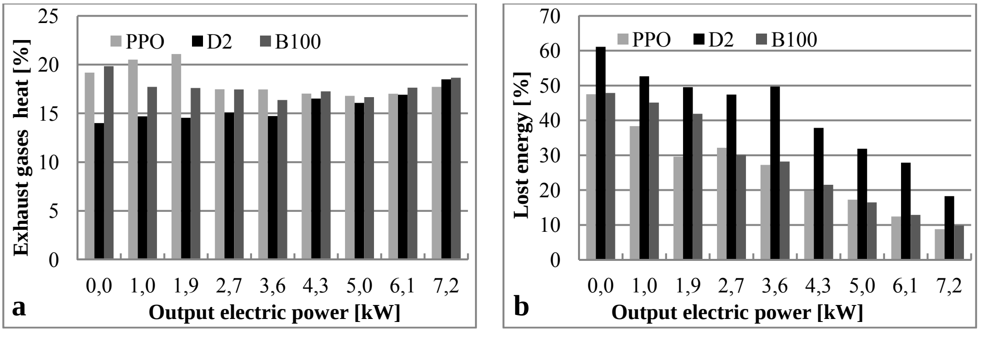

Fig. 3 Exhaust gases and lost energy percentage from fuel energy in dependence on output electric power

Minimum exhaust gases energy loss is at using D2 fuel at unloaded engine, and then by increasing the load it slightly grows (fig. 3a). At the use of bio-fuels the exhaust energy percentage is the highest at low engine load. At a moderate load it is reduced, and then with rising load slightly increase again and reach a value similar to that of D2 fuel.

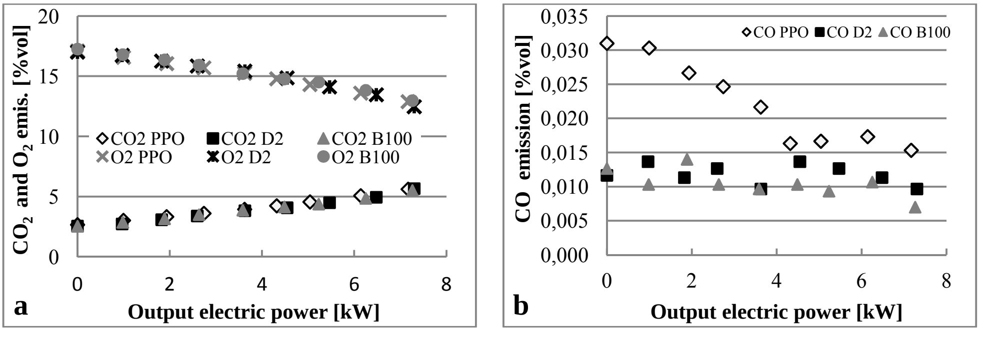

Fig. 4 CO_2, O_2 and CO emissions at different output electric power

Most of the energy is lost in the operation of CHP unit without electrical load (fig. 3 *Fig. 3*b). When the engine is not loaded, does not use so less fuel than the load of the motor smaller is according to full load. Therefore, this part of the fuel energy is gone. With increasing electric load, percentages of lost energy decrease and reach value fewer than 10% at using bio-fuels, while using D2, percentage of energy lost double.

Exhaust gasses analyses are done also on dependence of engine load through output electric power. At no load, O_2 emissions are about 17% and then decrease to 13% at full electric load (fig. 4a). There are no big differences between used fuels. CO_2 emissions vary opposite as O_2 emissions. At unloaded motor values are around 2.5%, and then increasing to 5.6% at full load. Similar trends are presented in literature (Hossain and Davies 2012; Wang et al. 2006). Type of fuel have also almost no influence on CO_2 emissions level, but stronger impact on CO emissions that can be seen also on fig. 4b. At low engine loads are the emissions of CO, when using PPO, also twice as high as using of D2 or B100 fuel. Than with increased load, the CO emissions reduced when using PPO and get closer to the values for D2 and B100 fuel, but they are still higher. CO emissions using D2 and B100 do not vary a lot with a load change. At higher engine loads, the emissions of CO using B100 is slightly lower than when using D2 fuel. Wang (Wang et al. 2006) also reported that CO emissions at lower loads at using D2 fuel, blended with PPO, and especially at using just PPO, are higher and then get lower with increasing load. Rakopoulos (Rakopoulos et al. 2006) presented similar results. The use of D2, blended with plant oils of different origin resulting higher CO emissions than use pure D2 fuel.

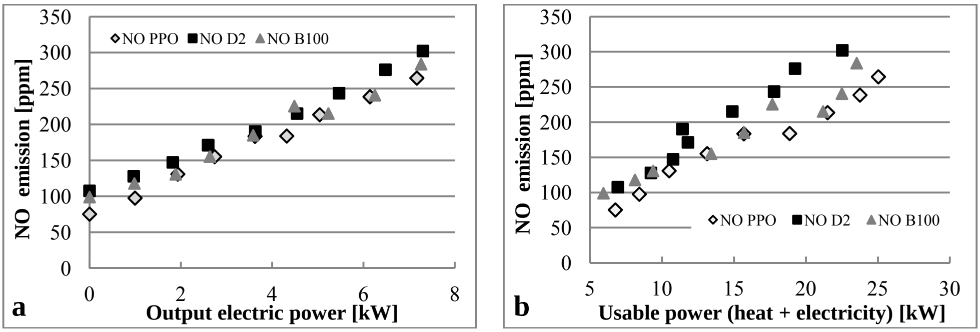

Fig. 5 NO emissions at different output electric power and at different usable power

NO emissions are increasing with increasing load (fig. 5a). When using the D2 fuel, NO emissions increase from the value of 108 ppm at unloaded engine to 302 ppm at full load. When using PPO, emissions are lower and increased from the initial 75 ppm to 265 ppm. If we compare the change of NO emissions using various fuels as a function of usable power (heat + electricity, fig 5b), then are the differences between D2 on one side and B100 and PPO on the other, even greater. Formation of nitrogen oxides is mostly dependent on combustion temperature and then on local concentrations of oxygen in the combustion chamber and duration of combustion. Higher engine load causes higher combustion temperatures and thus higher NO emissions, while oxygen concentrations and duration of combustion have minimal influence because of the same RPM at different load. In general, the emissions of NO using biofuels are greater than when using D2 (Raslavičius and Bazaras). But some authors (Wang et al. 2006; Rakopoulos et al. 2006; Tippayawong et al. 2002) reported also about lower NO_x emissions when using PPO. The reason is the lower heating value of PPO, and in our case, due to the partial load (lower temperatures) and operating at lower engine RPMs (extended duration of combustion).

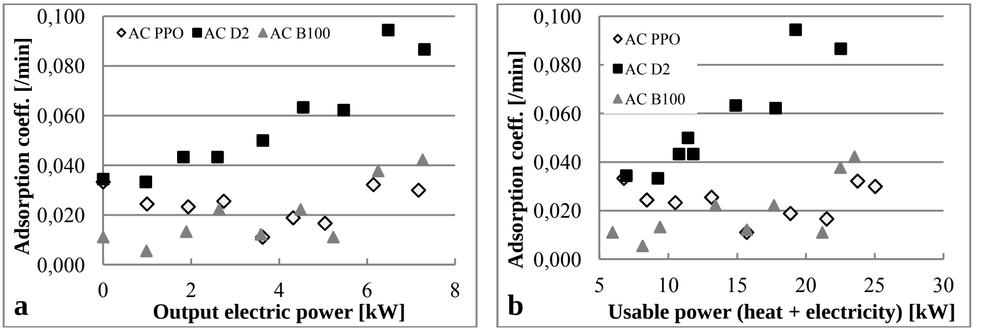

Fig. 6 Exhaust gasses adsorption coefficient at different output electric power and at different usable power

Black smoke or particle emissions are particularly problematic at diesel engines use, due to incomplete combustion of fuel, especially at maximal load. At bio-fuels use, particle emissions are lower than using D2 fuel. This can be also seen on fig. 6a, where emissions represented as adsorption coefficient. At D2 fuel use, emissions significant increase with rising load, while using B100 and PPO are emissions quite uniform at moderate load. At higher loads they increase too, but not so much as at D2 use. The differences are even greater when comparing the emissions as a function of usable power (fig. 6b). The lowest emissions at high engine load were at PPO use.

Lower smoke emissions using bio-fuels mention also different authors (Coronado et al. 2009; Tippayawong et al. 2002)

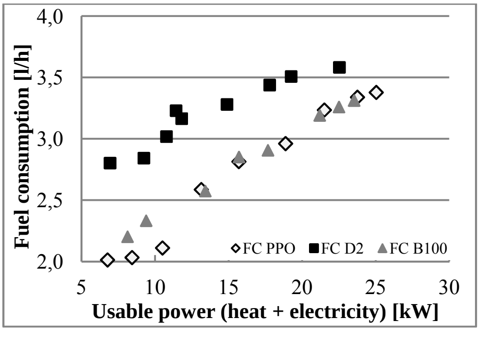

Fig. 7 Fuel consumption in dependence of usable power

Fuel consumption normaly increase with higher load, but the most favorable is that the fuel consumption in dependence of usable power at use of biofuels is lower compared to D2 (fig. 7). This has a positive effect on the economics of operation of CHP units and the environmental acceptability production of wide usable electricity and heat on such way.

Despite the lower combustion energy value of bio-fuels, the specific consumption is smaller due to lower percentage of lost energy and also better efficiency of converting energy in the internal combustion engine.

CONCLUSIONS

The experimental results show that there are some differences at energy conversion efficiencies and exhaust gasses emissions of micro CHP unit run by vegetable oil or biodiesel are comparable with run by mineral diesel fuel.

Percentage of electric energy and exhaust gasses heat at full load are almost the same at all three fuels. Usable heat energy percentage at PPO and B100 is higher than at D2 and for that difference is higher the lost energy percentage at D2.

With arising load, electric and usable heat efficiencies increase, while lost energy percentage decreases. Exhaust gasses heat percentage is almost independent on engine load.

Type of fuel has almost no effect on CO_2 and O_2 emissions at all loads.

NO emissions and black smoke are highest using D2 fuel, especially at higher load.

Fuel consumption at D2 compared in dependence of usable energy is higher than at other two used fuels.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

TESTING OF IMPROVED BOILER FOR BIOMASS BRIQUETTES

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SUMMARY

The paper presents the research results on the combustion of biomass briquettes made of various mixtures of sawdust and harvested crop residues (wheat straw, corn stover, and reed) in a small boiler with downdraft combustion, designed to burn wood or sawdust briquettes. The analysis of five types of biomass mixtures showed that their combustion properties are similar to the manufacturer's recommended fuel, but also revealed some improvement potential, specifically the thermal shielding of the primary combustion chamber using a refractory lining and the adjustment of the excess air between the two combustion chambers. The experimental measurements indicated a global thermodynamic efficiency increase from 86.73% to 94.08%, a combustion maximum efficiency increase from 91% to 96.2%, a significant reduction of maximum CO emissions (O_{2ref} = 12%) from 8292 ppm to 4756 ppm, and a similar reduction of maximum NO_x from 272 ppm to 126 ppm. These results have been obtained by using briquettes made of a 50/50 mixture of sawdust and corn stover.

Key words: *biomass boiler, efficiency, emission*

INTRODUCTION

Environmental pollution, climate changes, and the near future depletion of fossil energy resources have determined a more rational use of energy and also a sustained search for new sources of energy to replace the fossil fuels. The renewable forms of energy can substantially contribute to the preservation of resources, the environmental protection, the self-sustainability, and the long-term development.

In 2006, about 13% of the worldwide primary energy consumption was covered by the renewable resources, from which 77% was biomass [10]. In the UE, biomass accounted for approx. 63% of the total renewable energy.

An increasingly careful and extended use of biomass can provide: a greater contribution to the primary energy delivery worldwide; the reduction of greenhouse gases and other potential environmentally friendly effects; opportunities for rural communities economic and social development; the mitigation of waste disposal related problems and a better resources use.

There are two main types of biomass: waste products (any kind of plant or animal residue and the organic fraction of the solid municipal waste) and biomass resulting from energy crops. Only the agricultural residues that are not used as livestock feed and bedding, or soil amelioration can be used for energy production.

The raw crop residues present some disadvantages when used as energy sources, for example: reduced thermal output, variation of properties and quality, fast combustion; difficult automatic continuous feed of the combustion chamber; large storage space and transport issues. In order to overcome these problems, a density increase by compression would be necessary (producing briquettes or pellets). Residues must be dried and chopped before processing.

Crop residues are an important biomass resource in Romania due to the large contribution of the agriculture to the national economy. The main agricultural residues in Romania are: corn residues (2 million dry tons), wheat residues (2 million dry tons), sugar beet residues (0.3 million dry tons), sunflower residues (0.3 million t_{dm}) and oats residues (0.15 million t_{dm}) [11].

The new European Directive (2009/28/EC) aims for generating 20% of the total energy consumption in UE from renewable resources, and to replace 10% of the amount of transportation fuels with bio-fuels by 2020.

There are several approaches for converting raw biomass into energy. Direct heat production is the most common application, often competing with fossil fuels based technologies, starting from the small rudimentary stoves up to the most sophisticated and modern applications.

Recent studies of the biomass combustion technologies for different sized installations have been published [1-4, 6-9]. Unlike other research activities, the studies at "Dunărea de Jos" University of Galați have concentrated on the combustion of crop residues briquettes in small gasification boilers. The crop residues combustion generates additional challenges compared to the wood combustion, such as furnace slagging and chimney stack blocking. Moreover, pollutant emissions are higher due to the increased level of ashes (5% instead of 0.5%) and also nitrogen, sulphur, chlorine, and potassium (caused by chemical fertilizers, pesticides, and herbicides). Consequently, the present study was initiated to assess the potential for reducing these drawbacks by using mixtures of crop residues and sawdust.

The downdraft combustion with gasification is characterized by almost constant CO and CO_2 emission levels, with slight variations towards the end of the current batch combustion and at the beginning of the next batch [7]. The classic batch-loaded updraft combustion generates large variations of these emissions, not only at the beginning and the end of the batch, but also during the combustion process.

The goal of this study is to improve the combustion of biomass briquettes made of various mixtures of sawdust and agricultural residues (wheat straw, corn stalks and reed) in a small boiler with downdraft combustion, designed to burn wood or sawdust briquettes.

METHODS AND MATERIALS

The boiler used for the present study is a 40 kW heating boiler with downdraft combustion, designed to use wood or sawdust briquettes as fuel. The batch is loaded in the fuel stock or the main combustion chamber, where getting in contact with the combustion products from the previous batch and under the influence of the refractory walls, it is dried and pyrolyzed, releasing the volatile components, which combined with the primary airflow results in a combustible mixture. This mixture is then transferred through the refractory nozzles into the secondary combustion chamber where the main combustion process occurs, under the form of a "reversed flame".

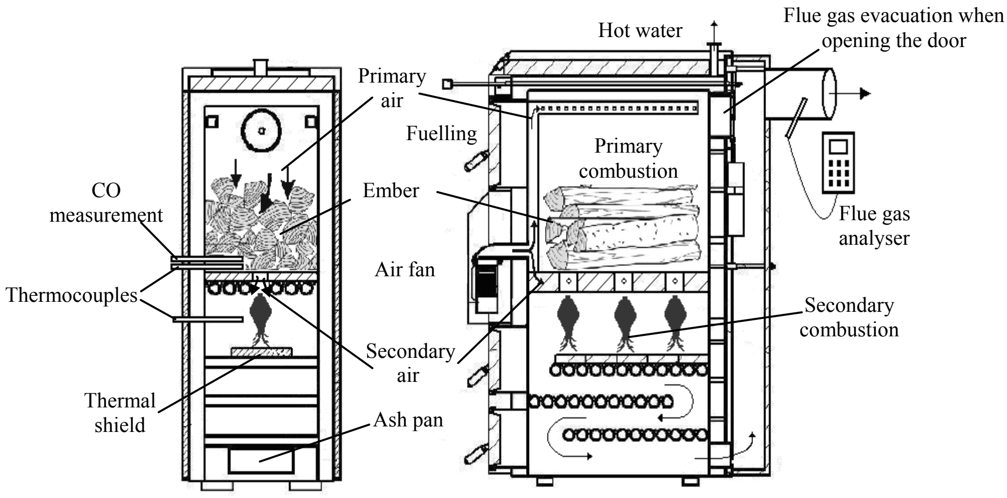

Fig. 1 Scheme of the 40kW heating boiler

Inside a downdraft combustion boiler, the combustion process is splitted between the two combustion chambers. By separating the processes of pyrolysis and char combustion, the mixing of the combustible gases with the secondary air is improved, leading to a reduction in pollutant emissions caused by incomplete combustion. The scope of the study is to identify methods to reduce the pollutant emissions and to increase the thermal efficiency. The laboratory boiler is designed with a certain degree of flexibility, allowing for the testing of various operating conditions (Fig. 1). Temperature, buoyancy, mass flows and pollutant emissions were measured, recorded and processed. Different combustion conditions were tested and all of the fuels used were analyzed. The experiments have been carried out according to the requirements of EN 303-5 –the European standard for solid fuel boilers. The temperature, CO, CO_2, NO_x and O_2 concentrations in flue gas, the combustion efficiency and the excess air ratio were analysed using the Eurotron Ecoline 4000 gas analyser. The test rig includes also thermocouples to measure the temperature in the combustion chambers and the Riken analyser for CO content in fuel gas.

The fuels selected for tests were one briquette produced from pure reed, four briquettes produced from mixture of sawdust with wheat straw and with ground corn stalk and one briquette produced from pure sawdust and wood log (acacia) as fuels recommended by the boiler manufacturer.

The properties of the briquettes used for the experiments run on the modified installation are presented in Table 1.

Table 1 Fuel properties

Fuel	Ultimate analysis (wt% of wet fuel with ash) [%]							Higher heating value, HHV [$MJ \cdot kg^{-1}$]	Density [$kg \cdot m^{-3}$]
	C	H	N	S	O	A	W		
Briquette of sawdust 50% + corn stalk 50%	46.1	5.5	0.4	0.0	38.0	3.30	6.7	18.6	1070

RESULTS AND DISCUSSION

The experimental results analysis indicated that the combustion of the crop residues briquettes is similar to the recommended fuels behavior, and highlighted the ways to improve the combustion process, specifically the application of thermal insulation using refractory lining inside the primary combustion chamber (for reducing the heat loss through the chamber walls and for boosting the combustion temperature) and the control of the excess air distribution (during the initial combustion phase, increasing the air delivery for the secondary chamber, while in the second phase forcing more air into the primary chamber).

The efficiency of the heating boiler is mainly affected by the load level, the operating conditions and the type of fuel used.

The experimental results suggest that the combustion efficiency is not constant with time, significantly decreasing towards the end of the batch. The chemical composition of the fuel also varies considerably during a batch. The higher heat output of the char partially compensates for the lower burning speed, caused by the reduced reactivity of the carbon residues compared to the volatile fractions. Under these conditions, maintaining a constant air flow will lead to increased excess air in the primary combustion chamber. This leads to the necessity of fitting the boiler with a system that should optimize the two combustion chambers air distribution.

Although the excess air is high, the CO emission levels are also high. This could be explained by the lower combustion temperature. If the excess air would be too low, the levels of incomplete combustion products, like CO, should considerably increase due to the insufficient mixing. And that would occur even if the local temperatures are high enough to promote complete combustion. At the beginning of the char combustion phase, the primary chamber temperature drops, most of the times below the minimum level that would allow a complete oxidation of CO formed by the heterogeneous combustion of char. The minimum temperature level required is 800ºC.

The NO_x are mainly present during the volatile fractions combustion phase, when the temperature is much higher. The NO_x levels have a tendency to decrease during the batch, as the nitrogen present in the fuel is consumed and the combustion temperature is lowered. The NO_x levels are only slightly influenced by the combustion temperature, while the levels measured during the char combustion phase, expressed in g/kg of dry fuel usually increase. The reduction of NO_x emission levels with higher excess air demonstrates that the main formation mechanism is the fuel NO_x and not the thermal NO_x.

In order to improve the combustion of the crop residues briquettes, a reduction of the total excess air was obtained by partially blocking the air inlet duct and by applying thermal insulation with refractory bricks at the internal walls of the primary combustion chamber.

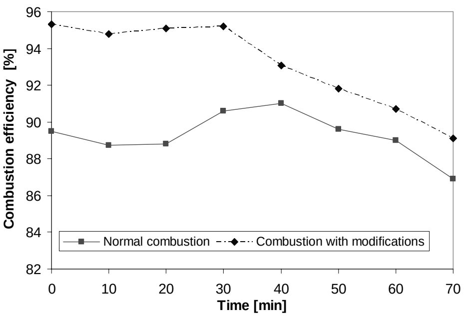

Fig. 2 Combustion efficiency

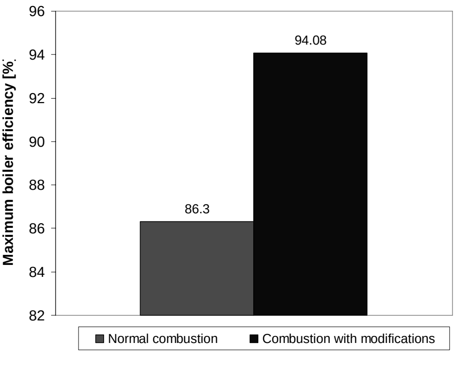

Fig. 3 Maximum boiler efficiency

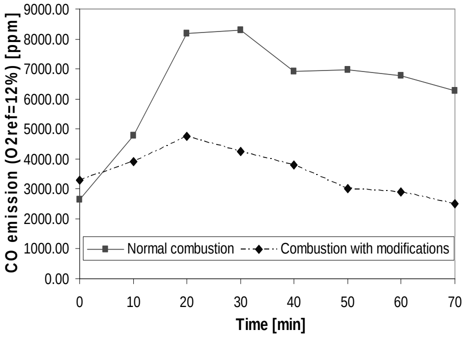

Fig. 4 CO emission levels

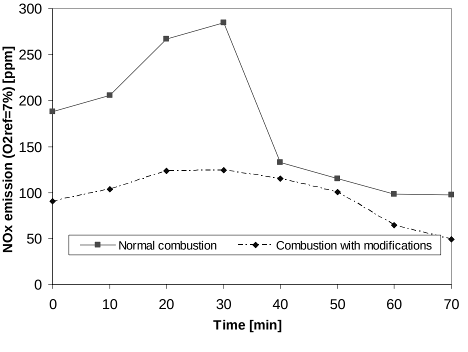

Fig. 5 NO_x emission levels

The latest experimental results obtained with briquettes made of a 50/50 mixture of sawdust and corn stalk, proved the following:

- The maximum combustion efficiency was raised from 91% to 96,2% (Fig. 2);
- The boiler efficiency increased from 86,73% up to 94,08% (Fig. 3);
- The maximum CO emission levels (O_{2ref} = 12%) dropped from 8292 ppm to 4756 ppm (Fig. 4);
- The maximum NO_x emission levels (O_{2ref} = 12%) decreased from 272 ppm down to 126 ppm (Fig. 5).

CONCLUSIONS

Crop residues briquettes combustion in a 40 kW heating boiler with downdraft combustion is similar to the manufacturer recommended fuels characteristics, i.e. wood or sawdust briquettes.

The experimental tests revealed that the operational performance of the boiler can be improved by use of refractory bricks in the primary combustion chamber and by controlling the excess air distribution for the two combustion chambers.

The combustion efficiency and the boiler efficiency are enhanced, while the pollutant emissions (CO and NO_x) are reduced.

Although the improvements obtained after performing the operational and design modifications are significant, the results do not satisfy the requirements of the European standard EN 303-5:2012 [10], and as far as CO emissions are concerned, further development is still necessary.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Pregledni rad
Review paper

POLJOPRIVREDNA TEHNIKA U UZGOJU ENERGETSKE KULTURE *MISCANTHUS X GIGANTEUS*

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SAŽETAK

Obzirom da se obrada, predsjetvena priprema tla za sadnju kao i njega nasada obavlja klasičnim konvencionalnim tehnikama u ratarstvu i travnjaštvu, naglasak u tehnici tijekom uzgoja Miscanthusa x giganteus*a je na strojevima i opremi za sadnju odnosno žetvu. Mogućnost izvođenja žetve* Miscanthusa x giganteusa *možemo podijeliti na dvije tehnike, i to na višefaznu (košnja, formiranje otkosa, baliranje ili prikupljanje-usitnjavanje) te jednofaznu (košnja-baliranje ili košnja-usitnjavanje). Međutim, obzirom na činjenicu da usjev ostaje na polju minimalno 15 godina, od izuzetne je važnosti stručno i kvalitetno provesti sve agro-tehničke mjere. Stoga, cilj ovog rada je dati pregled svih strojeva i opreme koji su nužni za učinkoviti uzgoj energetske kulture* Miscanthus x giganteus.

