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HIDRAULIČKI SIMBOLI - DEO II: PUMPE I IZVRŠNI ORGANI

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Sažetak: Na sadašnjem nivou tehnološkog razvoja, opšte je prihvaćeno mišljenje da savremena poljoprivredna tehnika, između ostalog, svoj napredak zasniva na širokoj primeni elektronski kontrolisanih hidrauličkih sistema, podržanih mehaničkim elementima prenosa snage i upravljanja. Ovaj rukopis predstavlja logičan nastavak prvog dela rada, pod nazivom „Hidraulički simboli - deo I: opšti simboli i oznake mernih instrumenata i indikatora", posvećenog pripadajućoj tematici. Zato je drugi deo rada posvećen prikazu i opisu hidrauličkih simbola pumpi i različitih tipova izvršnih hidrauličkih organa i to: linearnih, rotacionih i oscilatornih. Takođe su predstavljeni i simboli uređaja kombinovane namene, koji opciono mogu funkcionisati u dva različita radna režima, kao hidrauličke pumpe ili hidraulički motori. Simboli svih grupa hidrauličkih komponenata, koje su u fokusu ovog rada, standardizovani su i definisani ISO industrijskim standardima.

Ključne reči*: hidraulika, sistem, simbol, šema, pumpa, izvršni hidraulički organ*

UVOD

Razvoj savremene poljoprivredne tehnike jasno ukazuje na njenu tesnu vezu sa nizom različitih elektronskih, hidrauličkih, mehaničkih, električnih i termičkih sistema, međusobno spregnutih u funkciji ispunjenja istih ili povezanih sličnih zadataka [5].

[*] Kontakt autor. E-mail adresa: epetrodr@agrif.bg.ac.rs. Rad je proizašao iz aktivnosti projekta *"Unapređenje biotehnoloških postupaka u funkciji racionalnog korišćenja energije, povećanja produktivnosti i kvaliteta poljoprivrednih proizvoda",* broj TR 31051, Ministarstvo prosvete, nauke i tehnološkog razvoja Republike Srbije.

Hidraulika kao tehnička i naučna disciplina svoju primenu nalazi u različitim oblastima poljoprivredne tehnike, među kojima se posebno ističu: prenos snage i upravljanja uljnim hidrauličkim sistemima [5], [6], [13], navodnjavanje [9], [10], zaštita bilja [4], [7], [12].

Dugotrajno i pouzdano funkcionisanje hidrauličkog sistema zahteva pravilan izbor, opterećenje u nominalnim granicama, ispravnost i međusobnu usklađenost svih pripadajućih komponenata. Ipak, čini se da inženjeri i tehničari u većini praktičnih realizacija hidrauličkih sistema posebnu pažnju posvećuju hidrauličnim pumpama i izvršnim organima, oko čijeg upravljanja se u većoj ili manjoj meri angažuju svi ostali elementi hidrauličkog sistema ili podsistema [6].

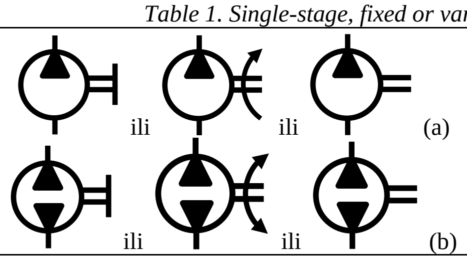
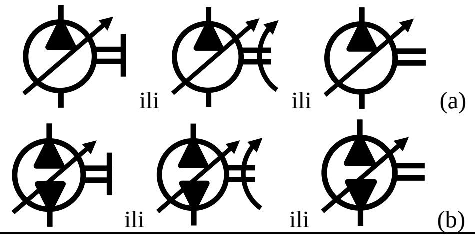
Izuzetno kompleksne konfiguracije hidrauličkih sistema čine veoma nepreglednim njihovo detaljno grafičko predstavljanje, uz istovremeno pružanje dovoljno infromacija o njihovim namenama i funkcionalnim vezama u celosti. Zato se u praksi pristupa pojednostavljenom prikazu hidrauličkih sistema u formi uprošćenih hidrauličkih šema. Tada se, umesto detaljnih tehničkih crteža, komponente prikazuju jednostavnim grafičkim simbolima [11], [13]. Na taj način, moguće je formirati odgovarajuće pojednostavljne hidrauličke funkcionalne šeme originalnih sistema, koje daju mnogo jasniji prikaz pozicija svih komponenata u sistemu, njihovih funkcija i međusobnih veza [13], [14].