Ključne riječi*:* Miscanthus x giganteus*, poljoprivredna tehnika, strojevi, oprema*

UVOD

Povećane potrebe modernog stanovništva za sve većom količinom konstantno dostupne energije, želja EU za energetskom neovisnošću, ekološki problemi uzrokovani intenzivnim korištenjem fosilnih goriva kao i njihov cjenovno nekontrolirani rast glavni su uzroci sve intenzivnijeg korištenja ekološki prihvatljivijih i kontinuirano obnovljivih izvore energije (Sirin i Ege, 2012).

Obzirom da Republika Hrvatska u 2013. god. postaje punopravna članica EU, samim time i preuzima obveze iz Direktive (2009/28/EC) Europske komisije (2009) koja nalaže promociju i uporabu energije iz obnovljivih izvora te definira cilj nazvan 20-20-20. Njome su sve članice EU obvezne do 2020. god. uštedjeti 20% energije, proizvoditi 20% energije iz obnovljivih izvora te smanjiti emisiju stakleničkih plinova za 20%. Očekuje se da će biomasa, uz energiju vjetra i voda, imati najveći doprinos u postizanju navedenih ciljeva, a uvođenjem energetskih kultura u svoju intenzivnu proizvodnju, Republika Hrvatska bi osigurala određeni udio biomase za proizvodnju tzv. "zelene" energije, definirane kvotama iz navedene Direktive. Iako je proizvodnja i korištenje biogoriva danas u značajnom porastu ona još uvijek predstavlja samo djelomičnu zamjenu za fosilna goriva. Među dostupnim izvorima obnovljive energije, koji mogu pomoći u „odgovoru“ na prethodno navedene izazove, su i energetske kulture.

Uzgojem i iskorištenjem energetskih kultura, osigurava se lignocelulozna sirovina za proizvodnju električne i toplinske energije, odnosno biogoriva druge generacije (EU Strategy for biofuels, 2006). Obzirom da se za proizvodnju biogoriva prve generacije koriste visokovrijedne sirovine prvenstveno namijenjene za prehranu stanovništva, a pritom se eksploatira i kvalitetno poljoprivredno tlo, krajem devedesetih postupno je došlo do razvoja biogoriva druge generacije. Moguće sirovine za proizvodnju biogoriva druge generacije su šumska i poljoprivredna biomasa, organski ostatak/otpad te energetsko-lignocelulozne kulture (Naik, 2010). Nadalje, od 2.150.000 potencijalno obradivih površina u Republici Hrvatskoj, čak 974.080 ha je neiskorišteno, od kojih je preko 600.000 ha površina lošije kvalitete nepogodnih za intenzivnu poljoprivrednu proizvodnju (Statistički ljetopis, 2010). Sukladno navedenom, potrebno je pronaći usjeve koji će biti ekonomski ali i ekološki prihvatljivi za uzgoj na tlima lošije kvalitete, poglavito u klimatsko-geografskim područjima nepogodnim za intenzivniju poljoprivrednu proizvodnju, a sve s ciljem kako proizvodnja energije ne bi konkurirala proizvodnji hrane. Jedan od tih energetskih usjeva, koji bi se mogao uzgajati na znatnom dijelu tih neiskorištenih tala, je i višegodišnja rizomatska energetska kultura *Miscanthus.* Hibrid *Miscanthus x giganteus* iz porodice trava (*Poaceae*) dokazala se kao zanimljiva i visokovrijedna kultura za proizvodnju lignocelulozne biomase na tlima lošije kvalitete, a samim time i kao sirovina za proizvodnju „zelene energije“ (Bilandžija i sur, 2012).

Hibrid *Miscanthus x giganteus* iz porodice trava (*Poaceae*) je energetska kultura koja se najčešće koristi za proizvodnju lignocelulozne biomase. Glavne karakteristike trave *Miscanthus x giganteus* su: izuzetna prilagodljivost uzgoju u različitim klimatsko-pedološkim uvjetima (od razine mora do 3000 m nadmorske visine), mogućnost uzgoja na tlima lošije kvalitete, prirodni je sterilni hibrid (ne postoji mogućnost nekontroliranog širenja), visoki prinosi suhe tvari po jedinici površine (prosjek 15-20 t/ha), izuzetna otpornost na bolesti i štetoćinje (tretiranje pesticidima nije potrebno; mala skala mogućnosti pojave *Fusarium sp.*), mali zahtjevi prema gojidbenim tretmanima, visoka energetska vrijednost (17,05 do 19,21 MJ/kg) te ujedno predstavlja i CO_2-neutralno gorivo tijekom energetskog iskorištenja.

Obzirom na činjenicu da se trava *Miscanthus x giganteus* eksploatira minimalno 15 godina od zasnivanja usjeva (puni prinos nakon druge godine), od izuzetne je važnosti stručno i kvalitetno provesti sve agro-tehničke mjere tijekom predsjetvene pripreme tla, sadnje, njege i žetve nasada. Stoga, cilj ovog rada je dati pregled svih strojeva i opreme koji su nužni i neophodni pri učinkovitom gospodarenju usjeva pod energetskom kulturom *Miscanthus x giganteus* .

PREDSJETVENA PRIPREMA I SADNJA

Prvi radni zahvat u pripremi tla za sadnju je podrivanje u dubljim horizontima na 35 – 40 cm, čime otklanjamo mogućnost nastanka tabana pluga koji može negativno utjecati na rast usjeva. Potom, iste jeseni, slijedi klasično oranje na 20 – 30 cm dubine standardnim oruđem kako bi se uslijed niskih temperatura tijekom zime brazde razrahlile i utjecale na stvaranje povoljne strukturu tla. Naposljetku, netom prije sadnje tlo bi trebalo dodatno obraditi drljačom kako bi se postigao fini površinski sloj (Zimmer i sur., 2009). Obzirom da se obrada, predsjetvena priprema tla za sadnju kao i njega nasada obavlja klasičnim konvencionalnim tehnikama u ratarstvu i travnjaštvu (tablica 1). Naglasak u tehnici tijekom uzgoja trave *Miscanthus x giganteus* je na strojevima i opremi za sadnju odnosno žetvu.

Tablica 1 Prikaz potrebne poljoprivrede tehnike i njihovo vrijeme primjene u uzgoju trave *Miscanthus x giganteus*

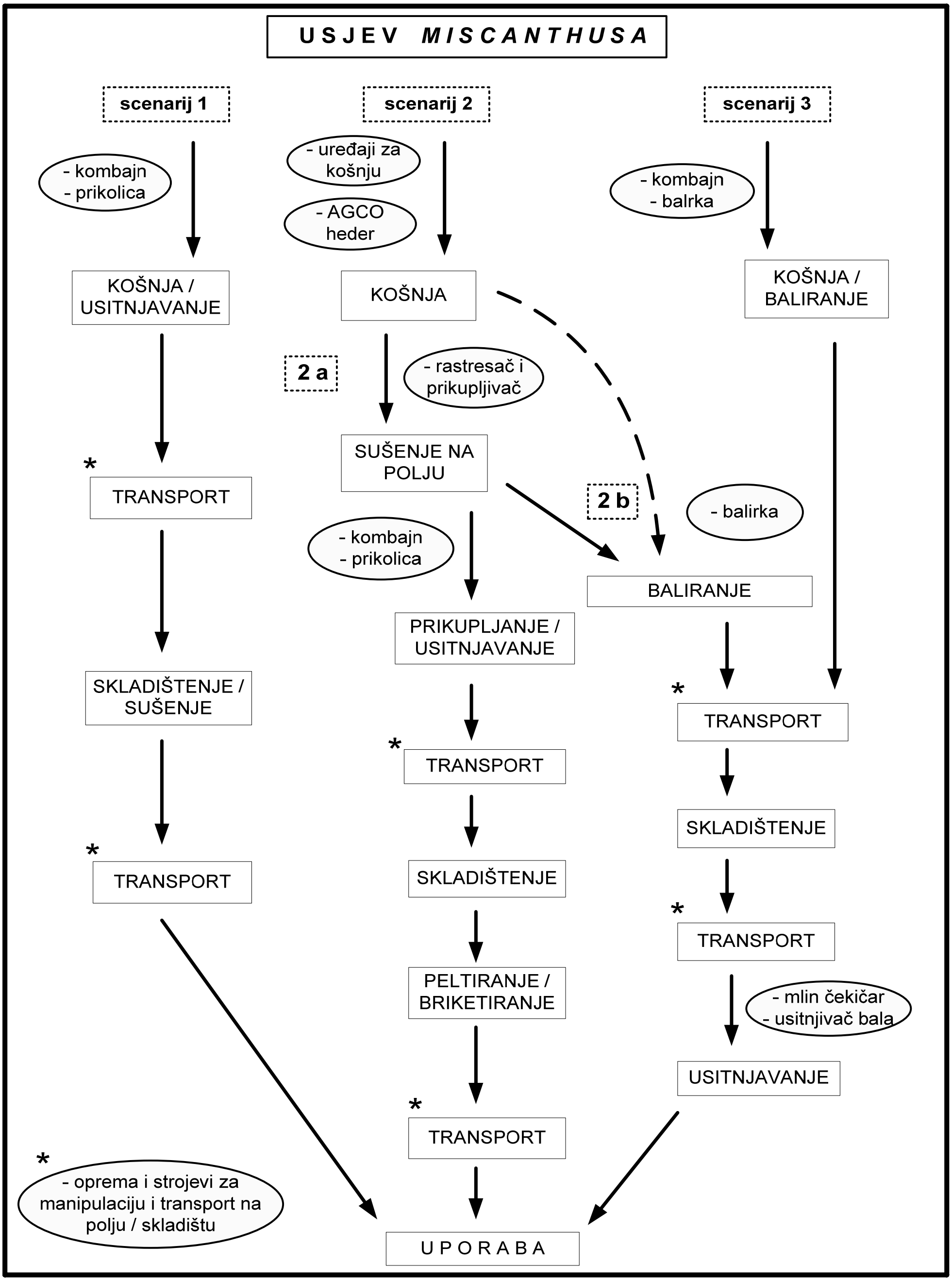
Poljoprivredna tehnika	Vrijeme primjene
Podrivač	Jesen (prije oranja)
Plug	Jesen
Prskalica	Proljeće (aplikacija herbicida – prije i po potrebi nakon sadnje)
Rotacijska drljača	Proljeće (prije sadnje)
Valjak	Proljeće (nakon sadnje)
Rasipač mineralnog gnojiva	Proljeće

Literaturni podaci ukazuju da je sadnju kulture *Miscanthus x giganteus* potrebno provesti na dubini od 5 – 20 cm. Sadnju je moguće provesti između veljače i lipnja, ali su najbolji rezultati postignuti tijekom sadnje između ožujka i svibnja. Izuzetno je važno sadnji pristupiti ranije čime se produžuje sezona rasta kada je udio vlage u tlu povoljan za nicanje, kako bi mladi nasad imao dovoljno vremena ojačati prije ulaska u prvu zimu (kritičan period u uzgoju). Uobičajena gustoća sklopa je 10 000 biljaka/ha, međutim, povećavanjem gustoće sklopa (do 20 000 biljaka/ha) utječemo na smanjene gubitka prinosa uzrokovanih lošijim sadnim materijalom (Smeets i sur, 2009). Odabir stroja za sadnju kulture *Miscanthus x giganteus* ovisi o vrsti sadnog materijala, koji mogu biti rizomi ili presadnice (dobivene mikropropagacijom iz kulture tkiva). Međutim, rizomi su identificirani kao najprikladniji sadni materijal tijekom podizanja usjeva, što su potvrdila brojna znanstvena istraživanja ukazavši da se njihovom uporabom ostvaruje najbolja ekonomska bilanca tijekom uzgoja (Atkinson, C.J., 2009).

Željena gustoća, postojana odabrana dubina sadnje te dobar smještaj rizoma može se postići korištenjem adaptirane poluautomatske sadilice za krumpir. Međutim, u zadnjih nekoliko godina u EU se za podizanja ekstenzivnih usjeva, na većim površinama, sadnja obavlja pomoću specijalnih sadilica za travu vrste *Miscanthus*, koje na tržištu nalazimo u različitim izvedbama. Uglavnom ih sve karakterizira dobar radni učinak (manje izvedbe 5 ha/h, veće 10-25 ha/h), dok je on kod sadilica za krumpir znatno manji (0,3 ha/h) ali i su one i dalje prikladne za manje površine. Nadalje, automatske/poluautomatske izvedbe specijalnih sadilica za *Miscanthus* rezultiraju značajnijom ekonomskom isplativošću obzirom na radni učinak i zahtjevu prema samo jednom/dvoje operatera. Konstruirani su tako da mogu saditi od 2 - 6 redova ovisno o izvedbama. Raonici otvaraju površinu, te se rizomi automatski poliježu u otvorenu brazdu nakon čega slijedi ponovno prekrivanje rizoma zemljom uz neposredno valjane. Valjci su uglavnom sastavni element u konstrukcijama specijalnih sadilica za razliku od sadilica za krumpir gdje se valjanje obavlja kao zasebni zahvat. Sadilice specijalne za *Miscanthus* imaju visok spremišni kapacitet za rizome od 5 tona, što pozitivno utječe na brzinu i učinkovitost sadnje. Ukoliko koristimo poluautomatske modificirane sadilice za krumpir sa sadnom cijevi za obavljanje sadnje potrebno je imati na raspolaganju od 3 - 5 operatera. Tijekom sadnje rizoma koji se koriste tom sadilicom potrebno je sortiranje kako bi se uklonili rizomi koji neće moći proći kroz cijev ili onih koji imaju manje od 2 – 3 „pupa“. Operatori na sadilici sortiraju i manualno ubacuju rizome, na zvučni signal, u sadnu cijev (promjera cca 15 cm) kojom se poliježu u tlo. Udaljenost između redova je cca 75 - 100 cm, dok razmak unutar redova ovisi o zahtjevima prema gustoći usjeva, koji se podešava brzinom traktora (Jones i Wals, 2001; Jørgensen S. U., 2007; Caslin i sur., 2010; Poenaru i sur, 2012).

Slika 1 Poluautomatska adaptirana sadilica (izvor: vlastita arhiva)

Slika 2 Specijalna automatska sadilica (izvor: www.newenergifarms.com)



Slika 3 Redoslijed radnih zahvata i potrebna tehnika za četiri moguća scenarija provođenja žetve energetske kulture *Miscanthus x giganteus* (scenarij 1, 2a i 2b, 3)

ŽETVA

Žetvu energetske kulture *Miscanthus x giganteus* možemo podijeliti na dvije tehnike izvođenja i to višefazna tehnika (košnja, formiranje otkosa, baliranje ili prikupljanje-usitnjavanje) te jednofazna tehnika (košnja-baliranje ili košnja-usitnjavanje) (Huisman, 2003). Na slici 3 je shematski prikazan redoslijeda radnih zahvata te potrebni strojevi i oprema za provođenje prethodno spomenutih tehnika.

KOŠNJA

Prvi zahvat u žetvi je *košnja*, kojom odvajamo stabljike od korijenja. Kosilice moraju otkos ostaviti u dobrom obliku za lakše provođenje narednih zahvata. Tipovi koji se mogu koristiti u žetvi Miscanthusa su rotacijske kosilice sa bubnjevima, rotacijske kosilice sa tanjurima, kosilice sa rotoudaračima, rotacijske kosilice sa kondicionerima, kao i kombajni hederi za žetvu kukuruza te najčešće korišteni univerzalni kombajn heder s rotirajućim nazubljenim valjcima (slika 4).

Slika 4 Univerzalni kombajni heder s rotirajućim nazubljenim valjcima (www.blogspot.com)

Prilikom košnje mora se voditi računa o mogućnosti reza što bliže tlu, da bi iskoristivost biomase bila što veća a gubitci što niži (0,55% po centimetru), kao i to da kosilica tijekom rada što je manje onečišćuje biomasu tlom. Žetva požete mase na 5 cm je za 40% viša od one požete na 10 cm (1 tjedno u 5. mj.), kao i u zadnjem tjednu ožujka kada je ta razlika 20%. Ukoliko je moguće (kada nema zahtjeva prema sušenju u otkosu) košnju bi trebalo kombinirati sa jednom ili više narednih operacija jer se u takvim izvedbama otkos ne ostavlja na tlu te se time izbjegava kontaminiranje biomase kao i nepotrebno nakupljanje vlage. Međutim, ostavljamo li pokošenu biomasu na polju radi smanjenja udjela vlage, kao mogućnost nameće se odabir onih kosilica koje u svojim izvedbama sadrže kondicionere (Jones i Wals, 2001; Ulrich, 2009). Kondicionerima se krute stabljike dodatno drobe što omogućuje ubrzani gubitak vlage nakon košnje te se time ujedno utječe na lakše provođenje daljnjih zahvata, poglavito baliranje. U tim slučajevima prirodnog sušenja na polju, moramo imati na raspolaganju strojeve za razgrtanje i nagrtanje kako bi mogli formirati otkose. Ukoliko biomasu ne bi formirali u otkose obujam pokošenog materijala bi doveo do začepljenja pick up jedinica, bilo na balirkama ili izvedbama kombajna sa priključenim pick-up jedinicama (prikupljanje-usitnjavanje) (Zimmer i sur., 2009). Premda, 2011. godine korporacija AGCO je razvila specijalan heder namijenjen za žetvu Miscanthusa, koji tijekom košnje ostavlja biomasu u formiranom otkosu i automatski ju priprema za baliranje.

KOŠNJA S USITNJAVANJEM

Miscanthus može biti pokošen i usitnjen u istome prohodu. U starijim usjevima redovi se više ne razlikuju pa je stoga neophodna redno neovisna priključna kosilica. Brojna istraživanja su pokazala da je za ovu namjenu najprikladnije koristiti krmni kombajn sa univerzalnim hederom s rotirajućim nazubljenim valjcima. Zahvatom *košnja – usitnjavanje* (slika 5) usitnjena biomasa se transportira usmjerivačnom cijevi u prikolicu, koja može biti priključena na traktor koji se paralelno kreće s kombajnom, međutim postoje i rjeđe korištene izvedbe u kojima je prikolica priključena na kombajn tako čineći s njime jedan agregat. *Košnjom - usitnjavanjem* se proizvodi biomasa u samljevenom obliku koja je u većini slučajeva prilagođena sagorijevanju u različitim bojlerima odnosno ložištima (Huisman, 2003).

Slika 5 Jednofazna žetva (košnja – usitnjavanje) (www.thealined.com)

Prilikom usitnjavanja potrebno je namjestiti noževe da usitnjavaju biomasu na veličinu od 10 - 50 mm, što se može regulirati podešavanjem brzine ulaza sirovine i frekvencije vrtnje sječkare (bubanj s noževima) te promjenom broja noževa na bubnju (Zimmer i sur., 2009). Biomasa samljevena na manje čestice ima tendenciju zagrijavanja tijekom skladištenja dok su veće čestice ne prikladnije za većinu energetskih stanica. Reduciranje veličine je neophodno spram odabrane tehnike manipulacije sirovine, tehnologije skladištenja kao i energetskog iskorištenja. Ukoliko se odlučimo na ovaj tip žetve moramo računati na povećane gubitke tijekom žetve. Naime, mana ovoga sistema je ta da pojačani vjetar može negativno utjecati na prinos tijekom prikupljanje biomase odnosno uslijed njezinog prebacivanja u prikolice. Prosječna gustoća suhe tvari usitnjene biomase varira između cca. 70 – 130 kg/m^3 ovisno o dužinama usitnjenih stabljika. Ova niska gustoća suhe tvari usitnjenog materijala zahtjeva veliki transportni i skladišni kapacitet (Jones i Wals, 2001, Nolan i sur., 2009).

KOŠNJA S BALIRANJEM

Ovakva tehnika žetve *košnja – baliranje* temelji se na istim principima žetve kao i u scenariju *košnja – usitnjavanje*, samo što se u ovom slučaju transporterom biomasa prebacuje direktno u prihvatni koš balirke. Balirka može biti direktno vučena kombajnom ili vučena traktorom koji se paralelno kreće sa kombajnom. Postoje dva tipa bala (kockaste i okrugle) prikladne za različite skale energetskog sagorijevanja (Jones i Wals, 2001). Velike kockaste i okrugle balirke su u mogućnosti proizvesti bale sa gustoćom (zbijenošću) 100-325 kg/m^3 i težinom 250-600 kg, što varira o karakteristikama samih bala. Ovisno o proizvođaču i tipu balirke dimenzije proizvedenih velikih četvrtastih bala (slika 5) su 0,8–1,2 m x 0,7–1 m x 2–3 m (širina x visina x dužina), dok one za velike okrugle bale iznose 0,9–1,8 m x 1,20–2,00 (promjer x duljina). Općenito, žetva (prikupljane) sa adekvatno odabranim balirkama daje visoku učinkovitost kako tijekom same žetve tako i tijekom transporta, te ih ujedno mora karakterizirati dobra svojstva prikupljanja i zbijanja bala. Radni kapacitet balirki tijekom rada s travom *Miscanthus* će biti niži nego za sijenom iz razloga što morfološka svojstva stabljika utječu na brzinu rada agregata te ujedno mogu uzrokovati probleme s „pick up" sistemom, poglavito ukoliko su tijekom košnje ostali značajno duži dijelovi stabljike (Caslin i sur, 2010; Nolan i sur., 2009). Kako bi osigurali adekvatno manipuliranje velikim balama u energetskim postrojenjima opremljenim sa automatskim transportnim sistemima za nadopunu ložišta mora se osigurati određena kontinuirana kvaliteta bala (postojan oblik i forma). Međutim, ukoliko se usitnjavanje provodi u skladištima moramo imati na raspolaganju opremu koja nam omogućuje usitnjavanje već formiranih okruglih ili četvrtastih bala (slika 6).

Slika 5 Velike četvrtaste bale (www.flickr.com)

Slika 6 Usitnjivač četvrtastih bala (www.trejon.se)

ŽETVA RIZOMA

Osim laboratorijskim putem, mikropropagacijom, novi sadni materijal (rizom) može proizvesti mehaničkim putem usitnjavanjem rizoma na postojeće formiranim usjevima. Naime, na tro/četvero godišnjem nasadu u vrijeme mirovanja vegetacije rizimi se mogu usitnjavanjavati koristeći rotacijski kultivator ili power harrowing, te se potom pristupa prikupljanju istih za ponovnu sadnju (Lewandowski, 2000; Jørgensen S. U., 2007). Prikupljanje rizoma se može provesti na dva načina, i to korištenjem kombajna za žetvu krumpira ili uređajem za prikupljanje kamenja. Nakon prikupljanja, rizomi se moraju održati vlažnima te ih je potrebno na adekvatan način uskladištiti (hladna skladišta, temp. <4 °C), međutim postoji i mogućnost kratkoročnog skladištenja, ukoliko se rizomi prikupe na hrpu te se prekriju slojem vlažnog tla. Vremenski period od vađenja rizoma pa do njihovog uskladištenja treba provesti u što kraćem roku. Uzgoj i žetva rizoma trebala bi se provoditi na laganim pjeskovitim tlima bez prisutnosti kamenja (Jørgensen S. U., 2007)

ZAKLJUČAK

Raspoloživa postojeća tehnika, mogućnost dorade i skladištenja te zahtjevi krajnjeg potrošača požete biomase u najvećoj mjeri ovise o izboru tehnike u sadnji i žetvi kulture *Miscanthus x giganteus*. Mogućnost izvođenja žetve *Miscanthusa x giganteusa* možemo podijeliti na dvije tehnike, i to na višefaznu (košnja, formiranje otkosa, baliranje ili prikupljanje-usitnjavanje) te jednofaznu (košnja-baliranje ili košnja-usitnjavanje), dok se sadnja rizoma, u novije vrijeme najčešće provodi specijalnim sadilicama za trave vrste *Miscanthus* ili adaptiranim sadilicama za krumpir (starije izvedbe). Međutim, prilikom odabira tehnike za žetvu mora se dati naglasak na mogućnost adekvatno provedenih zahvata, obzirom na izražene fiziološko – morfološke karakteristike trave *Miscanthus x giganteus*, što se prvenstveno odnosi na njegovu debljinu, visinu i težinu. Odabrana tehnika mora biti u mogućnosti požeti i oštećeni usjev uslijed nepovoljnih vremenskih prilika (jaki olujni vjetar, intenzivne snježne oborine). Kako se žetva trave *Miscanthus x giganteus* provodi u vremenskom periodu od 11. mjeseca pa do 3., 4. mjeseca naredne godine, korištenjem tehnike tijekom žetve utječemo na povećanje broja radnih sati pojedinih agregat, jer u većini slučaja mehanizacija u navedenom periodu miruje. Obzirom na činjenicu da usjev ostaje na polju minimalno 15 godina, od izuzetne je važnosti stručno i kvalitetno provesti sve agro-tehničke mjere tijekom podizanja i njege nasada.

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AGRICULTURAL TECHNIQUE IN THE PRODUCTION OF ENERGY CULTURE MISCANTHUS X GIGANTEUS

NIKOLA BILANDŽIJA, STJEPAN SITO

SUMMARY

Since the tillage, pre-sowing treatment and plantation maintainance is performed with the classical conventional techniques in arable farming and grassland production, the emphasis in technique for Miscanthus x giganteus *cultivation is on machinery and equipment for planting and harvesting. The harvest of* Miscanthus x giganteus *can be performed with two different techniques; the multi-phase (mowing, forming windrows, baling or collection-chopping) and single-phase (mowing – baling or mowing-chopping). However, as the crop remains on the same field for at least 15 years, it is of great importance that all agro-technical measurements are expertly implemented. Therefore, the aim of this paper is to give an overview on all machines and equipment that are essential for the effective cultivation of* Miscanthus x giganteus *as an energy crop.*

Key words: Miscanthus x giganteus*, agricultural engineering, machinery, equipment*

41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 620.95:631
Prethodno priopćenje
Preliminary communication

POTENCIJAL POLJOPRIVREDE ZAGREBAČKE ŽUPANIJE U PROIZVODNJI BIOMASE

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SAŽETAK

Cilj je rada ustanoviti potencijal poljoprivrede Zagrebačke županije u proizvodnji biomase. Anketno istraživanje provedeno na namjerno odabrana 103 poljoprivredna gospodarstva pokazalo je da postoji interes proizvođača za uključenje u projekt proizvodnje biomase poljoprivrednog podrijetla za proizvodnju energije na području Zagrebačke županije. Zainteresiranost je veća kod po proizvodnim resursima i proizvodnji većih gospodarstava, ali je još uvijek prisutna velika neinformiranost o značenju i korisnosti biomase u proizvodnji energije.

***Ključne riječi**: poljoprivreda, biomasa, obnovljivi izvori energije, poljoprivredni proizvođači, Zagrebačka županija*

UVOD

Kraj dvadesetog stoljeća obilježila je nestabilnost na tržištu fosilnih goriva, prvenstveno nafte, što je dovelo do velikih cjenovnih oscilacija sa tendencijom daljnjeg povećanja cijena. To potiče sve veću usmjerenost istraživanju i primjeni obnovljivih izvora energije od kojih je i energija iz biomase poljoprivrednog podrijetla.

Budući svjetski gospodarski rast značajno će ovisiti o odabiru tehnologije[1], ali današnji trenutak obilježen je „stalnom potrebom čovjeka za energijom“ (Kiš D. i sur., 2007.).

[1] U ovom slučaju tehnologiju dijelimo na energetski intenzivnu i energetski ekstenzivnu.

Snažan je utjecaj stopa gospodarskog rasta na potrošnju energije odnosno bez dodatnih količina i/ili energetskih vrela teško je zamisliv značajniji gospodarski rast.[2]

Globalizacija je, zakonom spojenih posuda, dovela do brzo reagirajućih utjecaja proizvodnje u jednom dijelu svijeta na potražnju za energijom u drugom dijelu i na taj način stvoreni sinergijski učinak sjedne strane i porast općeg standarda svjetski rastućeg pučanstva s druge strane potiču sve veću potrošnju energije.

Proizvodnja energije sve teže prati potražnju zbog ograničenih raspoloživih prirodnih energetskih resursa što uzrokuje porast cijena energenata.

Još uvijek se najveći dio potreba za energijom podmiruje upotrebom fosilnih goriva nafte, ugljena i zemnog plina što dovodi do sve većeg onečišćenja prirode kao i do sve vidljivijih klimatskih promjena na Zemlji[3] tako da se kao najveći problemi ističu globalno zatopljenje i pojava tzv. efekta staklenika[4].

Navedeni problemi nisu lokalnog nego globalnog karaktera te se čine značajni napori da se ti procesi zaustave odnosno smanji njihov utjecaj odnosno uzrok. U cilju toga došlo je potpisivanja mnogih sporazuma od kojih je najpoznatiji tzv. *Kyoto Protokol.* Temeljni njegov cilj je zaustavljanje porasta tzv. stakleničkih plinova u atmosferi. Taj proces zahtijeva smanjenje uporabe fosilnih goriva i povećanje udjela tzv. obnovljive energije. Obnovljivi izvori i vidovi energije su: solarna, hidro, geotermalna, eolska i energija biomase.

Republika Hrvatska ima značajne sve navedene obnovljive izvore ali u bližoj budućnosti najbrži i najznačajniji efekti se očekuju od biomase (Sušnik H., Benković Z., 2007.). Biomasa „prema Direktivi EU (*Direktiva 2009/28/EC*) definirana je kao biorazgradivi dijelovi proizvoda, otpada ili ostataka iz poljoprivrede, šumski otpad, otpad srodnih industrija, kao i biorazgradivi dijelovi industrijskog i gradskog otpada." (Bišćan, I., 2012). Biomasa je obnovljivi izvor energije značajnog potencijala za iskorištavanje ruralnih resursa, nije štetan za okoliš, a zanimljiv je dio pokušaja diversifikacije zaposlenosti ruralnog prostora i porasta dohotka lokalnog stanovništva.

U biomasu spadaju proizvodi biljnog i životinjskog podrijetla kao što su ostaci iz šumarstva i drvne industrije, brzorastuće drveće, otpadno drvo iz drugih djelatnosti, te drvo koje nastaje kao sporedni proizvod u poljoprivredi, ostaci, sporedni proizvodi i ostaci iz bilinogojstva, te biomasa dobivena uzgojem algi i gljiva, te otpad i ostaci iz stočarstva.

Uporaba biomase osim obnovljivosti dovodi do manje emisije štetnih plinova i otpadnih voda nego u slučaju uporabe fosilnih goriva. Osim toga „dodatne su prednosti zbrinjavanje i iskorištavanje otpada i ostataka iz poljoprivrede, šumarstva i drvne industrije, smanjenje uvoza energenta, ulaganje u poljoprivredu i nerazvijena područja i povećanje sigurnosti opskrbe energijom" (Bišćan, I. 2012).

[2] Gospodarski rast najmanje bi trebao biti na razini stope porasta pučanstva, a u stvarnosti uvećan za porast kupovnih novčanih glasova.
[3] Kratkoročno za čovječanstvo teško je razlučiti utjecaj nekih čimbenika kao što je izgaranje fosilnih goriva od normalnih dugoročnih prirodnih ciklusa kroz koje prolazi Zemlja. Međutim, sve veća upotreba fosilnih goriva sigurno ne pomaže održanju prirodnih klimatskih ciklusa, odnosno promjena.
[4] Efekt staklenika je proces kojim atmosfera zadržava dio sunčeve energije, zagrijava Zemlju i osigurava pogodnu klimu (Krička T. i sur., 2009.).

Zahvaljujući ideji dobivanja energije iz biomase razvila se raznovrsna tehnologija proizvodnje energije, te se ona dobiva u čvrstom (npr. peleti, briketi, sječka), tekućem (npr. biodizel, bioetanol, biometanol) i plinovitom stanju (npr. bioplin, plin iz rasplinjavanja biomase i deponijski plin).

Često se biomasa izgaranjem izravno pretvara u termoenergiju kojom se grije voda i dobivena vodena para koristi za grijanje ali čime i u proizvodnji električne energije. Postoje i drugi načini uporabe biomase. Tako „neke biljke daju ulje koje se može upotrebljavati kao pogonsko gorivo. Suhom destilacijom može se od biomase dobiti metanol, aceton, drveni ugljen i drugi proizvodi" (Bišćan, I., 2012).

Ulazak Hrvatske u Europsku uniju značajno će utjecati na njenu energetsku politiku u nadolazećem razdoblju pri čemu će značajno mjesto imati proizvodnja iz obnovljivih izvora.

MATERIJAL I METODE[5]

U izradi rada korišteni su primarni i sekundarni podaci. Za prikupljanje primarnih podataka korištena je metoda ispitivanja odnosno anketni upitnik. Anketirana su 103 člana poljoprivrednih gospodarstava tijekom prosinca 2011. i siječnja 2012.[6]. Gospodarstva su namjerno odabrana iz Popisa gospodarstava Zagrebačke županije i po proizvodnim kapacitetima i proizvodnji su iznad prosjeka Županije.

Anketa je bila anonimna i sastojala se od 13 pitanja. Korištena su dihotomna strukturirana pitanja, strukturirana pitanja s višestrukim izborom i otvorena nestrukturirana pitanja. Od ljestvica za mjerenje stavova korištene su nominalne i ordinalne ljestvice, te Likertova ljestvica. Prije unosa podataka u SPSS (Statistical Package for Social Scienses) program obavljena je prelogička kontrola[7] i prekodiranje odgovora[8] kod strukturiranih pitanja, a nakon unosa postkodiranje odgovora[9] kod nestrukturiranih pitanja. Nakon unosa podataka napravljena je postlogička kontrola[10] unesenih podataka. Korištena je jednovarijantna (analiza jedne varijable) i dvovarijantna (dvosmjerna tabulacija ili „ukrštanje") obrada podataka.

U radu su korišteni i sekundarni podaci, podaci Hrvatske poljoprivredne agencije (HPA) te podaci Agencije za plaćanja u poljoprivredi, ribarstvu i ruralnom razvoju (APPRRR) iz Upisnika poljoprivrednih gospodarstava i Nacionalnog sustava identifikacije zemljišnih parcela (ARKOD).

[5] Materijal i metode su preuzete iz Bišćan, I. (2012) i sastavni su dio Diplomskog rada koji je poslužio kao podloga ovoga rada.
[6] Većina anketiranih su bili i nositelji gospodarstava.
[7] Pregledavanje, provjera i ispravke pogrešaka prikupljenih podataka prije njihova unosa u računalo.
[8] Unaprijed određivanje kodova brojčanim vrijednostima.
[9] Naknadno određivanje kodova brojčanim vrijednostima svrstanim u kategorije temeljem zajedničkih sadržaja odgovora.
[10] Kontrola ispravnosti unesenih podataka.

Za izračun količine biomase poljoprivrednog podrijetla korišteni su ekspertni koeficijenti Energetskog Instituta Hrvoje Požar (EIHP) razvijeni u sklopu projekta Biogas Regions[11].

REZULTATI I DISKUSIJA

Poljoprivredna proizvodnja i proizvodnja biomase na području Zagrebačke županije

Poljoprivredna proizvodnja je značajna podloga za proizvodnju biomase pri čemu to može biti biljna ili stočarska proizvodnja. Vrsta sirovine određuje vrstu biomase kao i mogućnosti njene primjene.

Površinom i vrijednošću kukuruz i pšenica čine preko 90% proizvodnje žita u Republici Hrvatskoj kao i u Zagrebačkoj županji. Kukuruz je površinski (21.313 ha u 2010.) najznačajnija ratarska kultura Zagrebačke županije, te on predstavlja najveći potencijal za proizvodnju bioetanola[12]. Površine pšenice su oko 4.000 ha uz prinos od 4,5 t/ha.

Biodizel se primarno proizvodi iz biljnih ulja uljarica. Najznačajnije kulture u Zagrebačkoj županiji za proizvodnju biljnih ulja su soja (oko 970 ha) i uljana repica[13] (oko 550 ha) sa prognozama neznatne mogućnosti porasta površina i proizvodnje zrna u narednom razdoblju.

Navedene kulture potencijalno su najpogodnije kulture za proizvodnju biogoriva prve generacije u Zagrebačkoj županiji[14].

*Tablica 1*Moguća proizvodnja biomase biljnog podrijetla na području Zagrebačke županije (prosjek 2009./2010.)

Kultura	Proizvodnja (t)	Koeficijent	Moguća količina biogoriva (t)	Iskoristiva količina biogoriva (t)
Kukuruz	129.859	3,26	39.834	11.950
Soja	2.816	5,28	533	160
Uljana repica	1.535	2,45	626	188
Ukupno	134.210	-	40.994	12.298

Izvor: Preračunato prema internoj dokumentaciji Upravnog odjela za poljoprivredu, ruralni razvitak i šumarstvo Zagrebačke županije za 2009. i 2010. i koeficijentima Energetskog Instituta Hrvoje Požar, a preuzeto iz Bišćan, I., 2012.

[11] Biogas Regions project je međunarodni europski projekt započet s ciljem pokretanja proizvodnje bioplina u regijama diljem Europe.
[12] Veća količina uporabljena za proizvodnju bioetanola ne smije dovesti do smanjenja proizvodnje stočne hrane što bi dovelo do krize u stočarstvu i izravno ugrozilo standard potrošača.
[13] Najveći dio biodizela u svijetu se dobiva iz ulja uljane repice uz uporabljive nusproizvode kao što su sačma te slama koje se koriste za proizvodnju energije.
[14] Pšenica nije uzeta u obzir, jer je proizvodnja biomase iz te kulture prema ekspertnim procjenama skupa i neisplativa.

Ukupna moguća proizvodnja biomase biljnog podrijetla iz navedenih kultura je oko 41.000 tona biogoriva. Najveći potencijal predstavlja kukuruz (39.834 t bioetanola), zatim uljana repica (626 t biodizela) te soja (533 t biodizela). Kako se samo dio proizvodnje može koristiti za proizvodnju biogoriva (oko 30%), tada je potencijal proizvedenog odnosno iskoristivo oko 12.000 t od kukuruza, 189 t uljane repice te oko 160 t soje. Ipak, znatan potencijal za povećanje proizvodnje biomase biljnog podrijetla su nekorištene površine oranica koje se procjenjuju na oko 60.000 ha.

Stočarska proizvodnja je također mogući izvor sirovine za proizvodnju biomase. Nusproizvodi stočarstva su životinjski otpad i stajski gnoj. Osnovnu biomasu čini stajski gnoj. Velika količina stajskog gnoja koja nastaje u procesu stočarske proizvodnje, posebno svinjogojstvu, potencijalni je onečišćivač okoliša, te se ovom problemu posvećuje znatna pozornost kod čuvanja, prerade i manipulacije stajskim gnojem. Jedan od načina je njegovo korištenje u proizvodnji bioplina, a značajan dio i kao gnojivo u ratarskoj proizvodnji.

Na području Zagrebačke županije kod stočarstva najzastupljenije je govedarstvo (47.885 UG[15]) usmjereno na proizvodnju mlijeka, zatim svinjogojstvo (17.454 UG), te peradarstvo (4.308 UG) kroz proizvodnju jaja i brojlera. Na temelju brojnosti uvjetnih grla procijenjena je godišnja proizvodnja stajskog gnoja pri čemu je najviše stajskog gnoja iz govedarske proizvodnje, a najmanja iz peradarske proizvodnje. Primjenom udjela organske suhe tvari u svježoj tvari (oST) i prinosa metana po jedinici organske suhe tvari (m^3 CH_4/t oST) izračunat je ukupni i iskoristivi potencijal biomase animalnog podrijetla (Bišćan, I., 2012.).

Tablica 2 Moguća proizvodnja i energetska iskoristivost biomase životinjskog podrijetla na području Zagrebačke županije (prosjek 2009./2010.)

Vrsta supstrata	Udio organske suhe tvari u svježoj tvari	Suhi izmet (t)	Prinos metana po jedinici organske suhe tvari (m^3 CH_4/t)	Moguća količina bioplina (m^3 CH_4)	Iskoristiva količina bioplina (m^3 CH_4)
Izmet goveda (kruti)	0,0595	27.039	280	7.570.837	1.892.709
Svinjski izmet (tekući)	0,22	30.834	250	7.708.559	1.927.140
Izmet peradi (kruti)	0,33	13.492	300	4.047.609	1.011.902
Ukupno	-	71.365	-	19.327.005	4.831.751

Izvor: Isti kao za Tablicu 1

Na osnovi izračunatih podataka, ukupno moguća proizvodnja biomase animalnog podrijetla na području Zagrebačke županije je nešto veća od 19 milijuna m^3 CH_4. Najveću količinu bioplina moguće je "dobiti" iz svinjskog gnoja, nešto manju iz gnoja goveda, a najmanju količina bioplina iz gnoja peradi.

[15] UG ili uvjetno grlo je grlo stoke težine 500 kg.

Od ukupne količine bioplina iskoristivo je tek oko 25%[16]. Iz tekućeg svinjskog gnoja dobije se 1.927.140, iz krutog gnoja goveda 1.892.709 i iz krutog gnoja peradi 1.011.902 m^3 CH_4.

Rezultati ankete

Anketno istraživanje „Potencijal proizvodnje biomase poljoprivrednog podrijetla – zelene energije na području Zagrebačke županije“ provedeno je s ciljem istraživanja zainteresiranosti poljoprivrednika za proizvodnju biomase upotrebljive za proizvodnju biogoriva.

Prosječna dob ispitanika je bila 42,4 godine (od 19 do 63 godine). Većina ispitanika su bili muškarci (78,6%) iako u spolnoj strukturi poljoprivrednog stanovništva Zagrebačke županije nešto više su zastupljene žene[17], ali su većinom muškarci nositelji poljoprivrednih gospodarstava.

Najveći dio ispitanika je završio srednju školu (70,9%), manji dio višu školu i fakultet (16,5%), a najmanji udjel je onih sa završenom osnovnom školom (12,6%). S obzirom na zanimanje ispitanika, većina ispitanika su poljoprivrednici i zaposlene osobe (94,2%), a manji dio su nezaposleni i umirovljenici (4,8%).

Ispitanici žive u kućanstvima od jednog do devet članova. Prosječna veličina kućanstva ispitanika je 5 članova, a najveći dio ih živi u kućanstvima sa 4 člana (27,2%).

Prosječna veličina gospodarstva je 40,1 ha (od 1,5 do čak 280 ha), a najveći dio ispitanika je sa posjedom od 10 ha (8,7%).

Potencijal i ograničenja proizvodnje biomase anketiranih gospodarstava

Kako bi se dobio uvid u stanje zainteresiranosti ispitanika za bavljenje proizvodnjom biomase za proizvodnju zelene energije, ispitane su želje ispitanika i njihova ograničenja za ulazak u tu vrstu proizvodnje.

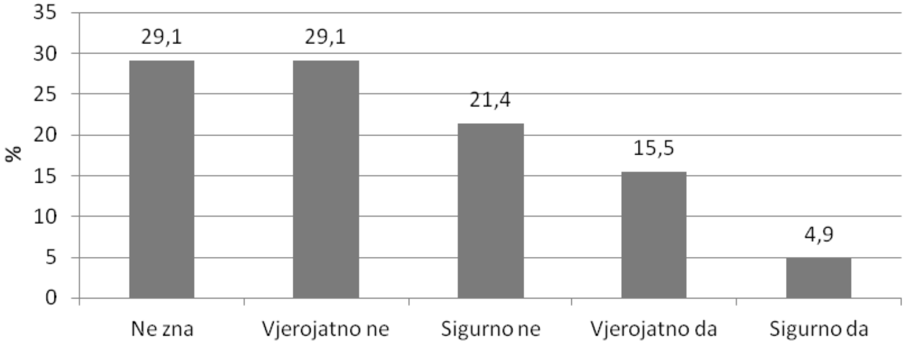
Većina ispitanika (50,5%) nema namjere baviti se proizvodnjom zelene energije u narednih pet godina, a njih 20,4% ima namjeru. Veliki je i postotak ispitanika koji ne zna odgovor na to pitanje (29,1%) što je dijelom rezultat njihove nedovoljne informiranosti o takvoj proizvodnji. Kod ispitanika koji su se izjasnili kako se vjerojatno ili sigurno namjeravaju baviti proizvodnjom zelene energije prevladavaju ispitanici s gospodarstvima većim od 50 ha.

Za ulazak u novi projekt mogući proizvođači često očekuju ispunjenje određenih preduvjeta.

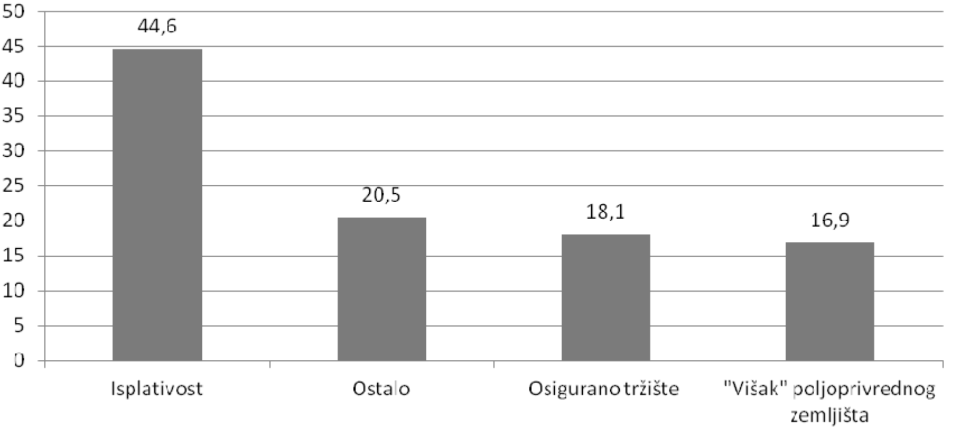
Kao prvu i glavnu pretpostavku ispitanici navode isplativost pri čemu to promatraju uspoređujući sa nekom drugom konkurentnom proizvodnjom (mlijeko). Značajni su preduvjeti sigurnost trženja te potencijalni „višak“ poljoprivrednih površina. Značajniji preduvjeti su „višak“ financijskih sredstva te prihvatljivi transport biomase.

[16] Takva iskoristivost je jer se dio stajskoga gnoja koristi u ratarskoj proizvodnji, jedan dio poljoprivrednika ima mali broj stoke, a znatan broj stoke se drži na otvorenom.

[17] Prema podacima Popisa stanovništva iz 2001. postotak ženskog poljoprivrednog stanovništva na području Zagrebačke županije iznosi 51,5%, a muškog 48,5%.



Grafikon 1 Stajališta anketiranih za uvođenje proizvodnje "zelene energije u idućih pet godina" (Izvor: Vlastito istraživanje)



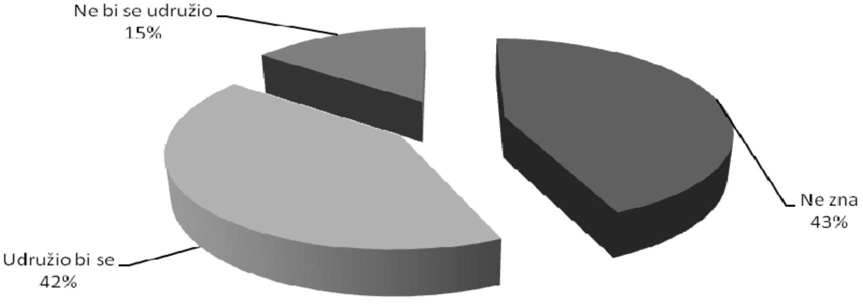
Grafikon 2 Nužni preduvjeti proizvodnje biomase za energiju (Izvor: Vlastito istraživanje)

Ipak, glavno ograničenje za veću proizvodnju biomase su raspoložive površine. Posebno se to odnosi na površine koje bi se koristile samo za proizvodnju biomase za proizvodnju zelene energije. Neznatno iznad polovice ispitanika (51,5%) smatra da za to ima raspoloživih površina, u prosjeku oko 22 ha (od 1 do 100 ha).

Zbog preradbenih kapaciteta, udruživanje proizvođača biomase je jedan od preduvjeta početka i širenja proizvodnje biomase za proizvodnju bioenergije. Značajan dio ispitanika je neodlučan (43%), nešto manji dio bi prihvatio udruživanje (42%), a znatno najmanji dio to ne bi učinio (15%).

Najveći postotak ispitanika smatra da bi udruživanje poljoprivrednih proizvođača u proizvodnji biomase trebala inicirati lokalna vlast (27,6%), manje njih (24,1%) smatra da bi inicijator trebao biti netko treći, a njih 20,7% smatra da bi to trebali biti sami poljoprivredni proizvođači. Veliki je i postotak ispitanika koji ne zna tko bi trebao biti inicijator (27,6%).

Kod pokretanja svake proizvodnje mnoštvo je ograničenja pri čemu je njihova značajnost različita od proizvođača do proizvođača. Ispitanicima je ponuđeno nekoliko potencijalnih ograničenja za njihovu uključenost u proizvodnju biomase.



Grafikon 3 Mišljenje o udruživanju s drugim poljoprivrednicima u proizvodnji biomase (Izvor: Vlastito istraživanje)

Tablica 3 Ograničenja za uključenost ispitanika u proizvodnju biomase; 1-uopće nije, 2-malo, 3-ograničenje je, 4-veliko, 5-vrlo veliko ograničenje (Izvor: Vlastito istraživanje)

Ograničenje	Najmanje	Najviše	Srednja vrijednost	Standardna devijacija
Cijena koju bi postigli	1	5	3,72	1,30
Cijena i dostupnost repromaterijala	1	5	3,63	1,30
Nabava strojeva i opreme	1	5	3,63	1,36
Priprema i plasman proizvoda	1	5	3,63	1,41
Količina koju bi mogli prodati	1	5	3,48	1,42
Rascjepkanost zemljišta	1	5	3,38	1,57
Dostupnost poslovnih informacija-cijene, kreditiranje itd.	1	5	3,26	1,43
Količina koju bi mogli proizvesti	1	5	3,26	1,31
Poznavanje tehnologije koju bi koristili	1	5	3,25	1,38
Veličina posjeda	1	5	3,25	1,44
Iskorištenost strojeva i opreme	1	5	3,23	1,43
Dostupnost savjeta stručnjaka	1	5	2,94	1,49
Radna snaga	1	5	2,78	1,47

Kao najvažnije ograničenje za uključenost u proizvodnju biomase ispitanici navode cijenu koju bi poljoprivredni proizvođači postigli. Nemogućnost, odnosno problemi plasmana i posebice u naplati poljoprivrednih proizvoda su visoko na drugom mjestu ograničenja. Stoga i količina biomase koju bi mogli prodati predstavlja određeno ograničenje. Istom važnošću ograničenja, kao i plasman proizvoda, ocijenjene su i mogućnosti nabave strojeva i opreme, te cijena i dostupnost repromaterijala.

Rascjepkanost zemljišta, dostupnost poslovnih informacija, količina biomase koju bi mogli proizvesti, poznavanje tehnologije koja bi se koristila, veličina posjeda, te iskorištenost strojeva i opreme za ispitanike predstavlja osrednje ograničenje.

Dostupnost savjeta stručnjaka se ne smatra preprekom za bavljenje proizvodnjom biomase. Najmanje ograničenje ispitanicima predstavlja radna snaga.

Bez obzira na to jesu li se ispitanici izjasnili da imaju namjere baviti se proizvodnjom biomase ili nemaju, njihovo mišljenje o obnovljivim izvorima energije i korištenju obradivih površina koje bi služile proizvodnji biomase za proizvodnju obnovljive energije je pozitivno. Čak 59,4% ispitanika ima pozitivno mišljenje o obnovljivim izvorima energije, 13,5% smatra da je to energija budućnosti, a njih 9,4% nema mišljenje o obnovljivim izvorima energije. Nešto iznad trećine (34,4%) ispitanika smatra da treba iskoristiti neobrađeno zemljište za proizvodnju biomase, njih 17,8% ocjenjuje ideju korištenja obradivih površina za proizvodnju biomase pozitivnom, a 11,1% ispitanika smatra da korištenje obradivih površina za proizvodnju biomase za dobivanje energije doprinosi plodoredu. Ne smije se ni zaboraviti zastupljenost ispitanika koji smatraju da bi se obradive površine trebale prvenstveno koristiti za proizvodnju hrane (16,7%).

ZAKLJUČAK

Najznačajnija uporaba biomase poljoprivrednog podrijetla u energetske svrhe na području Zagrebačke županije odnosi se na zrno kukuruza, soje i uljane repice, te gnoj goveda, svinja i peradi.

Oko petine ispitanika je voljno u narednih pet godina baviti se proizvodnjom biomase namijenjenoj za proizvodnju zelene energije. Većinom su to poljoprivrednici sa većim poljoprivrednim gospodarstvima.

Glavne pretpostavke uz koje bi se bavili proizvodnjom biomase su isplativost, osigurano tržište te višak poljoprivrednog zemljišta.

Glavna ograničenja ulasku u proizvodnju biomase su očekivana cijena proizvoda, nabavna cijena i dostupnost repromaterijala, mogućnost nabave strojeva i opreme i sl. Većina ispitanika ima pozitivno mišljenje o obnovljivim izvorima energije i korištenju obradivih površina koje bi služile proizvodnji biomase za obnovljivu energiju.

Zainteresiranost ispitanika postoji za proizvodnju zelene energije. Veliki potencijal za proizvodnju biomase nalazi se na neobrađenim površinama. Najveći problem za pokretanje proizvodnje biomase je neinformiranost te prosječno male poljoprivredne površine poljoprivrednih proizvođača. Korištenjem energije biomase pruža se i mogućnost za otvaranje većeg broja novih radnih mjesta te pridonosi razvoju ruralnih sredina, a najveća prednost proizvodnje biomase je očekivanje da bi energetika i energetska postrojenja dali znatan poticaj za dodatnu poljoprivrednu proizvodnju u Zagrebačkoj županiji.

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AGRICULTURAL POTENTIAL OF ZAGREB COUNTY IN BIOMASS PRODUCTION

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ABSTRACT

The aim is to determine agricultural potential of Zagreb County in biomass production. The survey conducted upon 103 purposely selected farms showed that there is an interest among farmers in joining the project of producing biomass from agricultural sources for energy production in the Zagreb County. The interest is higher in the manufacturing and production resources of larger farms, but there is still a great lack of information of the meaning and usefulness of biomass in energy production.

***Key words**: agriculture, biomass, renewable energy sources, agricultural producers, Zagreb County*

41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Originalni znanstveni rad
Original scientific paper

HEAVY METALS ABSORPTION CAPACITY OF SOME LINSEED VARIETIES

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ABSTRACT

According to some recent studies (Saastamoinen et al) regarding the ability of linseed to accumulate heavy metals from soil in the seeds, it was found that linseed has a huge capacity to assimilate this type of metals. This study aims to identify to what extent various heavy metals are absorbed from the soil and which is their influence on the nutritional quality of seeds and on the oil obtained from them.

The biological material used consists of five varieties of linseed registered in Romania: Lirina, Alexin, Floriana, Florinda and Iunia 96. The research was conducted in the pedoclimatic conditions of the Didactic and Research Base Timisoara. Fertilization was performed on following agrofunds: N0P0, N64P48, N96P64, N64P48 + foliar fertilizer combination Fertileader Viti + Corona K, N96P64 + foliar fertilizer combination Fertileader Magical + Corona K. The results obtained were as follows: Zn = 50, 01 - 54,68 ppm in plant and 62,05 - 120,4 ppm in soil, Fe = 31,3 - 37,4 ppm in plant and 28924 - 32452 ppm in soil, Pb = 12,7 - 14,3 ppm in plant and 20,07 - 54,32 ppm in soil, Cd = below the detection limit both in plant and in soil, Ni = 0,41 - 2,38 ppm in plant and 26,76 - 56,72 ppm in soil, Cu = 21,83 - 35,55 ppm in plant and 23,28 - 45,61 ppm in soil.

Linseed is a suitable culture for growing in industrially polluted regions; it removes considerable quantities of heavy metals (Zn, Pb and Cu) from the soil with their root system and can be used as potential crops for cleaning the soil from heavy metals.

***Key words**: linseed, fertilization, heavy metals, soil*

INTRODUCTION

The use at a growing level of linseed in medicine, food industry and even in the cosmetics industry as well the desire of people to adopt a healthy diet, have brought in attention a forgotten culture. Linseed (*Linum usitatissimum* L.) contains oil with a high content of linolenic acid which constitutes almost 55% of the total oil. This rate is 5.5 times higher than that of the best sources of linolenic acid (Bloedon et al). Besides, linseed is known as a source of omega 3 fatty acids, contains high quality protein and has a high content of lignans. Linseed is one of the richest sources of lignans in the human diet.

The most abundant lignans in linseed is secoisolariciresinol, present as a diglucoside (Ford et al, Kamal-Eldin et al).

Diglucoside has been associated with several health effects such as those on cardiovascular disease, diabetes control and reduction of the risk of some cancer types (breast, column and lung) (Adolphe et al). But linseed has a tendency to accumulate heavy metals from the soil to the seeds. Consumption of these metals, for example through food, has several negative effects on human health (Satarug et al). Recent studies have shown that cadmium can cause estrogen-like effects *in vitro* and *in vivo* (Johnson et al) so therefore a higher risk of breast cancer in humans (McElroy et al).

Because of its ability to extract heavy metals from soil, linseed is one of the best plants used for soil phytoremediation. Naturally, heavy metals are found in soil in small quantities but their concentration may increase due to human activity and so appears the need to analyze the soil, the crops and the food in terms of heavy metal content. The level of heavy metals absorption from the soil depends on several factors among which we can mention the type of crop and soil geochemical characteristics. Some cultures have a greater capacity to absorb this type of metals from the soil but most crop plants can not survive in soils contaminated with heavy metals (Wong et al).

Plants can accumulate heavy metals in different vegetative or reproductive organs specific to each species. Thus, the leaves of some plants may contain higher amounts of metals while seeds have a lower concentration (Ivanova et al). For example, grains accumulate small amounts of metals while vegetables accumulate large quantities especially in leaves (Puschenreiter et al). Nutritional deficiency caused by lack of metals in foods or quantities of metals that exceed a certain level, can produce toxic effects. Implementation of procedures and control mechanisms required by national and international regulations reduces the maximum level of toxic metals in food.

METHODS

The biological material used in this study consists of five flax varieties registered in Romania: Lirina, Alexin, Floriana, Florinda and Iunia 96. The samples of seeds, from the harvest of 2011, are the result of a trifactorial experience carried out in pedoclimatic conditions of the Didactic and Research Base Timisoara.

The experimental field was divided into three repetitions. Fertilization was performed on following agrofunds: N0P0, N64P48, N96P64, N64P48 + foliar fertilizer combination

Fertileader Viti + Corona K, N96P64 + foliar fertilizer combination Fertileader Magical + Corona K.

Soil samples, collected from five different points of the experimental field, were air dried at room temperature, grind and sieved through a 2 mm sieve. From each soil sample 0.1 g was weighted and subjected to mineralization with a mixture of HNO_3 : HCl = 3:1 in the microwave with a method adapted after the 3050B method of the United States Environmental Protection Agency (United States Environmental Protection Agency (1996). Method 3050B). After mineralization the sample is diluted to 50 mL volume with 0.5N HNO_3.

Samples of 3 g of ground seed were burned 8 h at 550 °C in furnace (Nabertherm B150, Lilienthal, Germany) and the ash was dissolved in HCl 20 % and are brought to 20 ml in a volumetric flask.

The macroelements and microelements were determined by AAS (Varian 220 FAA equipment). The standard solution for calibration curve were prepared by diluting the standards (1000 mg/L). Mix standard solutions (ICP Multielement Standard solution IV CertiPUR) were purchased from Merck. Double distilled water was used for the preparation of reagents and standards. Concentrate nitric acid (HNO_3 65 %), and concentrate HCl (37 %), were obtained from Merck Germany. All chemicals were trace metal grade (Suprapur).

Method detection limits (MDL mg/L) for analyzed elements were: 0.02 mg/L for Mg and K; 0.06 mg/L for Fe; 0.03 mg/L for Ca; 0.04 mg/L for Zn and Cu; 0.01 mg/L for Cd, 0.15 mg/L for Pb.

The Nt % was determined with the help of Kjeldahl mineralization - distillation unit (Velp Scientific 127) digested in H_2SO_4 distilled and titrated with 0.1N H_2SO_4 (Crista et al).

Metal concentration was obtained as the arithmetic average of three readings.

RESULTS AND DISCUSSION

The experimental field was located in the Didactic and Research Base Timisoara on a brown mollic eutricambosol moderate gleyed soil, moderate decarbonated on medium/coarse fluvial deposits, medium loam/medium loam. Soil metal levels in this area are presented in Table 1.

Only a small part of these metals found in soil are available for plants. Availability of metals is highly dependent on pH which is influenced by the level of mineral fertilization.

The content of Ca, Mg and heavy metals in the five varieties of linseed used in the study, differentiated on five different fertilization variants (N0P0 - F0, N64P48 - F1, N96P64 - F2, N64P48 + foliar fertilizer combination Fertileader Viti + Corona K - F3, N96P64 + foliar fertilizer combination Fertileader Magical + Corona K - F4) are shown in Table 2.

Calcium is a component of many minerals found in the soil in adequate amounts. Acid soils are usually low in calcium while high pH soils contain a higher amount of calcium. If soil pH value passes 7.2, because of soil calcium reserve, additional applied calcium is not adsorbed in the soil (Berbecea et al). Most of the free calcium forms with other elements such as phosphorus, almost insoluble compounds, make phosphorus less available. Lack of calcium in plant causes meristematic tissues death, stunted growth, formation of small and discolored roots. In plants like flax, petiols and pedicels frequently collaps.

Table 1 Content of microelements and macroelements in soil in the cultivation area of the studied linseed varieties

Crt. no.	Element	Metal content level in soil in the cultivation area of the studied linseed varieties	Normal values for Romania*
1.	Nt	0,23 - 0,25 %	-
2.	P	118,2 - 126,2 ppm	-
3.	K	1141 - 1650 ppm	-
4.	Zn	62,05 - 120,4 ppm	100
5.	Fe	28924 -32452 ppm	-
6.	Pb	20,07 - 54,32 ppm	20
7.	Cd	sub limita de detecție	1
8.	Ni	26,76 - 56,72 ppm	20
9.	Cu	23,28 - 45,61 ppm	20

* Order no. 756/03.11.1997 approving the regulation on environmental pollution assessment (Romanian Ministry of Water, Forest and Environmental Protection (1997). Order 756/1997)

Table 2 The content of Ca, Mg and heavy metals in the five varieties of linseed used in the study

Variety/ Fertlization	Lirina	Alexin	Floriana	Florinda	Iunia 96	Media
			Ca (%)			
F0	0.44	0.43	0.42	0.42	0.46	0.43
F1	0.49	0.48	0.48	0.5	0.49	0.48
F2	0.45	0.44	0.46	0.48	0.47	0.46
F3	0.47	0.47	0.46	0.48	0.49	0.47
F4	0.50	0.53	0.48	0.46	0.51	0.49
Average	0.47	0.47	0.46	0.46	0.48	
			Mg (%)			
F0	1.02	1.04	1.06	1.05	1.09	1.05
F1	1.06	1.03	1.04	1.06	1.10	1.06
F2	1.05	1.07	1.07	1.06	1.04	1.06
F3	1.08	1.08	1.06	1.07	1.06	1.07
F4	1.11	1.12	1.10	1.09	1.15	1.11
Average	1.06	1.06	1.06	1.06	1.08	

			Zn (ppm)			
F0	52.30	51.25	52.4	50.01	50.75	51.34
F1	50.99	51.97	52.63	53.65	51.37	52.12
F2	51.26	52.36	51.82	54.02	52.06	52.3
F3	51.20	52.67	54.68	51.45	53.09	52.61
F4	53.92	50.95	52.35	51.6	51.88	52.14
Average	51.93	51.84	52.77	52.14	51.83	
			Fe (ppm)			
F0	32.95	31.30	33.50	35.60	32.73	33.21
F1	34.19	33.62	35.26	32.64	34.19	33.98
F2	34.85	32.43	34.08	33.45	33.50	33.66
F3	37.40	36.31	33.85	35.80	35.95	35.86
F4	36.04	36.25	36.67	34.50	35.50	35.79
Average	35.08	33.98	34.67	34.39	34.37	
			Pb (ppm)			
F0	13.26	13.41	13.94	12.96	14.00	13.51
F1	14.01	13.02	13.50	13.54	13.63	13.54
F2	12.98	13.61	14.25	13.67	14.30	13.76
F3	12.84	13.54	13.26	13.08	13.57	13.25
F4	13.69	12.70	13.47	13.97	13.26	13.41
Average	13.35	13.25	13.68	13.44	13.75	
			Cd (ppm)			
F0	below the detection limit					
F1	below the detection limit					
F2	below the detection limit					
F3	below the detection limit					
F4	below the detection limit					
Average	below the detection limit					
			Ni (ppm)			
F0	1.37	1.54	2.24	1.93	0.59	1.53
F1	0.95	1.56	1.34	0.41	0.88	1.02
F2	2.09	1.36	1.50	1.03	1.95	1.58
F3	1.60	1.98	0.54	1.69	2.38	1.63
F4	1.45	2.10	1.74	1.34	1.37	1.6
Average	1.49	1.7	1.47	1.28	1.43	
			Cu (ppm)			
F0	27.60	28.64	29.40	28.32	27.50	28.29
F1	27.21	24.50	26.74	30.25	31.54	28.04
F2	25.87	21.83	25.97	24.67	29.90	25.64
F3	35.55	30.75	32.90	32.64	33.80	33.12
F4	29.80	34.12	30.54	32.40	34.08	32.18
Average	29.2	27.96	29.11	29.65	31.36	

Analyzing the data presented in Table 2, we see that the lowest percentage of calcium is found in variety Floriana in unfertilized variant while the highest percentage is found in variety Alexin in the variation of fertilization N96P64 + foliar fertilizer combination Fertileader Magical + Corona K in which Fertileader Magical contains 12% calcium oxide (CaO), which led to a strong absorption of this element from the soil given that the soil pH is between 6.65 and 7.56. Lower values were recorded in portions of the soil where the pH exceeds 7.2. However, given the fact that plants need calcium content between 0.5% and 3%, a level considered optimal for growth and development, we can say that the obtained results place this item to a critical level (Mengel et al).

Magnesium is also a component of many minerals that are found in soil and is absorbed by plants as Mg^{++} ions. Although it is considered that at a 10-15% content of magnesium of the total exchangeable cations, a deficiency in this element cannot be produced, high concentrations of K^{+} influences the absorption of Mg^{++}.

Magnesium is an essential element for plants, indispensable in the chlorophyll formation, in the synthesis of carbohydrates, lipids and proteins. Insufficient magnesium in plants is manifested by the appearance of yellow-orange stains on leaves edge or the appearance of dark green chlorotic stains. Ideal soil Ca:Mg ratio range between 5:1 and 8:1 (Mihoc et al).

Magnesium content in plants is influenced by soil K excess and N deficiency. The lowest concentration is found in the variety Lirina in the unfertilized variant while variety Iunia 96, in the fertilization variant N96P64 + foliar fertilizer combination Fertileader Magical + Corona K has the highest concentration of magnesium. Mg concentration in the tissue and uptake by the plant were increased by P applications (Grant et al).

Zinc is indispensable for plants. It is absorbed by those from the living environment in the form of ions and plays a role in plant growth, increased resistance to drought and cold as well as chlorophyll synthesis. Zinc deficiency in the plant body reduces plant growth, causes arrangement in rosette of terminal branches and leaves, yellow stains on leaves, flowers abortion or weak fruiting with small, underdeveloped seeds. Linseed is susceptible to zinc deficiency, which can also cause leaf chlorosis and the death of the growth peak. High concentrations of zinc, over 70 mg/kg, prevent absorption of other micronutrients from the soil, especially iron.

Analyzing the data obtained, it is found that the lowest level of zinc is found in variety Iunia 96 while the highest is found in variety Floriana.

Comparing the concentration of zinc in soil (62-120 ppm) with the average value of this element in seeds (52.14 ± 1.05 ppm) we can say that linseed is a relatively good crop for soil decontamination and can be used to clean the soil from heavy metals. The values of this metal in seeds fall in a narrow range even under the influence of different fertilization variants or under the influence of variety.

Iron is used by plants in the form of ferrous and ferric salts. It is absorbed by plants through the root system and influence photosynthesis and nitrogen metabolism. Iron deficiency causes yellowing of the leaves and slows the growth of the plant. The excess of phosphorus hinders a good supply of plants with Fe (the optimal P/Fe ratio is 40-50). Also, the Fe/Mn ratio is considered to be a cause of disturbances occurring in plant nutrition, at a high content of Mn, Fe deficiency occurs. Researches made on flax showed that high iron reduced the molybdenum content (ppm/dm) of both shoot and root in flax provided the iron was not excessive. High molybdenum usually reduced the iron content of the shoot, but markedly increased it in the root. Molybdenum-induced chlorosis could thus be partly attributed to inhibition in iron translocation, but the beneficial effect of high molybdenum or high iron on colour was not obviously correlated with the analytical data (Warington et al).

Although soil iron content is very high ranging from 28924 -32452 ppm with an average of 30688 ppm, in the analyzed seed samples the average concentration of iron is only 34.5 ± 1.54 ppm which shows that linseed has a low capacity of absorption of this element. Corona K foliar fertilizer contribution (0.1% Fe), in fertilization variants F3 and F4 brings increase of 8% of the average Fe content of seeds.

Lead is one of the stongest pollutants with bioaccumulation effect. In Romania, according to Order no. 756/03.11.1997 approving the regulation on environmental pollution assessment, the maximum permissible concentration in soil is of 20 ppm. Lead has negative effects on the plants, may affect photosynthesis and can reduce the assimilation of calcium. The average value in tested seeds is of 13.5 ppm with the highest concentration in the variety Iunia 96 and the lower in the variety Alexin.

The high content of lead in linseed (13.5±0.43 ppm) compared with the concentration in soil (20-54 ppm) includes this plant among those with the phytoremediation properties of soils contaminated with Pb.

Pb concentration in analyzed linseed exceeds maximum allowable concentration of 1 ppm in food (Murad et al). From this point of view, caution is recommended for direct consumption or for derived linseed products (oil, meal).

Cadmium is a metal with a strong toxic action on organisms. It is present in soil mainly as cadmium carbonate ($CdCO_3$), compound that exerts a major control of the solubility of cadmium in soils with high pH, and in gleyed soil cadmium is present mostly as sulphide. However the drain of these soils and return to oxidizing conditions lowers pH which results in increased mobility of cadmium. Absorption depends on the concentration of cadmium, pH, soil type, contact time and concentration of complexes ligand. The average concentration of cadmium in soil is 0.11 ppm, and of unloaded soil is 0.1 to 1 ppm. Researches concerning cadmium accumulation showed that Cd was accumulated by roots of *Linum usitatissimum* L., followed by shoots, while reproductive parts (capsules and seeds) played comparably smaller role. The increasing soil Cd concentration resulted in increasing Cd accumulation by roots, while transport to above-ground. Research highlights: the differences exist between *Linum* technological types in cadmium accumulation. Increased Cd soil content results in high retention of Cd in roots (Bjelkováa et al). The results obtained from the study show that both in soil and in plant, cadmium level is below the detection limit.

Naturally, nickel is found in soil in small quantities. Most of the nickel compounds that are released into the environment will adsorb to sediment and become immovable. However, in acid soils nickel will dissolve and will accumulate in groundwaters. Analyzing the data presented in Tables 1 and 2 it can be seen that linseed has a relatively low absorption capacity of nickel from the soil, with an average value of 1.47 ± 0.53 ppm nickel in plant compared to 41.74 ppm nickel existing in the soil; the variety Alexin has the highest absorption capacity, with an average value of 1.7 ppm. Fertilization with N and phosphorus (F1) brings a decrease of Ni content by 33% compared with the unfertilized variant.

Copper enters in the chemical composition of many substances. Copper content in plants varies from trace to 46 ppm. Copper deficiency occurs mainly in wetlands. This is manifested by wilting and discolouring to a shade of white of young foliage. It is reported particularly in trees and cereals. At cereals, tops of the plants turn white, leaves twist and die, internodes growth is stopped. To an intense lack ear is not formed. Copper is an essential micronutrient for seed germination, in water providing and in photosynthesis. In high concentrations, copper becomes toxic. Copper deficiency has negative effects on the formation of the nodules and molecular nitrogen fixation, on fructification and on plant photosynthesis. Hinders ammonium ion metabolism in plants accumulates in large quantities and causes the appearance of white or whitish brown lesions on top or on the edge of the leaf. Copper deficiency affects more the process of fertilization than the vegetative growth. Copper toxicity is manifested by stopping the growth of plants, foliage takes on a bluish tint and twist, then the chlorosis appears and finally necrosis, starting at the top and edges and moving toward the main ridge. Copper toxicity occurs, in most crop plants, at concentrations of 25 to 35 ppm.

The average concentration of copper recorded in the analyzed samples ranges from 29.45 ± 3.46 ppm value in plant and 34.44 ppm in soil. The highest concentration was recorded in variety Junia 96 (31.36 ppm). Corona K foliar fertilizer adds Cu content which makes that the concentration level of this element in seeds to grow by 17% in version F3 and by 13% in version F4. Linseed easily extracts Cu from soil, idea supported also by the presence of copper in linseed at a concentration level of 21.83-35.55 ppm, close to the one found in soil (34.44 ppm).

CONCLUSIONS

Linseed needs a calcium content between 0.5% and 3%, a level considered optimal for growth and development, but the analysis of the obtained results places this item to a critical level. Magnesium content in plants is influenced by soil K excess and N deficiency. Mg concentration in the tissue and uptake by the plant were increased by P applications. Comparing the concentration of zinc in soil (62-120 ppm) with the average value of this element in seeds (52.14 ± 1.05 ppm) we can say that linseed is a relatively good crop for soil decontamination and can be used to clean the soil from heavy metals. Corona K foliar fertilizer contribution (0.1% Fe), in fertilization variants F3 and F4 brings increase of 8% of the average Fe content of seeds. The high content of lead in linseed (13.5±0.43 ppm) compared with the concentration in soil (20-54 ppm) includes this plant among those with the phytoremediation properties of soils contaminated with Pb. Pb concentration in analyzed linseed exceeds maximum allowable concentration of 1 ppm in food. Fertilization with N and phosphorus (F1) brings a decrease of Ni content by 33% compared with the unfertilized variant. Corona K foliar fertilizer adds Cu content which makes that the concentration level of this element in seeds to grow by 17% in version F3 and by 13% in version F4; linseed is extracting easily Cu from soil.

In conclusion, we can say that linseed is a suitable culture for growing in industrially polluted regions; it removes considerable quantities of heavy metals (Zn, Pb and Cu) from the soil with their root system and can be used as potential crops for cleaning the soil from heavy metals.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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PROTEIN AND OIL CONTENT IN SOME HEMPSEED (*Canabis sativa* L) VARIETIES AND ANTIOXIDANT ACTIVITY OF HEMPSEED OIL

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SUMMARY

The paper analyzes the chemical constituents (protein and oil content) found in some hemp varieties authorized in Romania. The seeding material applied on the surveyed plot is composed of dioic hemp (Armanca and Silvana) and monoic hemp (Zenit, Diana, Denise). In addition to the basic fertilization, several fertilization treatments were applied: N68P64K16+3L.ha^{-1} Fertileader Viti, N70P96K0+4L.ha^{-1} Fertileader Magical, and N87P96K0+3kg.ha^{-1} Corona K. Protein content ranges between 19.49 and 21.59% in the studied monoic and dioic seeds. Moreover, fertilization increased the protein content of hemp seeds by 2% up to 7% in monoic varieties and up to 10% in dioic varieties. The seeding distance of 20 cm allows an adequate nutritional surface for hemp plants. The seeding distance does not produce significant changes in protein content for the studied varieties. The oil content ranges from 20.76-28.52% in the studied varieties and fertilization increases the oil content from 23.18% up to 25.48%.

Hempseed oil is known for its high content of polyphenolic compounds, with an average content of 21.23µM GAE/g in the studied oil samples. It has a high antioxidant activity, reaching 80.73 µM Fe^{2+}/g, as measured by the FRAP test.

***Key words**: hempseed, fertilization, protein content, oil content*

INTRODUCTION

Hemp seeds (*Cannabis sativa L*) are rich in oil, minerals and proteins required by the human body. Proteins are essential for life and participate in every process within the cells. The importance of proteins in alimentation dwells in their structure, as they provide the essential intake of amino acids which the organism cannot synthesize. Additionally, hemp has a high arginine (3.10%) and glutamic acid (4.57%) content [Callaway 2004]. The protein content of hulled hemp seeds is high (30-35%), as compared to sunflower seeds (22.78%) and pumpkin seeds (24.54%) [House *et al.* 2010]. Proteins in hempseed and hemp flour are easily digestible [Callaway 2004].

Unlike soy, neither protein nor hempseed oil produce allergies. Because of the lack of gluten, hemp seeds are an important source of vegetal protein for people with celiac disease [Staastamoinen *et al.* 2010]. Protein contents can be influenced by factors such as variety (genetics), agricultural conditions such as soil fertility and changes in the ratio of seed components (*e.g.* shell) [Şandru *et al.*1996]. The oil content ranges between 25-35% in whole seeds, and shelled seeds it exhibit 42% [Callaway 2004]. Hempseed oil ensures fatty acid (omega 6 and omega 3) intake in accordance with health requirements [Callaway *et al.* 1997]. By its active components (linoleic acid, α-linoleic acid, and γ-linolenic acid), hempseed oil enhances the fluidity of the cellular membrane, cell functions, and reduces the effects of aging [House *et al.* 2010].

Besides saturated and unsaturated fatty acids, hempseed oil contains other natural compounds which are essential for human health: β-caryophyllene, myrcene, β-sitosterol, α-tocoferol, γ-tocoferol, polyphenolic compounds [Leizer *et al.* 2000]. Polyphenols, along with tocoferols, have an important role in the oxidative stability of polyunsaturated fatty acids of these oils, shelf-life, as well as in its sensorial and nutritional properties [Kalt *et al.* 1999; Yu *et al.* 2005; Siger *et al.* 2008].

Hempseed oil has a high nutritional value confirmed by its positive effects, such as lowering blood pressure and reducing cholesterol levels. Hempseed oil displays outstanding antioxidant properties through the presence of polyphenolic compounds. The content of polyphenolic compounds in hempseed oil (2.45 mg caffeic acid equivalents/100g oil) studied by Siger *et al.* (2008) is comparable to that of pumpkin oil (2.46 mg caffeic acid equivalents /100g) and higher than that of olive oil (4 ppm) studied by Koski *et al.* (2003). The high level of polyphenols indicates high antioxidant activity in both oils.

The antioxidant profile of hempseed oil as described in literature, according to the DPPH test (2,2-diphenyl-1-picrylhydrazyl method), has the value of 62.37±0.32 mg trolox/100g oil by; according to the ABTS test (2,20-azino-bis-(3-ethylbenzthiazoline-6-sulfonic acid), its value is 39.69±0.46 mg trolox/100g oil [Uluata and Özedmir 2012]. The presence of high levels of isomers of tocopherols (α-25.58 mg/kg, β-5.96 mg/kg, γ- 597.91 mg/kg, and the isomer δ-39.,61mg/kg oil) exhibits high antioxidant activity in hempseed oil [Uluata and Özedmir, 2012].

The aim of this paper is to study the influence of fertilization and seed spacing of monoecious and dioecious hemp seeds upon protein and oil content. The polyphenolic content and antioxidant activity of hempseed oil is the object of the present research.

MATERIALS AND METHODS

The hempseed varieties employed for the purpose of the study, monoecious hempseed (Zenit, Diana and Denise) and dioecoius hempseed (Armanca, Silvana) are authorized according to the Official Catalogue of crop plant varieties in Romania, edition 2011. The seed samples come from the tri-factorial experiment performed on a sub-divided plot at the SCDA in Lovrin in 2011. The basic fertilization consisted of 100 kg ha^{-1} NH_4NO_3 applied during spring in order to prepare the soil for germination. The fertilization options were: N68P64K16+3 $L.ha^{-1}$ Fertilizer Viti (with a P:K ratio of 6:12)-b1, N70P96K0+4$L.ha^{-1}$ Fertilizer Magical (with Ca and Mg)-b2 and N87P96K0+3$kg.ha^{-1}$ Corona K (with N:P:K=8:11:39)-b3 factor. The spacing between rows was 70 cm, but the inter row distance between plants was modified from 20 to 50 cm so as to enable surveying the influence of the nutrition surface upon protein content.

After harvesting and sampling, laboratory analyses of the protein and oil content of hempseeds were performed.

Protein content: In accordance with the SR EN ISO 20483:2007- Kjeldahl method, the protein content of whole hempseed was determined using a Gerhardt digestion block with 6 spaces. In order to determine protein content, 5 grams of whole hemp seeds were ground, mixed and a sampled of 0.1-1.0 g ground seed was taken, 20 ml of sulphuric acid (d=1.84 g/cm^3), 4 g catalysts (1g Se+100g $K_2S_2O_4$) were added and it was subjected to mineralization. Organic nitrogen was reduced to ammonium sulphate and distilled into a basic solution. A Velp UDK 127 distiller was employed for the distillation procedure. A standard control was digested with glutamic acid for each series of samples.

Oil content: In accordance with SR EN ISO 659:2009, when determining the oil content of the analyzed hemp seeds, 5.0 g of seeds with ground shells were subjected to extraction with petroleum ether, using the automated Foss Soxtec 2055 system.

Total phenol assay: The total phenolic content was quantified according to the method advanced by Singleton *et al.* (1999) with some modifications. A calibration curve with gallic acid was prepared and the absorbance of the standards and samples was measured at 750 nm, using a UV-Vis spectrophotometer (Analytic Jena Specord 205). Measurements were recorded as μmol gallic acid equivalents (GAE) per gram extract. All determinations were performed in triplicate.

Antioxidant activity (FRAP assay): The antioxidant activity was measured using the ferric reducing antioxidant power (FRAP) assay according to Benzie and Strain (1996). The reduction of ferric to ferrous iron at low pH (3.6) in acetate buffer produces a coloured ferrous-tripyridyltriazine complex. The FRAP values are obtained by reading the absorbance change at 595 nm, which are linear over a wide concentration range. The FRAP values were expressed as μmol Fe^{2+} equivalents per gram extract. All determinations were performed in triplicate.

RESULTS AND DISCUSSION

Protein content

The protein content of the 2011 hempseed yield is displayed in Figure 1 in comparison with the protein content of the biological material used in the experiment. Proteins in the Armanca seeds display the highest value, while the Zenit variety exhibits the largest decrease as compared to the biological material.

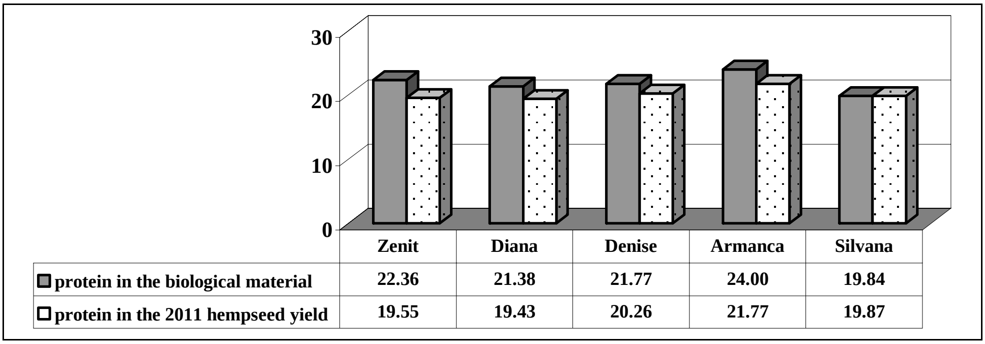

Figure 1 Protein content (%) in the biological material used for sowing in comparison with the protein in the 2011 hempseed yield

The studied monoecious varieties display similar protein values ranging between 18.66 and 21.44%, with the application of fertilizers and various seeding spaces (Table 1). Depending on the variety, the Denise seeds have a higher content of protein than the control seeds, while the Diana seeds display a difference of 0.12% from the control seeds. The nitrogen intake determines an increase of 7% in the protein content of hemp seeds, which is statistically positive. The seeding distance of 50 cm generates slight increases in protein content.

Table 1 Protein content (%) of hemp seeds from three monoecious cultivars

A Factor - Variety	C Factor –Seeding space (cm)	B Factor - Fertilization: N0P0K0 b0	N68P64K16 +3 L.ha^{-1} Fertileader Viti - b1	N70P96K0 +4L.ha^{-1} Fertileader Magical - b2	Average A factor: Protein content %	%	Diff ±	Significance
ZENIT	20	19.14	20.73	19.10	19.55	100	-	-
	50	18.94	20.00	19.36				
DIANA	20	18.66	19.70	19.19	19.43	99	-0.12	0
	50	19.19	20.60	19.22				
DENISE	20	19.43	20.49	20.05	20.26	104	0.71	x
	50	19.90	21.44	20.25				

Specification	N0P0K0 b0	N68P64K16 +3L.ha^{-1} Fertileader Viti-b1	N70P96K0 +4L.ha^{-1} Fertileader Magical - b2
Protein %	19.21	20.49	19.60
%	100	107	102
Difference	-	1.28	0.32
Significance	-	xxx	xx

Specification	20 cm	50 cm
Protein, %	19.61	19.88
%	100	101
Difference	-	0.27
Significance	-	0

A Factor - DL 5% - 0.71%; DL 1% - 0.98%; DL 0.1% - 1.35%
B Factor - DL 5% - 0.19%; DL 1% - 0.29%; DL 0.1% - 0.46%
C Factor - DL 5% - 0.49%; DL 1% - 0.66%; DL 0.1% - 0.88%

The Armanca variety displays the highest protein content (23.80%) with Fertileader Viti N68P64K16 foliar fertilization applied on an agrofond, with a 50 cm seeding distance (Table 2). The fertilization with nitrogen fertilizers produces a slight increase in protein content, the increase being statistically assured. The seeding distance of 50 cm does not modify the protein content of the seeds in a significant manner.

In the case of the Corona K-b3 N87P96K0+ 3kg.ha^{-1} fertilization variant, with a seeding distance of 20 cm, the protein of hemp seeds reaches 20.80% (Diana variety) and 23.50% (Armanca variety).

Table 2 Protein content (%) of hemp seeds from two dioecious cultivars

A Factor - Variety	C Factor– Seeding space (cm)	B Factor - Fertilization			Average A factor			
		N0P0K0 b0	N68P64K16 +3 L.ha^{-1} Fertileader Viti - b1	N70P96K0 +4L.ha^{-1} Fertileader Magical - b2	Protein content %	%	Diff ±	Significance
ARMANCA	20	21.08	23.49	21.04	21.77	100	-	-
	50	20.86	23.80	20.36				
SILVANA	20	19.09	19.86	20.32	19.87	92	-1.90	000
	50	18.61	20.77	20.55				

Specification	N0P0K0b0	N68P64K16 +3 L.ha^{-1} Fertileader Viti -b1	N70P96K0 +4L.ha^{-1} Fertileader Magical - b2
Protein %	19.91	21.98	20.57
%	100	110	103
Difference	-	2.07	0.66
Significance	-	xxx	x

Specification	20 cm	50 cm
Protein %	20.80	20.84
%	100	100
Difference	-	0.02
Signification	-	0

A Factor - DL 5% - 0.49%; DL 1% - 0.67%; DL 0.1% - 0.93%
B Factor - DL 5% - 0.53%; DL 1% - 0.80%; DL 0.1% - 1.29%
C Factor - DL 5% - 0.44%; DL 1% - 0.60%; DL 0.1% - 0.80%

Table 3 Protein content (%) in hemp seed in different fertilization conditions

Fertilization	Protein content %	RelativeProduction (%)	Difference ±	Significance
N0P0K0 b0	19.49	100	-	
N68P64K16 +3 L.ha^{-1} Fertileader Viti - b1	21.09	108	1.60	x
N70P96K0+4L.ha^{-1} Fertileader Magical - b2	19.95	102	0.45	0
N87P96K0+ 3kg.ha^{-1} Corona K-b3	21.59	111	2.10	x

DL 5% - 1.44%; DL 1% - 2.18 %; DL 0.1% - 3.50%

Data in Table 3 indicate an increase in protein content, as well as an increase in the nitrogen percentage in the fertilizer. The highest level of protein is obtained with the N87P96K0-b3 option, upon fertilization with a dose of $3kg.ha^{-1}$ Corona K.

Given that neither the fertilization rate nor the seeding distance produced significant differences in protein levels in the Vera *et al.* (2006) experiment, neither does the seeding distance between plants change the protein content of hemp seeds significantly.

Oil content

According to Table 4, the average oil content of the five hemp varieties under the influence of fertilization and depending on the seeding distance between plants ranges between 20.76 and 28.52%, with dioecious varieties being richer in oil than monoecious varieties. Both dioecious genotypes have shown significant increase in comparison to the control, the Zenit variety. Determinations were performed on each variant.

Table 4 Average oil content (%) in five hemp seed varieties under the influence of fertilization and seeding distance

Variety	Oil %	Relative production (%)	Difference ±	Significance
ZENIT	22.49	100	-	-
DIANA	20.76	92	-1.73	0
DENISE	23.45	104	0.96	0
ARMANCA	28.52	127	6.03	xxx
SILVANA	27.08	120	4.59	xx

DL 5% - 2.1%; DL 1% - 3.2%; DL 0.1% - 5.1%

Under the influence of foliar fertilization and NPK fertilizers, oil content increases from 23.18% up to 25.48% (table 5). Furthermore, it is noteworthy that phosphorus enhances oil content. Each fertilization variant is statistically assured and increases oil content by 1.41% up to 2.30%. Due to an increased phosphorus intake by means of N68P64K16 Fertileader Viti fertilizer, seed oil content increased by 6% as compared to the control seed, while the N87P96K0 Corona K fertiliser variant increased seed oil content by 10%. Also, in the N68P64K16+ $3L.ha^{-1}$ Fertileader Viti-b1 fertilization variant with aseeding distance of 20 cm, hempseed oil content increased from 20.92% (the Zenit variety) up to 28.70% (the Armanca variety).

Hempseed oil is an adequate source of vitamin E, carotene, minerals required by the human body, as well as polyphenols that prevent the development of free radicals. Hempseed oil obtained by extraction with petroleum ether (Table 7) contained the largest amount of phenolic compounds (3.61 $mg.g^{-1}$ as gallic acid equivalents), compared to cold pressed hempseed oil value (0.44 $mg.g^{-1}$) obtained in the Yu *et al.* (2005) experiment. The polyphenolic compounds in the analyzed oil reached the same levels as those in cold pressed garlic oil, *i.e.* 3.35 mg $GAE.g^{-1}$ oil, and higher levels than those in pumpkin oil (0.98 $mgGAE.g^{-1}$) [Parry *et al.* 2006].

Table 5 Oil content (%) of the five hemp cultivars under the influence of different fertilization variants

Fertilization	Oil content %	Relative production (%)	Difference ±	Significance
N0P0K0 b0	23.18	100	-	
N68P64K16 +3 $L.ha^{-1}$ Fertileader Viti - b1	24.59	106	1.41	x
N70P96K0 +4$L.ha^{-1}$ Fertileader Magical - b2	24.75	107	1.56	x
N87P96K0+ 3$kg.ha^{-1}$ Corona K-b3	25.48	110	2.30	xx

DL 5% - DL 5% - 1.41 %; DL 1% - 2.13%; DL 0.1% - 3.42%

Increasing the seeding distance to 50 cm produces significant modifications in the oil percentage in hemp seeds (Table 6).

Table 6 Oil content (%) depending on the seeding distance between plants

Seeding space	Oil content %	Relative production (%)	Difference ±	Significance
20cm	23.73	100	-	-
40 cm	24.53	103	0.80	xx
50cm	25.19	106	1.46	xxx

DL 5% - 0.46%; DL 1% - 0.69%; DL 0.1% - 1.11%

Although the polyphenolic content of hempseed oil is conspicuously inferior to the one in fresh bilberries (683.88 mg $GAE.100^{-1}g$) [Poiana *et al.* 2012], the former is outstanding in terms of antioxidant activity.

Table 7 Total polyphenols and total antioxidant activity in hempseed oil

Polyphenol content		Antioxidant activity in hempseed oil (FRAP)	
μM GAE. g^{-1}	mg GAE .g^{-1} oil	μM Fe^{2+}·mL^{-1}	μM Fe^{2+}.g^{-1}
21.23 ± 1.82	3.61± 0.03	0.0481± 0.004	80.73 ± 6.57

*GAE: Gallic acid; FRAP: ferric reducing antioxidant power

CONCLUSIONS

- In conclusion, the experimental analyses confirm the influence of factors such as variety and fertilization upon the protein content and composition of protein and amino acids in whole hemp seeds. Armanca displays the highest average protein content (21.77%) among the studied varieties.

- In the Romanian varieties that have been analyzed, protein levels (%) are slightly lower than the literature data, ranging between 23.5 and 31.3% [Mediavilla *et al.* 1999].
- Protein content increases by 11% in a N:P:K=87:96:0 agrofond with foliar fertilization and a N:P:K ratio of 8:11:39. Phosphorus and potassium are required, in order that a proper intake of nitrogen enhance the protein content in the seeds. Protein in the hemp seeds does not vary significantly in relation to modifications of the seeding distance.
- As opposed to Turkish varieties in which oil content ranges between 29.6 and 36.5% [(Kiralan *et al.* 2010], the oil content of the studied medium-early maturing hemp varieties is situated on a lower level, ranging between 20.76 and 28.52%.
- Under the influence of fertilization with different nitrogen doses, significant changes do not occur in the oil content of hemp seeds. The largest increase reaches 10% under the influence of Corona K foliar fertilization applied on a N87P96K0 agrofond.
- The optimal inter row seeding distance between plants was shown to be 50 cm, resulting in oil content above 25%.
- Given its potent antioxidant activity, hempseed oil may be used as an active ingredient in various cosmetic products. Finally, the prophylactic properties of its polyphenolic compounds deserve particular attention.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

THE SUITABILITY OF UTILISING COTTON STALK FOR LOW COST BINDERLESS PANELS

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SUMMARY

In this study cotton stalks were used to manufacture binderless particleboards with a low cost process (hot pressing under 26 kg/cm^3 at 110 ºC during 15 min). Some panels were subjected to a second and a third pressing cycle. The physical and mechanical properties tested were: modulus of rupture, modulus of elasticity, internal bonding strength, thickness swelling after 2 and 24 hour immersion in water, water absorption, density, and thickness, following the European standards for particleboards. The bending strength of the panels made with particles under 0.25 mm increased with the pressing cycles. The thickness swelling improved by increasing the times of pressing for the two particle sizes. Most of the panels met the requirements for general uses. Panels manufactured with a particle size under 0.25 mm and three pressing cycles reached the requirements for interior fitment (including furniture manufacturing).

Key words: *Particleboard, Gossypium hirsutum L., mechanical properties, environmentally-friendly*

INTRODUCTION

The cotton industry in Spain (*Gossypium hirsutum* L.) is dependent on the EU subsidies that are coupled to the production. The last EU Common Agricultural Policy (CAP) reform resulted in a reduction of the cotton area from some 89.000 ha to 62.000 ha, the reduction in production of 60 %, and reduction of direct employment of 43 %. The future of this crop after the CAP reform for 2013 is uncertain. As the income from cotton farming has become very low and often insufficiently remunerative. Other possibilities of fetching adequate returns to farmers are to be explored. In this connection, judicious utilisation of cotton by-products for value-added materials could play a greater role in generating additional income to the farming community.

Cotton stalk is rich in cellulose and composition and fibre structure is comparable to many hard wood species (about 79 % holocellulose and 27 % lignin). Some researchers have studied the use of cotton stalks to manufacture particleboards by using urea formaldehyde (UF) as a binder (Guler and Ozen, 2004). However, UF adhesive can release low concentrations of formaldehyde gas from bonded wood-based products. When the products are new, high indoor temperatures or humidity can cause increased release of formaldehyde degrading the indoor air quality. In the European Union, formaldehyde is considered as high-level pollutant (Ferrandez-García et al, 2012). Therefore, the objective of this study, was to develop binderless particleboards from cotton stalks by hot pressing, using a low cost procedure.

MATERIALS AND METHODS

Materials

The raw material was cotton stalks. The stalks were gathered after the harvest, from the field in the vicinity of the University Miguel Hernandez. They were cleaned from the remaining leaves and husks and left outside for air drying, until they reached 8 % of moisture content. The stalks were chipped and screened. Two particles sizes were used in this study: the fines (<0.25 mm) and the particles that passed the sieve of 1 mm but were retained by the sieve of 0.25 mm (0.25-1.00 mm).

Table 1 Manufacturing Conditions of Particleboards

Panel Type	Particle size (mm)	Pressing cycles	Pressing Temperature (ºC)	Pressing Pressure (MPa)	Pressing time (min)
A1	<0.25	1	110	2.6	15
A2	<0.25	2	110	2.6	15+15
A3	<0.25	3	110	2.6	15+15+15
B1	0.25-1.00	1	110	2.6	15+15
B2	0.25-1.00	2	110	2.6	15+15
B3	0.25-1.00	3	110	2.6	15+15+15

Six types of panels were made. The particles were mixed with 10 % of water (based on the weight of particles) at 20 ºC, by hand in a bucket and then the mixture was placed in a mold. No wax or any other hydrophobic substances were used. The mat configuration was single layer. Boards measuring 600 mm x 400 mm were manually formed in the mold and pressed in a hot press under 2.6 MPa at 110 ºC for 15 min. After pressing, the boards stayed in the mold while cooling down for 1 hour at ambient conditions. During the cooling down, the pressure was not kept. After that, the particleboards were brushed with distilled water at a rate of 12 g /1000 cm^2 on the upper surface and then they were hot pressed for a second time under the same pressing conditions. Some panels (A3 and B3) were subjected to a third pressing cycle. The experimental design is shown in Table 1. Three replicate panels were made for each board type. Once finished, the particleboards were conditioned at a temperature of 20 ºC and 65 % relative humidity for four days. The finished particleboards were trimmed to avoid edge effects and then cut into various sizes for property evaluation according to EN 326-1 (1999).

Physical and mechanical properties measured

Some physical properties were determined in accordance to appropriate EN Standards: density (EN 323, 1993), water absorption (WA), and thickness swelling (TS) after 2 and 24-hour immersion (EN 317, 1993). The mechanical properties determined were: modulus of rupture (MOR), modulus of elasticity (MOE) (EN 310, 1993), and internal bond (IB) (EN 319, 1993). Each panel was cut to get six samples for determining density (50 mm x 50 mm), three samples for determining WA/TS (70 mm x 70 mm), six specimens for the measurement of MOR/MOE (different lengths, depending on the thickness, x 50 mm width) and three specimens for the measuement of IB (50 mm x 50 mm). Tests for mechanical properties, WA, TS, and density were conducted on an Imal universal testing machine (Model IB600, Modena, Italy).

RESULTS AND DISCUSSION

The results of thickness swelling and water absorption after 2 and 24 hour immersion are summarised in table 2.

Table 2 Dimensional stability of the particleboards made with cotton

Panel type	TS 2 h	TS 24 h	WA 2 h	WA 24 h
A1	61.71 (3.87)	72.94 (0.72)	79.17 (11.51)	118.25 (10.93)
A2	47.80 (7.61)	64.06 (10.39)	87.67 (52.07)	126.44 (48.06)
A3	27.74 (1.43)	49.46 (8.94)	36.30 (13.88)	54.42 (0.05)
B1	63.37 (7.38)	100.79 (4.18)	92.67 (15.14)	148.07 (0.43)
B2	59.19 (4.18)	93.91 (4.47)	106.84 (2.53)	157.07 (1.99)
B3	55.06 (12.89)	82.38 (4.68)	92.62 (17.44)	143.44 (12.74)

Values in parenthesis are standard deviations. TS: Thickness swelling; WA: Water absorption

Thickness swelling

Particleboards should have a maximum thickness swelling value of 16% for 24 h immersion for load bearing (P4 grade EN 312, 2003). Average thickness swelling of the specimens for 2 h immersion ranged from 27.74 to 63.37 %. For 24 h immersion, the results lay between 49.46 and 100.79 %. There is no minimum value of TS in the standards for general uses and furniture manufacturing in dry ambient (P1 and P2 grades, respectively). None of the panels met the standard value of TS for load bearing (grade P4), but they could be used, if their mechanical properties meet the standards, for general uses and indoor fitment. The TS was better for the particleboards made with the particles under 0.25 mm. In all cases the TS improved by increasing the pressing cycles.

Mechanical properties

Based on EN standards (EN 312, 2003), the minimum requirement of MOR for general uses is 12.5 N/mm^2 and an IB value of 0.24 N/mm^2 are the minimum requirements for general uses in dry ambient (P1 grade). A MOR value of 13 N/mm^2, a MOE value of 1800 N/mm^2, and an IB value of 0.35 N/mm^2 are the minimum requirements for furniture manufacturing (P2 grade). For load bearing (P4 grade), the values of MOR, MOE, and IB are 15 N/mm^2, 2300 N/mm^2, and 0.40 N/mm^2, respectively. The values of MOR ranged from 11.12 to 18.98 N/mm^2. Panels A2, B1, and B3 met the requirements of MOR and IB for general uses as can be observed in table 3. Panel A3 exceeded the MOR, MOE and IB requirements for indoor fitment (including furniture manufacturing). The MOR significantly increased when increasing the time in the hot-press. The third pressing cycle affected the IB, improving it for the two particle sizes.

Table 3 Average values of some physical and mechanical properties of the panels

Panel type	Thickness (mm)	Density (kg/m^3)	MOR (N/mm^2)	MOE (N/mm^2)	IB (N/mm^2)
A1	3.83 (0.19)	1160.77 (102.64)	11.12 (0.03)	1277.15 (250.94)	0.23 (0.078)
A2	4.01 (0.15)	1014.60 (142.30)	15.42 (1.35)	1933.86 (137.76)	0.20 (0.063)
A3	3.82 (0.52)	1113.79 (123.30)	18.98 (0.14)	2136.92 (101.41)	0.36 (0.040)
B1	5.09 (0.19)	962.96 (47.21)	12.49 (0.19)	1501.04 (6.60)	0.27 (0.014)
B2	5.18 (0.54)	964.35 (41.18)	12.23 (1.08)	1504.92 (36.71)	0.16 (0.007)
B3	4.76 (0.08)	1101.52 (49.76)	13.49 (1.87)	1658.08 (98.48)	0.40 (0.057)

Values in parenthesis are standard deviations

CONCLUSIONS

The manufacture of binderless particleboards from cotton stalks by using a low cost process is technically feasible. Most of the panels met the requirements for general uses. Panel A3 reached the requirements for interior fitment (including furniture manufacturing). Further investigation is needed in order to reduce the thickness swelling of the panels.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

PROPERTIES OF THERMAL INSULATING PANELS FROM SORGHUM WASTE

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SUMMARY

Traditionally cereal straw has been used for thatching due to its low thermal conductivity. Sorghum vulgare L is considered the forth most important summer crop in the world after soya, corn, and sunflower. Sorghum is a source of starches and glucose for the pharmaceutical industry and for biofuel. In this research sorghum waste (straw and leaves) was used as a lignocellulosic raw material to manufacture panels and study some physical and mechanical properties. The results showed that the manufacturing of good insulation panels, using sorghum waste and low content of urea formaldehyde is feasible. The thermal conductivity of the produced panels was similar to that of other insulation materials, with an average value of 0.065 W/mK.

Key words: *Particleboards, thermal conductivity*

INTRODUCTION

Sorghum vulgare L. is considered the forth most important summer crop in the world after soya, corn, and sunflower. Sorghum is a source of starches and glucose for the pharmaceutical industry and for biofuel.

After the harvest, the non-edible parts of the plant, the stalks and leaves are left over and must be disposed of, most of the times by burning. Traditionally cereal straw has been used for thatching due to its low thermal conductivity.

Urea formaldehyde (UF) resin is the most important adhesive for manufacturing wood-based products for indoor. Among its advantages are: low price, good technological properties, absence of color in cured polymer and easiness of application (Pirayesh et al., 2012). However, UF can release low concentrations of formaldehyde gas from bonded wood products, especially under hot, moist conditions. Formaldehyde can react with proteins of the body to cause irritation and inflammation of membranes of eyes, nose, and throat, and may be a carcinogen. Driven by regulations mandating lower formaldehyde emissions, considerable research has led to new adhesive formulations with significantly reduced levels of formaldehyde emissions in both manufacturing operations and bonded wood products. New standards in the United States and European countries have reduced the acceptable upper limit for formaldehyde emissions. Therefore UF is still used in the 90 % of the particleboard industry.

In this research sorghum waste (straw and leaves) was used as a lignocellulosic raw material to manufacture panels bonded with a low level of UF to give an added value to the residue.

MATERIALS AND METHODS

The raw material was sorghum waste, that contains straw and leaves. It was cleaned from impurities and left outside for air drying. Then the particles were obtained in a ring knife chipper, after that they were classified using sieves. As resin a 5 % of UF (65 % of soluble solids) and as a hardener amonium nitrate at a 0.4 % (based on the weight of particles).

Table 1 Processing parameters of the particleboards

Panel type	Particle size (mm)	Press Temperature (ºC)	Press Presure (MPa)	Pressing Time (min)
A1	0.25-1.00	120	2.1	4
A2	0.25-1.00	120	2.6	4
B1	1.00-2.00	120	2.1	4
B2	1.00-2.00	120	2.6	4
C1	2.00-4.00	120	2.1	4
C2	2.00-4.00	120	2.6	4

The processing parameters were: three particle size groups, 0.25-1 mm, 1-2 mm and 2-4 mm, two different pressing pressures, 2.1 and 2.6 MPa, and a press temperature of 120 ºC. The mat formation was in single-layer. Three panels samples were made for each combination of parameters. The finished panels were conditioned at 20 ºC and 65 % relative air humidity for four weeks. The physical properties measured were: density (according to EN 323, 1993), thickness swelling (TS) after 2 and 24 h inmersion (according to EN 317, 1993), and thermal conductivity (according to EN 12667, 2001). The mechanical properties determined were bending strength modulus of rupture (MOR) and modulus of elasticity (MOE) (according to EN 310, 1993)), and internal bond strength (IB) (according to EN 319, 1993). Tests for physical and mechanical properties were conducted using the Imal Universal Testing Machine (Model IB600, Modena, Italy). Tests for the thermal conductivity were performed using the Heat Flow Meter (NETZSCH Instruments Inc, USA).

The finished particleboards were trimmed to avoid edge effects to a final size of 60cm x 40cm, and then cut into various sizes for property evaluation according to EN 326-1 (1994).

Each panel was cut to get six samples for determining density (50 mm x 50 mm), three samples for determining WA/TS (70 mm x 70 mm), six specimens for the measurement of MOR/MOE (different lengths, depending on the thickness, x 50 mm width), three specimens for the measurement of IB (50 mm x 50 mm) and one sample for determining thermal conductivity (300 mm x 300 mm).

RESULTS AND DISCUSSION

Thickness swelling

Table 2 shows the results of the thickness swelling test and the water absorption after two and 24 hours. The TS value increased when increasing the press pressure from 2.1 to 2.6 MPa, for the three particle sizes. There are no minimum requirements of TS for P1 grade (particleboards for general use) nor for grade P2 (interior fitment). The maximum value of TS for grade P4 (load bearing) is 15 % for 24 hour immersion.

Table 2 Average results of dimensional stability of the particleboards of sorghum waste

Panel type	TS 2 h	TS 24 h	WA 2 h	WA 24 h
A1	17.55 (5.93)	27.53 (4.19)	71.27 (15.09)	88.64 (9.28)
A2	22.09 (5.76)	35.75 (3.67)	68.98 (10.88)	84.44 (5.02)
B1	16.63 (5.19)	26.57 (5.54)	61.16 (7.14)	69.69 (4.75)
B2	22.07 (6.99)	28.42 (7.61)	70.48 (7.55)	74.37 (7.70)
C1	13.64 (2.75)	20.21 (5.74)	67.24 (3.54)	70.60 (8.17)
C2	17.63 (5.26)	27.05 (5.01)	61.98 (5.44)	68.05 (2.75)

Values in parenthesis are standard deviations

The values of TS after 24 hours immersion ranged from 20.21 to 35.75 %. The particleboards obtained did not meet the TS requirement for load bearing.

Mechanical properties

The results of the mechanical properties are presented in table 3. The panels had an average thickness of 6.96 mm. The density ranged from 644 to 853 kg/m^3. The values of bending strength (MOR and MOE) were very low. This must be due to the very low content of resin. Both, MOR and MOE did not depend on the pressure. Based on EN 312 standards the minimum value of MOR for general uses is 12.5 N/mm^2 . There is no requirement of MOE for this category. The Japanese standard for insulating particleboards (JIS A 5905, 2003) recommends a minimum MOR of 1 N/mm^2, for density less than 400 kg/m^3 all panels met this recommendation, but their density should be lowered. The thermal conductivity value lay between 0.063 and 0.075 W/m K, which is similar to expanded perlite boards (0.40-0.70 W/m K) and to vermiculite (0.046-0.070 W/m K) (Panyakaew and Fotios, 2011). The thermal conductivity did not depend on neither of the density, nor of the pressure, but was affected by the particle size.

Table 3 Average results of some physical and mechanical properties of the particleboards

Panel type	Thickness (mm)	Density (kg/m^3)	MOR (N/mm^2)	MOE (N/mm^2)	Thermal Conductivity (W/m K)
A1	6.97 (0.53)	780.67 (69.23)	5.11 (0.93)	769.12 (134.81)	0.063 (0.0035)
A2	6.62 (0.57)	853.19 (42.55)	4.79 (0.20)	919.68 (178.67)	0.063 (0.0059)
B1	7.31 (0.96)	758.28 (35.39)	4.38 (0.38)	645.00 (94.14)	0.072 (0.0028)
B2	6.32 (0.45)	736.01 (37.49)	4.65 (0.23)	692.38 (184.12)	0.068 (0.0058)
C1	7.43 (1.02)	644.37 (36.87)	3.55 (0.44)	419.45 (185.97)	0.075 (0.0037)
C2	7.15 (0.82)	746.67 (28.60)	3.45 (0.22)	398.46 (94.37)	0.069 (0.0044)

Values in parenthesis are standard deviations

CONCLUSIONS

The results showed that the manufacturing of good insulation panels, using sorghum waste and low content of urea formaldehyde is feasible. The thermal conductivities of the produced panels were similar to that of other insulation materials, with an average value of 0.065 W/mK. Further investigation is needed in order to obtain panels with a density less than 400 kg/m3.

ACKNOWLEDGEMENTS

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Originalni znanstveni rad
Original scientific paper

EFFECT OF PRESSING CONDITIONS ON PHYSICAL AND MECHANICAL PROPERTIES OF BINDERLESS BOARDS MADE FROM ALMOND HULLS (*Prunus dulcis* (Mill.) D. A. Webb)

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SUMMARY

Almond hulls were used as a raw material to manufacture particleboards without adhesives, in order to give a value added to the residue. This study investigated the effect of the pressing parameters on some physical (hardness) and mechanical properties (modulus of elasticity, modulus of rupture, and internal bond strength) of single layer boards. The mats were consolidated after three cycles of hot pressing at 100 ºC and under 26 kg/cm^2 of pressure, followed. The experimental panels were tested according to the procedures defined by European Union (EN) Standards. The boards obtained were high density. The results showed that MOR, MOE, IB and hardness improved after the third pressing cycle. Their hardness Brinner was bigger than that of the wood based particleboars. The boards had an average IB value of 1.26 N/mm^2. The bending strength was low due to the very low pressing conditions.

Key words: *Particleboard, brinell hardness, density, pressing phases, formaldehyde-free*

INTRODUCTION

Almond, scientifically known as *Prunus dulcis* (Mill) D.A. Webb, belongs to the Rosaceae family and it is also related to stone fruits such as peaches, plums and cherries. The almond is native to the Mediterranean areas. It was spread by humans in ancient times along the shores of the Mediterranean into northern Africa and southern Europe and more recently, transported to other parts of the world, notably California (USA). The United

States, is the major producer of almonds in the world, followed by Spain, that accounted 0.22 million tonnes in 2010 (FAO, 2010)

The almonds fruit have three distinct parts: the inner kernel or meat, the middle hard shell portion, and an outer green shell cover or hull. Almond hull by-product, is obtained by drying the portion of the almond fruit that surrounds the hard shell. Hulls are used as supplemental livestock feed (Jahanban-Esfahlan et al, 2010). It is a source of carbohydrates and polyphenolics, substances that have been used as adhesive for wood-based products (Ferrández-García et al, 2012).

In this research, almond hulls were used as a raw material to manufacture binderless boards in an attempt to develop value added application for this residue.

MATERIALS AND METHODS

Materials

The raw material of this study was almond hulls. They were cleaned from dirt and impurities and dried until they reached an 8 % of moisture content. After that they were chipped and screened. The particles used in this study were the ones that passed through the sieve of 2 mm and were retained by the sieve of 1 mm.

Water was used as a plasticizer at a level of 10% (based on the weight of particles). No other substances were used.

Methods

Three types of panels were made. The particles were mixed with 10% of water (based on the weight of particles) at 20ºC, by hand in a bucket and then the mixture was placed in a mold. No wax or any other hydrophobic substances were used. The mat configuration was single layer. Boards measuring 600mm x 400mm were manually formed in the mold and pressed in a hot press under 26 Kg/cm^2 at 100ºC for 15 min. After pressing, the boards stayed in the mold while cooling down for 1 hour at ambient conditions. After that, some panels were brushed with distilled water at a rate of 12g /1000 cm^2 on the upper surface and then they were hot pressed for a second time under the same pressing conditions. Some panels were subjected to a third pressing cycle. Three replicate panels were made for each board type. Once finished, the particleboards were conditioned at a temperature of 20ºC and 65% relative humidity for four days. The finished particleboards were trimmed to avoid edge effects and then cut into various sizes for property evaluation according to EN 326-1 (1999).

Physical and mechanical properties measured

Some physical properties were determined in accordance to appropriate EN Standards: density (EN 323, 1993) and hardness (EN 1534, 2000) Mechanical properties determined were: modulus of rupture (MOR), modulus of elasticity (MOE) (EN 310, 1993), and internal bond (IB) (EN 319, 1993). Each panel was cut to get six samples for determining density (50 mm x 50 mm), six specimens for the measurement of MOR/MOE (different lengths, depending on the thickness, x 50 mm width) and three specimens for the measuement of IB (50 mm x 50 mm). Tests for mechanical properties, and density were conducted on an Imal universal testing machine (Model IB600, Modena, Italy). The test for determining hardness was done employing a Starret portable universal hardness tester (model 3811A).

In a previous study we manufactured binderless panels of almond hulls and what we obtained after the hot pressing was very plastic boards that looked like rubber. They were left aside. A month after, these boards became hard enough to be considered for further investigation, what led to the present study.

RESULTS AND DISCUSSION

The results of the physical and mechanical properties of the experimental boards are presented in table 1. The boards manufactured by one pressing step were discarded. The boards tested were the ones produced in two and three pressing steps.

The boards obtained can be considered high-density. The average values of hardness ranged from 144.26 to 177.60 N/mm^2. The hardness Brinell of pure aluminium is 15 N/mm^2, mild steel has a hardness value of 120 N/mm^2, and 304 stainless steel has a hardness value of 250 N/mm^2. Having this data into account it can be considered that the produced panels of almond hulls are very hard. Pinus radiata has a hardness of 70 N/mm^2 (Holmberg, 2000).

Table 1 Average values of physical and mechanical properties of the almond hulls binderless panels

Pressing Steps	Density (Kg/m^3)	Hardness brinell (N/mm^2)	MOR (N/mm^2)	MOE (N/mm^2)	IB (N/mm^2)
2	1344.00 (58,80)	144.26 (22.23)	6.95 (0.95)	638.22 (80.25)	1.07 (0.287)
3	1394.86 (35.56)	177.60 (19.70)	9.39 (1.47)	1029.05 (170.81)	1.52 (0.221)

Values in parenthesis are standard deviations

The values of bending strength (MOR and MOE) were very low. This is due to the very low pressing pressure and temperature. Both, MOR and MOE increased with increasing the cycles of pressing. Based on EN standards (EN 312, 2003), the minimum requirement of MOR for general uses is 12.5 N/mm^2 . In this cathegory there is no requirement of MOE. The IB values obtained ranged between 1.07 and 1.52 N/mm^2. The minimum requirements of tensile strength (IB) are: 0.24 N/mm^2 for general uses in dry ambient (P1 grade), 0.35 N/mm^2 for interior grade (P2), and 0.40 N/mm^2 for load bearing (P4 grade). The IB of the panels manufactured achieved the load bearing grade.

If we classify the results of hardness of the panels into three groups (125, 150, and 200 N/mm^2), the effect that the harness had in the other properties can be seen in fig. 1 and 2.

The MOR value increased when increasing the hardness (fig 1). The same trend was observed for the IB (fig. 2).

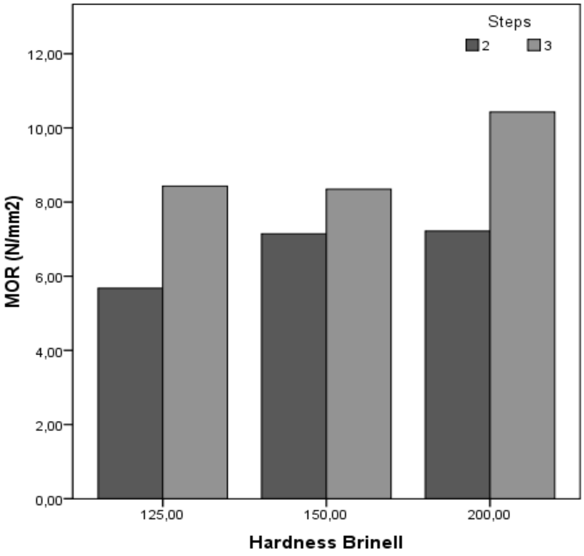

Fig. 1 The effect of hardness Brinell on modulus of rupture (MOR)

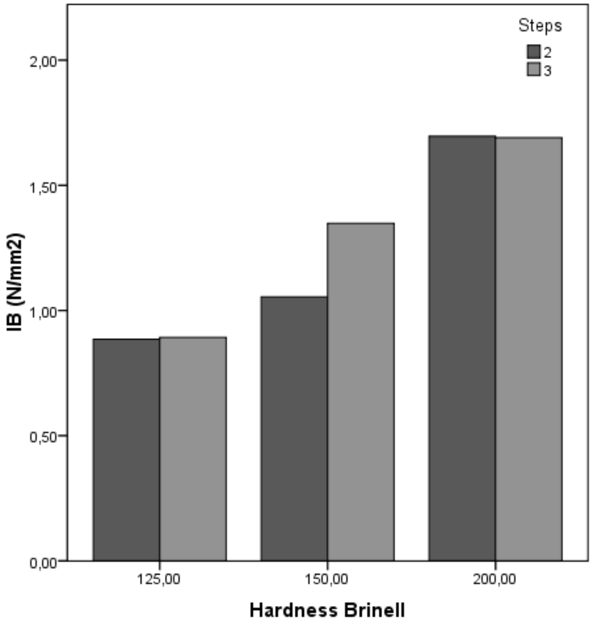

Fig. 2 The effect of Brinell hardness (N/mm^2) on internal bonding strength (IB)

CONCLUSIONS

This study shows that it is technically possible to make almond hull binderless particleboards. One of the potential markets for this kind of board could be as the core material for laminated floors, where high-density wood fiberboard is currently being used. The hardness of the panels had a profound effect on the bending and tensile strength.

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The authors are grateful for the support of the Ministerio de Economía y Competitividad of Spain (MINECO) through the project ref. BIA 2009-11605.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Originalni znanstveni rad
Original scientific paper

STRUCTURAL CHANGES OF THE CORN STARCH FROM ROMANIA USED TO MAKE BIODEGRADABLE PACKAGING

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SUMMARY

The effect of the components proportion and the effect of heat in the recipes used in order to obtain biodegradable corn starch-based packing made by thermoplastic extrusion of indigenous starch, with an amylose content of 21%, where pursued both at the macroscopic scale by rheometry, and trough microscopic methods, which provides information on atomic and molecular level. The components proportion affects the interconnection process of the polymeric chains and thus the viscosity and elastic behavior.

At a given concentration, depending on heat treatment or exposure to plasticizers, the stability of the temporary junctions between polymeric chains may be affected, with consequences on the viscoelastic behavior

Any dynamic effect on the molecular scale, determined by the action of recipe components proportion, and thermal processes leads to changes of the interconnection process of the polymeric chains and of the local conformation of the macromolecules.

All these structural changes were analyzed by the NMR, FT-IR and rheological measurements, which provide some subtle information on molecular level.

Key words: *corn starch, structural changes, biodegradable packaging*

INTRODUCTION

The use of polymers from renewable resources to manufacture plastics, including packaging materials, have attracted, over the last years, the attention of researchers and investors, due to both disastrous effects of the manufacturing and recovery after use of the synthetic plastics on the environment and the increase awareness regarding of the drastic reduction of world oil reserves.

Starch has advantages such as low cost, wide availability, and total compostability without toxic residues, though there are also issues on the availability of agricultural surfaces to make plants at world scale (Xie F., 2012) .

In Romania, there are processing capacities of over 20,000 tons/year starch and the raw materials used are corn and potatoes.

The starch granule is a very complex structure which have been discussed and reviewed

by many authors (Jane J. 2006, Tester R. F. 2004). It is a heterogeneous material: chemically, it contains both linear (amylose) and branched (amylopectin) structures; physically, it has both amorphous and crystalline regions (Liu H., 2006). In principle, the amorphous regions are determinate by amylose and branching points of amylopectin, while crystalline component by the short-branched chains from amylopectin.

From a technological perspective, by using conventional processing techniques such as extrusion, native granular starch (also known as raw starch) can be converted into a molten state with the presence of low content of plasticizers such as water and glycerol.

The researches carried out worldwide, in the current scientific context, highlight the fact that processing natural polymers, particularly the starch, is much more complicated and harder to control than the synthetic polymers because that involves many physical changes and chemical reactions such as water diffusion, granular expansion, gelatinization, decomposition, melting and crystallization (Liu H., 2009).

The structure of starch can be described in terms of physicochemical properties of the constituent molecules, compositional variation, interactions at the molecular level associations of molecular interactions (architecture) and the macro level of the whole granule itself.

Nuclear magnetic resonance (NMR), especially nuclear magnetic relaxation method, FTIR spectroscopy and rheology are the powerful methods for studying both synthetic and natural polymers. It is widely used for determination of morphology, compatibility, chain conformation and dynamics of polymers and polymer systems (Todica M. 2005, Kulagina T.P. 2011, Capek P. 2010, Xie F. 2009).

The paper presents our structural investigations in order to obtain biodegradable corn starch-based packing made by thermoplastic extrusion of indigenous starch, with an amylose content of 21%.

METHODS

The normal corn starch (21 % amylose content), manufactured by SC Amylon Sibiu, Romania, having a water content of 10.76 % (wt. b), particle sizes between 2.3 and 37.3 μm and a density of 0.561 g/cm^3 was mixed with glycerol with a concentration of 99.5% and a density of 1.262 g/cm3 and water in different ratios. For homogenization, the components were thoroughly mixed and stored in sealed containers for 24 hours before performing the tests.

The ^{1}H NMR data were recorded using the Bruker Minispec spectrometer with the 10 mm probe-head working at 19.688 MHz Larmor frequency. For spin-lattice relaxation times T_1 measurements 10 pulses were used for the magnetization saturation with a decremented inter-pulse time. The re-magnetization time was increases in 72 unequal steps with a 1.1 multiplication factor up to 956 ms. In all measurements the temperature was set to 35 ^{o}C. Finally, in order to find the T_1 times distributions, the CPMG decays and saturation recovery curves were analyzed using the UPIN algorithm, which perform a Laplace inversion of the measured data (Borgia G. C. 1998).

The FT-IR/ATR spectra were recorded at room temperature on a conventional Equinox 55 (Bruker, Germany) spectrometer equipped with a DTGC detector, coupled with an ATR sampling device (Miracle, Pike Techn.). The resolution was of 2 cm^{-1}.

Rheometry measurements were performed for mixture of starch/glycerol/water with the ratio of 2/1/1. It was used a Brookfield centrifugal viscometer, type DV-II+PRO, over a range of share rates between 0 and 3,66 s^{-1}, at temperatures between 40 and 70 ^{0}C.

RESULTS AND DISCUSSION

The spin-lattice relaxation time T1, with a specific NMR time of the order of one second, can edit any characteristics of starch structure, i.e. the morphology or degree of crystallization. Fig. 1a presents the normalized saturation recovery build-up curves for pure starch and starch with, with glycerol and with water and glycerol. The build-up curves specific to pure starch and mixture of starch and glycerol are similar. In contrast, the presence of additional water content produces observable changes in the measured saturation recovery build-up curves. A quantitative interpretation can be given using the corresponding T_1 distribution curves presented in Fig. 1b. The semi-crystalline nature of the native starch (Jane J. 2006) can be observed from the bi-modal distribution shown with continuous line in Fig. 1b.

Four our sample which contain 10.76 % initial water the crystalline phase was estimated at about 7.2 %. By addition of 15 % of water the sample become 100 % amorphous characterized by a single narrow peak (see the dashed dark gray line in Fig. 1b) located at ~ 105 ms. The addition of 20 % glycerol leads to the destruction of crystalline phase with 88.1 % less amorphous phase (see the peak located at ~60 ms) and 11.9 % extremely mobile phase (see the peak located at ~173 ms). The presence of a significant water content to the mixture of starch, glycerol and water leads to a more homogeneous amorphous phase of the mixture (see the narrow peak located at ~ 112 ms). In conclusion, 15 to 20 % content of water and/or glycerol cal lead to significant changes in the T_1 distributions associated with the starch amylose/amylopectin microstructure and morphology. In the following we are interested into the changes produced by small increased in the glycerol or water content for mixtures which contain all three components.

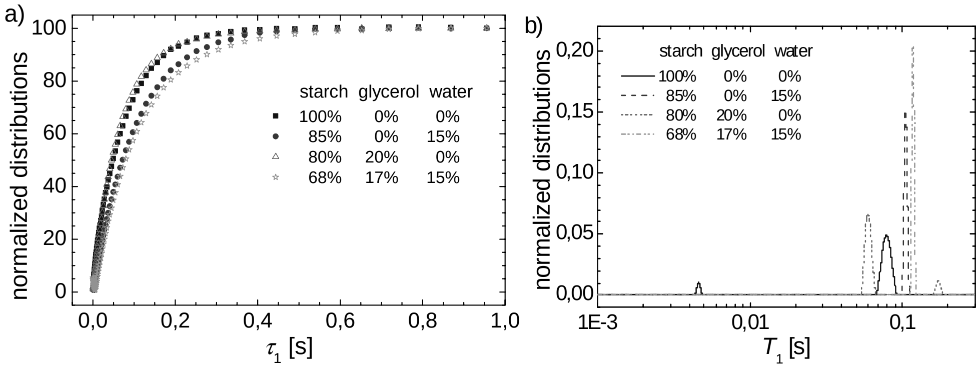

Fig. 1 Normalized build-up curves of magnetization recovery after saturation for starch with different content of glycerol and water plasticizers (a) and the spin-lattice relaxation times T_1 distributions (b) obtained by Laplace inversion of (a) – CPMG curves

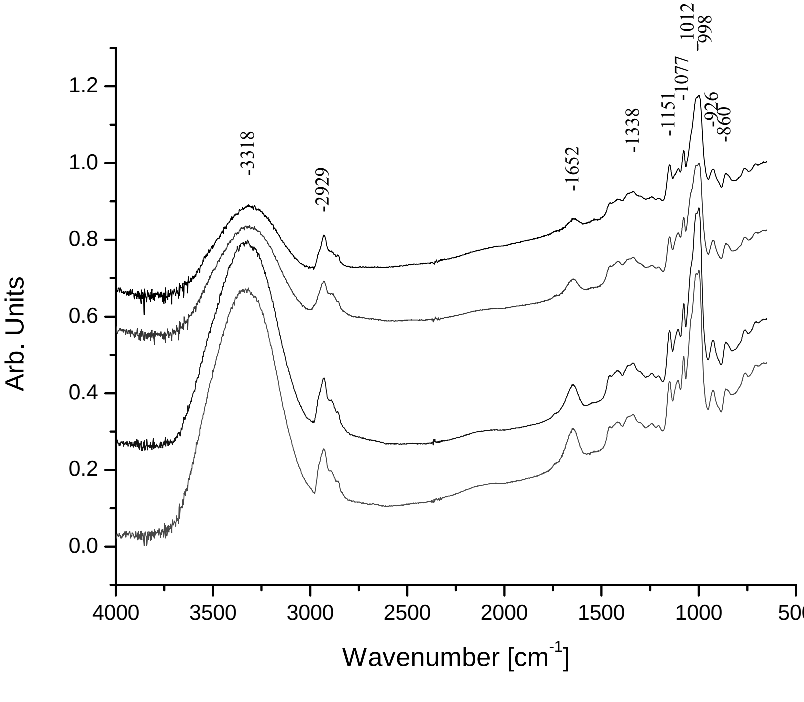

Fig. 2 IR spectra of starch samples with different amounts of water and glycerol

Fig. 2 shows the characteristic IR spectra of pure starch and starch with water, with glycerol and with water and glycerol. The representative bands are situated in the following five regions: 3300 cm^{-1}, 2900 cm^{-1}, 1610 cm^{-1}, 1300 cm^{-1} and 1000 cm^{-1}. The two bands at 3300 cm^{-1} and 1610 cm^{-1} are ascribed to water stretching and bending vibrations (Morales A.F. 2012, Iizuka K. 1999)). The other three absorptions are originated mainly from the vibrational modes of the amylose and amylopectin, the principal components of starch (Morales A.F. 2012).

The two absorption bands from at 2930 cm^{-1} and 2850 cm^{-1} are assigned to vibrations of CH_2 groups (Liu H., 2006). The absorptions from 1350 cm^{-1} region are due to bending modes of O-C-H, C-C-H and C-O-H angles from amylose and amylopectin formations (Bellon–Maurel V. 1995).

The strong absorption peaks, appeared in the 1150 – 900 cm^{-1} region, are assigned to C-C and C-O stretching vibrations. The bands at 1000 cm^{-1} and 850 cm^{-1} are sensitive to the changes in crystallinity and the intensity of 1000 cm^{-1} band determines the orientation in intermolecular H – bonding of CH and CH2 in CH2OH (Morales A.F. 2012, Kacurakova M. 1996).

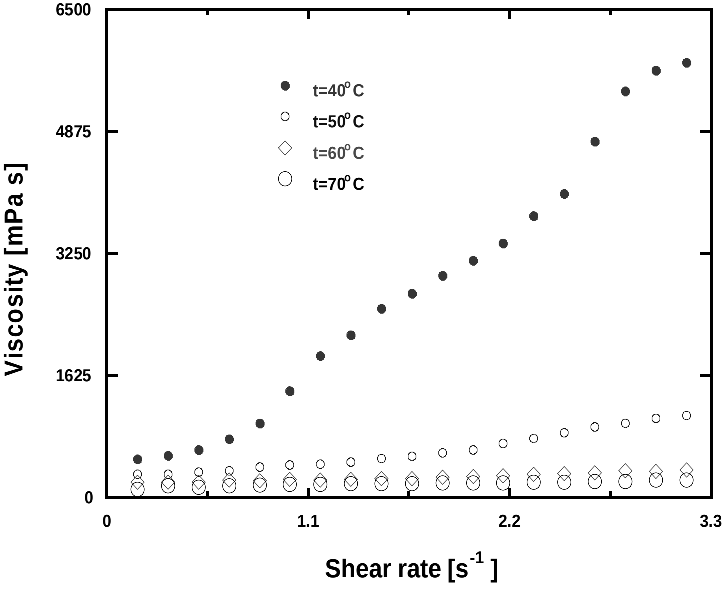

Fig. 3 Dependence of viscosity on shear rate, at different temperatures, for mixture of starch/glycerol/water ratio of 2/1/1

It can be seen that the main intensity variations of the absorption bands with the content and ratio of the added plasticizers appear in the 1000 cm^{-1} region. These changes may be related with the quantities and crystalline – amorphous ratio of the corn starch in the investigated samples. In principle, the amorphous regions are determinate by amylose and branching points of amylopectin, while crystalline component by the short-branched chains from amylopectin.

On the other hand very little changes appear in the 2930 – 2850 cm^{-1} and 1350 cm^{-1} region bands with the modifications of the plasticizers content in the starch sample.

The reological measurements for mixture starch/gycerol/water, show that at low temperatures (t = 40 °C) there is a dependence of viscosity (η) function of shear rate ($\dot{\gamma}$) which does not comply with the Newtonian model.

It can be seen (Fig. 2) that if the temperature increases (t = 50 0C), the viscosity further has a non-newtonian dependence of share rate, but its values decrease. If the temperature increases further (t = 60, 70 ^{0}C), this dependence tends to linearity.

The shear stress (σ) also presents a nonlinear dependence which in the first approximation can be strength type, $\sigma = \eta \cdot (\dot{\gamma})^n$, Fig. 4 (Todica M. 2005).

These different behaviors can be explained by different thickness of the layer of glycerol with water, adherent to the starch particles. At low temperatures, where this layer is thicker, the starch forms large conglomerates, rather rigid, far from Newtonian spherical molecular model. At higher temperatures it is possible that starch particles to remain in the same structural form, so the same size, but the plasticizers layer adherent to these to be thinner, and therefore the conglomerates become smaller and more mobile, closer to the Newtonian model.

CONCLUSIONS

The ^{1}H NMR relaxometry, FTIR spectroscopy and rheological measurements was proved to be a suitable tool for the investigation of change of corn starch structure in the presence of water and glycerol plasticizers.

The T_1 distributions show an oscillatory behavior of the degree of crystallinity function of glycerol content and a linear behavior function of water content.

The main intensity variations of the FTIR absorbtion bands with the content and ratio of the added plasticizers that appear in the 1000 cm^{-1} region, may by related with crystalline – amorphous forms of the corn starch in the investigated samples.

The different rheological behaviors of starch in the presence of water and glycerol at low and high temperatures can be explained by different thickness, in the two situations, of the layer of glycerol with water, adherent to the starch particles.

ACKNOWLEDGEMENTS

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 628.4.043
Prethodno priopćenje
Preliminary communication

MECHANICAL PROPERTIES OF PROFILES FROM RECYCLED AGRICULTURAL PLASTIC WASTE MIXED WITH WOOD POWDER

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SUMMARY

In recent years the concern about plastic waste from agriculture has raised significantly. A growing social and political awareness on environmental issues has led to laws and regulations aimed at controlling and reducing waste production, encouraging recycling and reuse as well.

The mechanical recycling of polymers determines a loss of some of their original chemical, physical and mechanical properties due to the role played by some of the degradation factors (UV radiation, thermal stress, agrochemicals etc.) that they were subjected to during their working life. The properties of the regenerated material can however be improved through the addition in the plastic mixture of other material, such as wood, glass, calcium etc.

In this paper, the properties of plastic profiles obtained through mechanical recycling of agricultural plastic material mixed with wood powder (70% LDPE + 30% wood powder) were analyzed. The results of the tensile, compression and bending tests here reported show that the mixture of recycled plastic from agricultural application with a suitable different material could be considered as an interesting option for the improvement of the mechanical characteristics of these new regenerated products.

Key words: *agricultural plastic waste, plastic bars, wood powder, mechanical properties*

INTRODUCTION

Current intensive and semi-intensive agricultural practices used throughout Mediterranean Countries require the use of large quantities of plastics, 615000 tons in 2004 (Briassoulis and Dejean, 2010), due to the benefit resulting in increased yield, earlier harvest, less reliance on herbicides and pesticides and less water consumption (Djevic and Dimitrijevic, 2009; Briassoulis, 2005).

In recent years the concern about plastic waste has raised significantly (Lopez et al 2007). Parallel to this, there has been a growing social and political awareness of environmental issues that has led to the passing of laws and regulations of all kinds in an attempt to control and reduce waste production, and to encourage recycling and reuse.

Recycling of plastic waste is not new (La Mantia et al, 1996). The first industrial applications in Japan date from 1973. It is well known that it is possible to manufacture rods, stakes, bars, boards, plates, etc. from mixed plastics waste but the mechanical properties of these products are worse since there are some factors having a negative influence on the quality of this “secondary raw material”, when the polymers are reprocessed, so some of their chemical, physical and mechanical properties can worsen (Scarascia-Mugnozza et al, 2006; Sica, 2000).

The mechanical properties of the recycled material may be also influenced by the presence of other factors, such as additives. For example the addition of starch to LDPE blends increases the tensile strength and the elongation at break and reduces the Melt Flow Index values (Pedroso et al, 2004). One of the possibilities to improve the properties of plastic products is using diverse fillers like talc, calcium carbonate, HDPE, densified PE (Sica et al, 2008; Scarascia-Mugnozza et al, 2010).

Previous research on some recycled PP composites with two types of wood fibres regarding their mechanical and dynamic properties carried by Liber-Knec et al (2006) showed that elasticity modulus of investigated composites improved considerably, while strength remained more or less constant, showing rather a marginal decrease. Elongation at break decreased significantly after adding wood fibres. Also modulus of elasticity was affected, which was about 15 % higher for PP composite with wood fibre BK 40/90.

In this paper, the properties of plastic profiles obtained through mechanical recycling of agricultural plastic material mixed with wood powder (70% LDPE + 30% wood powder) were analyzed.

MATERIAL AND METHOD

Recycled manufactured products were obtained through the mechanical recycling of agricultural plastic films previously used for three years as covering tunnel-greenhouses in a farm located near Lecce (Southern Italy). The plastic recycled bars were produced by an Italian manufacturer for the stockpiling, selection and mechanical recycling of heterogeneous plastic wastes (Alfa Edile, Brindisi). After the collection and transportation to the recycling factory, the plastic films were granulated, melted at about 220 °C and introduced into the extruder to produce 1.5 m long square section bars with the average side equal to 49.4 mm.

Ten recycled bars obtained exclusively from regenerated granule of Agricultural Plastic Waste (APW) were realized in order to compare them with ten recycled bars obtained from 70% of regenerated granules of APW and 30% of wood powder.

The mechanical properties of these bars were analyzed in the Laboratory for Testing Material of the University of Basilicata (Potenza), by using a computerised universal press machine Galdabini PMA 10 type. The environmental conditions during the trial were: mean room temperature 20 °C, mean relative humidity 70%. From the recycled bars, specimens were obtained according the following dimensions:

Tensile test: strip-specimen, length 190 mm, width 49.4 mm, thickness 5.85 mm;

Compression test: cubic-specimen obtained directly by cutting the bars, side = 49.4 mm;

Bending test: bar-specimen, section 49.4 mm x 49.4 mm, span length 1,100 mm.

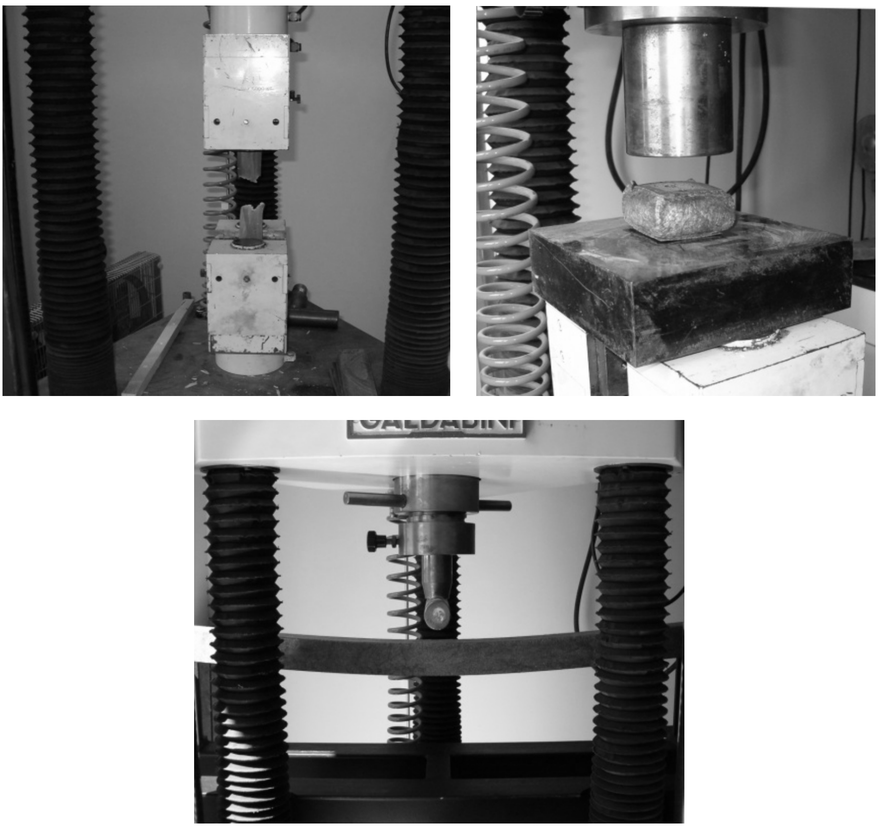

Figure 1 Tensile, compression and bending tests on the regenerated agricultural plastic waste specimens

Tensile tests were performed, according to the Italian UNI 8422 Standard (UNI, 1982), with a length between vices of 70 mm, at a constant deformation speed equal to 10 mm min^{-1}. Compression tests were performed at a constant deformation speed equal to 10 mm min^{-1}. Bending tests were performed at a strain constant speed of 70 mm min^{-1} according with the Italian Standard UNI 7219-73 (UNI, 1972), through the application of a load in the mid-span of a free length of 1.00 m between the supports.

RESULTS AND DISCUSSION

The results obtained during the tensile test (Tab. 1) show that APW has a similar maximal resistance compared to the mixture of the APW and wood powder while the situation observed for the material behavior at the end of the elastic phase is different.

Table 1 Results of the tensile tests of the regenerated plastic materials

	APW	APW + wood powder
σ_e [N mm^{-2}]	6.42	8.87
E [N mm^{-2}]	111.38	557.26
A_e (%)	5.85	0.008
ν	0.46	0.44
G	104.86	496.68
σ_{max} [N mm^{-2}]	10.04	10.44
A_b (%)	374.07	8.70

It can be seen that adding of wood powder caused a significantly lower elongation at break A_b (Fig. 2, Tab. 1) causing the new recycled material to be more brittle.

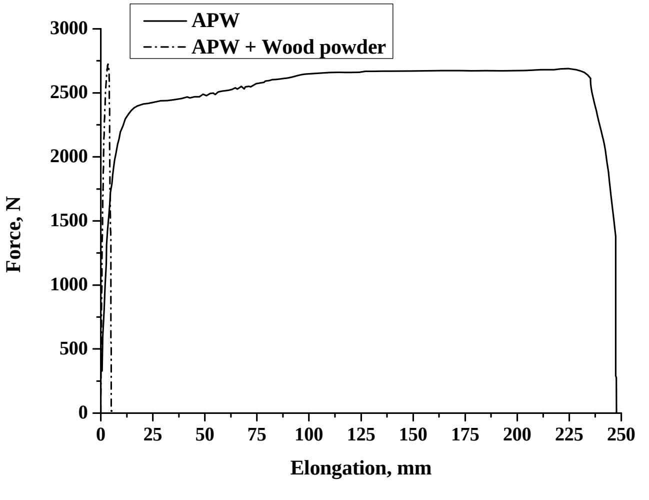

Figure 2 Force-elongation diagram of tensile tests

The analysis of the Young modulus (E) from the tensile tests (Tab. 1) showed that the recycled mixture of APW has lower values compared to its mixture with wood powder, leading to the conclusion that the adding of wood powder made this mixture much rigid compared to the APW mixture.

Conclusions about the rigidity of the mixture of APW and wood powder can be further confirmed if elongation at break for the tensile testing is analyzed. In the elastic phase the elongation of the mixture of APW and wood powder was only 0.008% while the elongation at break was 8.7%, which is significantly lower compared to the APW characteristic.

APW showed the higher value of the Poisson's ratio, that leads to the conclusion that this material is more extendible compared to the mixture of APW and wood powder. For most of metals and many other materials, values for the Poisson's ratio have a range from 0.25 – 0.35. The theoretical upper limit is 0.5 and it is characteristic for rubber.

When compression test is analyzed it can be seen (Tab. 2) that recycled mixture of the APW and wood powder showed higher strength at the end of the elastic phase. As for the area of plastic deformation before breaking of the material, none of the samples was broken under the given load of 55000 N (Fig. 3) and both materials had maximal strength equal to 20.00 N mm^{-2}.

Table 2 Results of the compression and bending tests on the regenerated plastic materials

Test	Parameter	APW	APW + wood powder
Compression	σ_e [N mm^{-2}]	4.28	8.35
	E [N mm^{-2}]	127.45	225.82
	σ_{max} [N mm^{-2}]	>20.00	>20.00
Bending	σ_e [N mm^{-2}]	1.90	3.81
	E [N mm^{-2}]	305.67	772.32
	σ_{max} [N mm^{-2}]	6.13	10.06

The analysis of the Young modulus (E) from the compression tests (Tab. 2) showed that recycled mixture of APW has lower values compared to its mixture with wood powder, leading again to the conclusion that the adding of wood powder made this mixture much rigid compared to the APW mixture in conditions of compression too.

The bending tests that were conducted showed that the recycled mixture of APW and wood powder has higher resistance at the end of the elastic phase, compared with the recycled APW material (Tab. 2, Fig. 4). During the bending tests APW materials showed so high elasticity that the maximum travel stroke of the testing machine (equal to 170 mm) was not enough to cause the breaking of the specimens. On the contrary, APW added with wood powder showed a higher resistance and a limited elasticity, so that three bars were finally broken.

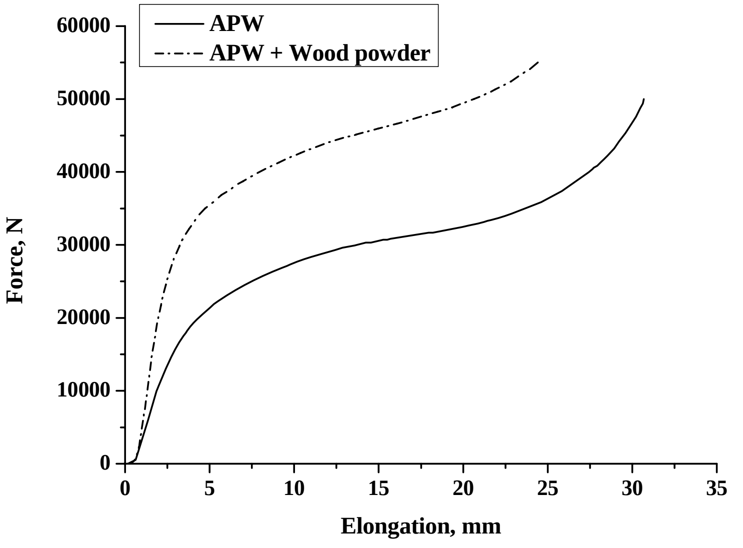

Figure 3 Force-elongation diagram of compression tests

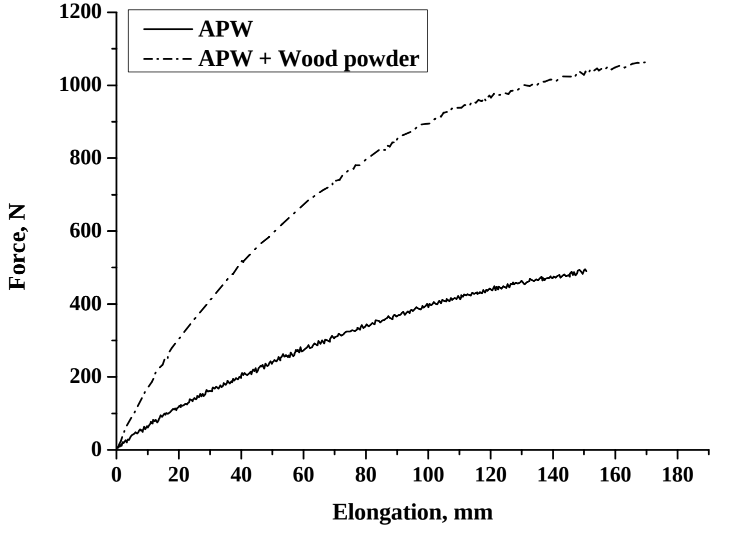

Figure 4 Force-elongation diagram of bending tests

The values of the Young modulus obtained by the bending tests show a significantly higher value in the case of mixture of APW and wood powder, so confirming that this mixture is more rigid.

CONCLUSIONS

In this research adding of wood powder into the APW and recycling such material was analyzed in the sense on how does this mixture behave in conditions of tensile, compression and bending stress. The recycled APW showed good tensile and compression characteristics. The addition of the wood powder, in terms of tensile stress, has lowered the APW elasticity causing the new recycled material to be more brittle. Concerning the compression test recycled mixture of the APW and wood powder showed higher strength at the end of the elastic phase. In conditions of bending stress mixture of APW and wood powder showed itself as more rigid. It can be concluded that the mixture of APW and wood powder in ratio 70% and 30% causes new material to be more brittle and sensitive to tensile and compression loads. Other possibility to improve the mechanical properties of the recycled APW is to investigate using some other additives or the same with different percentages in order to improve further the properties of the “secondary raw material”.

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41. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.16:634.11
Prethodno priopćenje
Preliminary communication

EKONOMSKI REZULTATI U PROIZVODNJI JABUKA UZ KORIŠTENJE SREDSTAVA IPARD PROGRAMA

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SAŽETAK

U radu se istražuje ekonomska opravdanost proizvodnje jabuke bez i sa korištenim sredstvima iz IPARD programa. Autori polaze od tri scenarija kod podizanja nasada. U prvom scenariju se ne predviđaju sredstva iz IPARD programa, u drugom scenariju su IPARD sredstva u iznosu od 50% investicije i ne pokrivaju trošak zemljišta i traktora te u trećem scenariju isti iznos IPARD sredstava koja ne uključuju trošak zemljišta. U radu je korišten model kalkulacije pokrića varijabilnih troškova (Gross margin). U razdoblju pune rodnosti pri proizvodnji od 40.000 kg/ha i prosječnoj otkupnoj cijeni jabuka od 2,91 kn u prvom scenariju se ostvaruje gubitak odnosno posluje se ispod praga rentabilnosti. Najbolji rezultat se ostvaruje u trećem scenariju kada je prag rentabilnosti kod 2,77 kn/kg. Dobiveni rezultati ukazuju na važnost korištenja IPARD sredstava u proizvodnji jabuka.

***Ključne riječi**: jabuka, proizvodnja, ekonomski rezultati, IPARD program*

UVOD

Jabuka zauzima treće mjesto u ukupnoj svjetskoj proizvodnji voća, odmah iza banana i grožđa. Najvažnija je voćna vrsta i u Hrvatskoj jer zauzima 22% ukupnih površina pod voćem te daje 36% ukupne vrijednosti voćarske proizvodnje. Do devedesetih godina prošlog stoljeća većina proizvodnje jabuka se odvijala u velikim državnim poduzećima, a nakon toga povećanje proizvodnje bilježimo na obiteljskim poljoprivrednim gospodarstvima.

Današnja proizvodnja jabuka u Hrvatskoj ne zadovoljava domaću potražnju. Zbog toga značajan dio domaće potrošnje se namiruje iz uvoza, pri čemu se često uvozi jabuka niske kakvoće čime se stvara nelojalna konkurencija domaćoj proizvodnji (Grgić i sur. 2012).

Značajan problem je i paralelno tzv. sivo domaće tržište jabuka čemu pogoduje nedovoljno razvijena zakonska regulativa.

Ulaskom Hrvatske u Europsku uniju povećat će se konkurencija na domaćem tržištu što će dovesti do porasta ponude i očekivanog smanjenja cijena jabuka. Prema ekspertnim procjenama, s obzirom na obilježja današnje proizvodnje, tek polovica hrvatskih voćara je sposobna opstati na tržištu, a veća šansa je jedino kroz modernizaciju proizvodnje i bolju međusobnu povezanost proizvođača pri nabavi repromaterijala i prodaji samih proizvoda (stvaranje zadruga, klastera i sl.). Takvi proizvođači će moći sa svojim suvremenim nasadima, sortimentom i primijenjenom tehnologijom biti cjenovno i kvalitetom konkurentni uvoznoj jabuci (Cerjak i sur. 2011).

Podizanje novih suvremenih nasada jabuka otežano je relativno visokim početnim ulaganjima što u vrijeme oskudnih i skupih komercijalnih kreditnih plasmana stvara značajne probleme proizvođačima. Stoga veliki broj proizvođača okrenuo se financiranju putem HBOR-ovih kreditnih linija, a dodatna sjajna mogućnost je korištenje predpristupnih fondova Europske unije danas, odnosno fondova nakon ulaska Hrvatske u Uniju. Kod korištenja predpristupnih fondova značaj problem je tromi sustav domaće administracije (Obad 2012). Predpristupni fondovi osim izravne koristi služe i uvježbavanju poslovne discipline i suradnje po uzoru na europske standarde (Franić i sur. 2007).

MATERIJAL I METODE

Ekonomski rezultati u proizvodnji jabuka istražuju se za tri scenarija.

Prvi scenarij predviđa investiciju u podizanje nasada jabuka bez korištenja sredstava iz IPARD programa. *Drugi scenarij* se temelji na korištenju IPARD sredstava od 50% investicije bez uključenosti troška zemljišta i traktora. *Treći scenarij* također predviđa korištenje sredstava iz IPARD programa od 50% investicije bez uključenosti troška zemljišta.

U radu se za utvrđivanje ekonomskih pokazatelja u proizvodnji jabuka koristi model kalkulacija pokrića varijabilnih troškova; PVT (*engl. Gross margin, njem. Deckungs Beitrag*) koji je podloga za izračune Točke pokrića 1, 2, 3 te Praga rentabilnosti. Ovaj model je primjenjiv jedino ukoliko se proizvodnja ostvaruje punim kapacitetom čemu prethodi investicijsko razdoblje koje kod jabuka traje oko pet godina.

Točka pokrića 1 predstavlja prosječnu cijenu proizvoda koju proizvođač mora ostvariti kako bi pokrio varijabilne troškove proizvodnje i trošak obrtnih sredstava. Ukoliko je tržišna cijena niža od točke pokriće 1, *proizvođač bi odmah trebao prestati sa proizvodnjom.*

Točka pokrića 2 predstavlja prosječnu cijenu proizvoda koja se mora ostvariti kako bi se pokrili varijabilni troškovi proizvodnje, trošak obrtnih sredstava i trošak rada. Ukoliko je tržišna cijena niža od točke pokriće 2, *proizvođač bi trebao prestati sa proizvodnjom u kratkom roku* jer nisu pokriveni troškovi zemljišta niti rada u cijelosti.

Točka pokrića 3 predstavlja prosječnu cijenu proizvoda koja se mora ostvariti kako bi se pokrili varijabilni troškovi proizvodnje, trošak obrtnih sredstava, trošak rada i trošak zemljišta. Ukoliko je tržišna cijena niža od točke pokriće 3, *sa proizvodnjom bi trebalo* *prestati u srednjem roku* jer nisu pokriveni svi varijabilni troškovni, odnosno troškovi zemljišta.

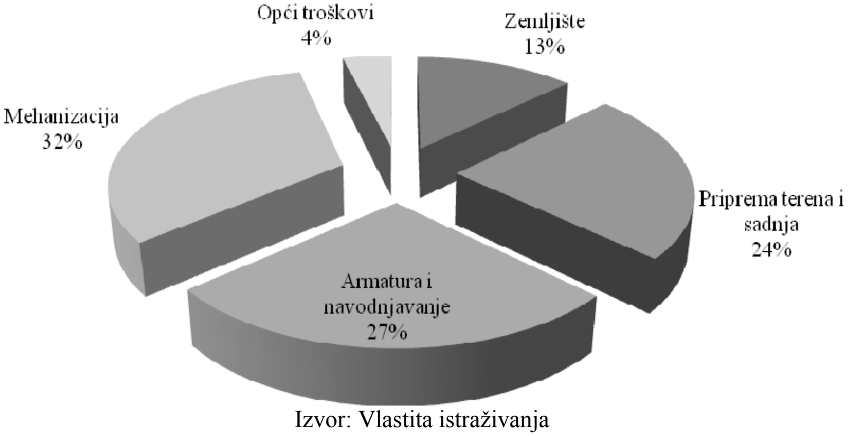
Prag rentabilnosti predstavlja prosječnu cijenu proizvoda koja bi pokrila ukupne troškove proizvodnje (varijabilne troškove proizvodnje, trošak obrtnih sredstava, troškove rada, trošak zemljišta i fiksne troškove). Proizvođač mora biti iznad ovoga praga kako bi pokrio sve troškove proizvodnje te generirao dobit i akumulaciju za investicije po otpisu osnovnih sredstava. *Ukoliko je tržišna cijena niža od praga rentabilnosti, dugoročno bi trebalo prestati sa proizvodnjom* budući da se ne ostvaruje profit.

REZULTATI I DISKUSIJA

Glavna proizvodna područja za uzgoj jabuka u Hrvatskoj su gornje Međimurje, Hrvatsko Zagorje, gornja Podravina, Prigorje, Žumberak, Moslavina, južni obronci Bilogore, zapadna i srednja Slavonija, osobito obronci Papuka, Psunja, Požeške gore, Krndije i Dilja, zatim brežuljkasti dio slavonske Podravine i slavonske Posavine te dio Korduna i Banije.

Povoljni agroekološki uvjeti i tradicija voćarske proizvodnje u Hrvatskoj omogućuju komercijalnu proizvodnju jabuka koja može osigurati zadovoljavajuću razinu dohotka i upošljavanje članova obiteljskog gospodarstva (Njavro i sur. 2006).

Pred proizvođačima jabuka je mnogo izazova. Buduća proizvodnja jabuka mora se temeljiti na znanju, biti održiva (ekološki učinkovita) i mora ponuditi potrošaču usmjeren zdrav proizvod (Čmelik 2012). Novi nasadi jabuka u Hrvatskoj, koji bi zadovoljili suvremene tehnološke uvjete i bili ekonomski prihvatljivi, su nasadi površine od minimalno 5 do 10 ha. Ovo je posebno bitno zbog skupe mehanizacije jer proizvodnja na manjim površina cjenovno nije konkurentna na sve otvorenijem hrvatskom tržištu (Grgić i sur. 2009). Jedna od mogućnosti je skupna nabava zajedničkih strojeva i opreme odnosno stvaranje strojnih prstenova ili nabava mehanizacije i opreme uz potporu. Izbor tehnologije uzgoja znatno određuje rentabilnost proizvodnje (Grgić i sur. 2007).



Izvor: Vlastita istraživanja

Grafikon 1 Struktura troškova podizanja nasada jabuka

Analizirani voćnjak nalazi se u kontinentalnoj Hrvatsko, površine 10 ha, razmaka sadnje 3,5x1,0 m odnosno 2.700 stabala/ha, uzgojnog oblika vitko vreteno, na podlozi M9, sorata Idared, Jonagold, Zlatni Delišes, a pretpostavljeni rok eksploatacije je 20 godina. Predviđeno je da se 80% investicije financira kreditom kamatne stope od 6%.

Troškovi podizanja nasada jabuka iznose 325.500 kn/ha. Preko trećine troškova (32%) su troškovi mehanizacije, nešto manje (27%) čine troškovi armature i sustava navodnjavanja te pripreme terena i sadnje (24%). Troškovi zemljišta, u pretpostavci kupnje, su 13% ukupnih troškova te opći troškovi iznose 4% troškova ukupne investicije[1].

Predviđena osnovna mehanizacija se sastoji od traktora srednje snage, atomizera i pratećih nastavaka za traktor za obradu tla, ali poželjna je i dodatna mehanizacija/oprema kao što su deponator za mineralna gnojiva, viličar za manipulaciju boks paleta, prikolica, kombi i/ili kamion za dostavu, električne škare za rezidbu, roto-freza sa bočnim pomakom, itd. što u konačnici povećava ukupna prosječna ulaganja.

Mnoštvo je rizika u proizvodnji jabuka. Proizvodnja se odvija na otvorenom te je potrebno navodnjavanje i podizanje protugradne mreže. Znatan problem su i visoki varijabilni troškovi zbog malih razjedinjenih proizvođača koji kupuju vrlo male količine inputa po visokim cijenama. Razjedinjenost proizvođača problem je i kod neizgrađenog sustava skladištenja (manji broj proizvođača posjeduje moderne ULO hladnjače) jer im je investicija u hladnjaču prevelika s obzirom na proizvedenu količinu jabuke.

Godišnji troškovi proizvodnje jabuka pri punoj rodnosti su različiti s obzirom na scenarijska rješenja. U Prvom scenariju ukupni troškovi su 119.836 kn/ha, u Drugom 113.464 te u Trećem scenariju 112.984 kn/ha. Smanjenje troškova je zbog smanjenja troškova kapitala odnosno zbog većeg udjela sredstava iz IPARD programa.

U ukupnim troškovima proizvodnje varijabilni troškovi su 84.762 kn i predstavljaju od 70,7% do 75%. U varijabilnim troškovima najveći dio je trošak rada (61,9%)[2], zatim trošak proizvodnje (31,9%)[3] te znatno manje trošak obrtnih sredstava (3,4%)[4] i trošak zemljišta (2,8%)[5].

Fiksni troškovi proizvodnje su najviši u Prvom (35.074 kn/ha ili 29,3% ukupnih troškova) a najmanji u Trećem scenariju (28.222 kn odnosno 23,6%). U fiksnim troškovima najznačajnija je amortizacija (18.950 kn/ha)[6] te trošak kapitala koji je različit s obzirom na scenarije (od 15.624 kn u Prvom scenariju do 8.772 kn u Trećem).

Puna rodnost predviđa proizvodnju od 40.00 kg/ha. Najveći dio proizvodnje je prve klase (65%), 20% je druge klase te 15% je industrijska jabuka. Uz prosječnu prodajnu

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[1] U situaciji podizanja nasada većih površina, troškovi mehanizacije i opći troškovi bili bi apsolutno i relativno niži nego u ovoj kalkulaciji.

[2] U trošak rada ulazi trošak berbe (35 kn/h), trošak rezidbe (40 kn/h) te plaće voditelja voćnjaka i jednog stručnog suradnika

[3] Troškovi proizvodnje su troškovi sredstva za zaštitu bilja, gnojiva, ostalog potrošnog materijala te varijabilni troškovi mehanizacije.

[4] Trošak obrtnih predstavlja 6% kamate na 60% varijabilnih troškova tj. troškova rada i troškova proizvodnje.

[5] Trošak zemljišta obračunat je kao 6% kamata na kupovnu cijenu.

[6] Amortizaciono razdoblje za nasad je 20 godina, a za mehanizaciju i opremu 10 godina.

cijenu od 2,91 kn predviđa se prihod od 116.200 kn/ha. Uz potporu[7] od 2.055 kn/ha ukupan prihod je 118.255 kn/ha.

Tablica 1 Ekonomski račun u proizvodnji jabuke u punoj rodnosti-scenarijski rezultati

Prihodi proizvodnje		Scenarij I	Scenarij II	Scenarij III
Količina jabuka	kg	40.000	40.000	40.000
Prva klasa	%	65	65	65
Druga klasa	%	20	20	20
Industrijska jabuka	%	15	15	15
Prodajna cijena prva klasa	%	3,50	3,50	3,50
Prodajna cijena druga klasa	kn/kg	3,25	3,25	3,25
Prodajna cijena industrijska	kn/kg	1,20	1,20	1,20
Prosječna prodajna cijena	kn/kg	2,91	2,91	2,91
Ukupno prihod jabuka	kn	116.200	116.200	116.200
Prihodi potpora				
Potpora za zemljište	kn	2.055	2.055	2.055
UKUPNI PRIHOD	kn	118.255	118.255	118.255
1. Varijabilni troškovi	kn	84.762	84.762	84.762
1.1. Troškovi proizvodnje	kn	27.000	27.000	27.000
1.2. Trošak obrtnih sredstava	kn	2.862	2.862	2.862
1.3. Trošak rada	kn	52.500	52.500	52.500
1.4. Trošak zemljišta	kn	2.400	2.400	2.400
2. Fiksni troškovi	kn	35.074	28.702	28.222
2.1. Amortizacija	kn	18.950	18.950	18.950
2.2 Trošak kapitala; kamate 6%	kn	15.624	9.252	8.772
2.3. Ostali troškovi	kn	500	500	500
UKUPNI RASHOD	kn	119.836	113.464	112.984
FINANCIJSKI REZULTAT				
Bruto dobit/gubitak	kn	-1.581	4.791	5.271
Točka pokrića 1	kn/kg	0,70	0,70	0,70
Točka pokrića 2	kn/kg	2,01	2,01	2,01
Točka pokrića 3	kn/kg	2,07	2,07	2,07
Prag rentabilnosti	kn/kg	2,94	2,79	2,77

Izvor: Vlastita istraživanja

[7] Prema Zakonu o državnoj potpori, poljoprivredi i ruralnom razvoju za svaki ha voćnjaka koji se obrađuje poduzetnik ima pravo na potporu u iznosu do maksimalno 2.055 kn/ha, što je sukladno predviđenom proračunu za 2012. godinu.

Sukladno nastalim troškovima kod podizanja nasada, troškovima proizvodnje i ostvarenom prihodu u pinoj rodnosti postižu se i razni ekonomski rezultati kod pojedinih scenarija. U Prvom scenariju u proizvodnji jabuka se ostvaruje gubitak, dočim u Drugom i Trećem se ostvaruje dobit. Najbolji rezultati poslovanja ostvaruju se u Trećem scenariju.

Povećanje ekonomske efikasnoti u proizvodnji jabuka može se ostvariti na tri načina.

Prvi način je povećanje proizvodnje jabuka čime bi se smanjili prosječni fiksni troškovi po jedinici proizvoda odnosno smanjila cijena koštanja. Ovo je moguće pravovaljanjijom primjenom odgovarajuće agrotehnike i agrotehničkih mjera. Međutim, u normalnim uvjetima rentabilnost raste usporedno s proizvodnjom po jedinici površine do određene granice nakon koje rentabilnost počinje opadati (Grgić i sur. 2007).

Drugi način je smanjenje varijablnih troškova, uz nepromijenjene fiksne troškove, što bi također utjecalo na smanjenje prosječne cijene koštanja.

Treći način je postizanje više prosječne prodajne cijene jabuka ali i povećanjem udjela jabuka prve klase, a smanjenjem udjela druge klase i industrijske jabuke. Proizvođači jednim dijelom mogu utjecati na prosječnu otkupnu cijenu jabuke jedino povećanjem njihove kakvoće, ali ipak znatan utjecaj ima tržište odnosno potražnja tj. dohodak potrošača.

Dobiveni rezultati pokazuju da postoji značajan utjecaj korištenja sredstava IPARD programa na ekonomske rezultate u proizvodnji jabuka.

ZAKLJUČAK

Ulazak Hrvatske u Europsku uniju povećati će konkurenciju na domaćem tržištu jabuka. Domaći proizvođači jabuka biti će konkurentni jedino u uvjetima proizvodnje u suvremenim površinski većim nasadima. Investicije u nove nasade su relativno visoke sa dužim rokom povrata što u okolnostima oskudnosti i skupih kredita postaju sve teže ostvarive. Troškovi podizanja nasada jabuka iznose 325.500 kn/ha pri čemu su relativno najveći troškovi mehanizacije (32%) te troškovi armature i navodnjavanja (27%). U vrijeme pune rodnosti troškovi proizvodnje su od 119.836 kn/ha kod Prvog scenarija, 113.464 kn/ha kod Drugog do 112.984 kn/ha kod Trećeg scenarija. U troškovima proizvodnje varijabilni troškovi su znatno iznad fiksnih troškova i iznose od 70,7% do 75% ukupnih troškova. Pri očekivanoj rodnosti od 40.000 kg/ha i prosječnoj prodajnoj cijeni jabuke od 2,91 kn/kg prihod od jabuka je 116.200 kn/ha odnosno 118.255 kn/ha sa uključenom državnom potporom.

Istraživanje je pokazalo da je ulaganje u nove nasade jabuka danas jedino ekonomski opravdano ako se koriste i sredstva iz IPARD programa. U uvjetima korištenja kredita iz drugih izvora proizvodnja jabuka nije ekonomski isplativa. Međutim, podizanje novih nasada jabuka je izgledno s obzirom na očekivano i daljnje postojanje potpore za njihovo podizanje, visoku potražnju za jabukom i vrlo povoljne klimatske prilike u Republici Hrvatskoj za većinu voćarskih kultura.

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ECONOMIC RESULTS IN THE APPLE PRODUCTION WITH IPARD PROGRAM FUND USE

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ABSTRACT

This paper examines the apple production economic feasibility with and without the means of IPARD funds. The authors start from the three plantation rising scenarios. In the first scenario there is no IPARD program funds foresight, in the second scenario the IPARD funds amount 50% of the investment and do not cover the cost of the land and tractors. In the third scenario, the same IPARD funds amount and do not cover the cost of the land. In the paper it was used the calculation model that covers variable costs (Gross margin). The loss is realized and production operates under the profitability threshold during the best fruitfulness production of 40,000 kg/ha and at average purchase price of 2,91 KN in the first scenario. The best result is achieved in the third scenario, when it is achieved gross margin of 2,77 KN/kg. These results indicate the importance of using IPARD funds in apple production.

Key words: *apple, production, economical results, IPARD*