U ovom nastavku rada o hidrauličnim oznakama prikazani su najvažniji simboli pumpi i izvršnih organa, sledeći metodologiju primenjenu u prvom delu rada [11], i referencama [8] i [14]. Treba napomenuti da su simboli hidrauličkih komponenata definisani međunarodnim ISO standardima [1], [2], [3].

GRAFIČKI SIMBOLI HIDRAULIČKIH PUMPI

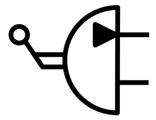
U ovom delu rada su predstavljene grafičke oznake različitih tipova hidrauličkih pumpi. Pri tome, dvostruka linija simbola (Tab.1.) označava vratilo za prijem snage od pogonskog motora.

Tabela 1. Jednostepene hidrauličke pumpe stalnog i promenljivog protoka.
Table 1. Single-stage, fixed or variable volume hydraulic pumps.

	**Jednostepena pumpa stalnog protoka:** (a) jednosmernog dejstva (jednog smera potiskivanja); (b) dvosmernog dejstva (dva smera potiskivanja).
	**Jednostepena pumpa promenljivog protoka:** (a) jednosmernog dejstva - jednog smera potiskivanja; (b) dvosmernog dejstva - dva smera potiskivanja.

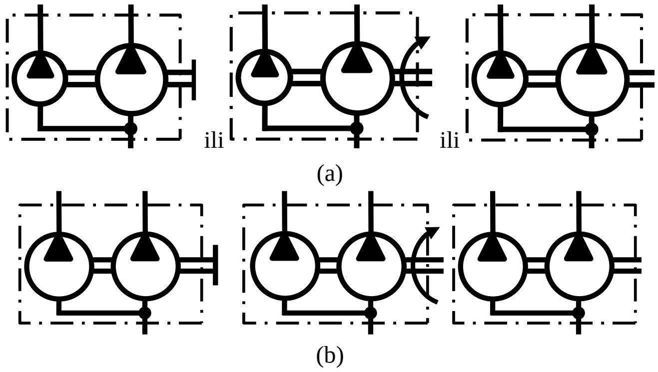
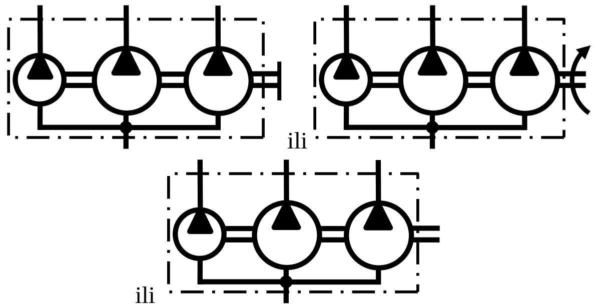
Grafičko predstavljanje jednostepenih hidrauličkih pumpi stalnog i promenljivog protoka ilustrovano je crtežima u tabeli 1, dok je odgovarajuća oznaka ručnih pumpi prikazana u tabeli 2.

Tabela 2. Jednostepene ručne hidrauličke pumpe.
Table 1. Single-stage, manual hydraulic pumps.

	**Ručno pokretana hidraulička pumpa.**

Simboli jednostepenih jednosmernih višestrujnih hidrauličkih pumpi stalnog protoka prikazani su u tabeli 3. Dve ili više hidrauličkih pumpi, postavljenih u istom ili pridruženim kućištima, hidraulički funkcionišu u paralenom režimu rada. Pokreće ih isti motor preko zajedničkog pogonskog vratila. Mogu biti istih ili različitih karakteristika, ali rade pri istom broju obrtaja zajedničkog pogonskog vratila.

Tabela 3. Jednostepene jednosmerne višestrujne hidrauličke pumpe stalnog protoka.
Table 3. Single-stage, fixed volume, multiflow, unidirectional hydraulic pumps.

	**Jednostepena jednosmerna dvostrujna pumpa stalnog protoka.** Dve pumpe rade u paralelnim strujnim krugovima i mogu biti: (a) različitog kapaciteta, (b) istih karakteristika.
	**Jednostepena trostrujna pumpa** stalnih protoka. Tri pumpe rade u paralelnim strujnim krugovima. Mogu biti istih ili različitih protoka/karakteristika.

Grafičke oznake jednostrujnih dvostepenih pumpi stalnog protoka prikazane su tabeli 4. U ovim konfiguracijama, dve redno vezane pumpe pokreće isti motor preko zajedničkog vratila. Redna veza pumpi povećava napor, a protok kroz obe pumpe je isti.

Tabela 4. Jednostrujna jednosmerna dvostepena pumpa stalnog protoka.
Table 4. Single flow, fixed volume, two-stage, unidirectional hydraulic pumps.

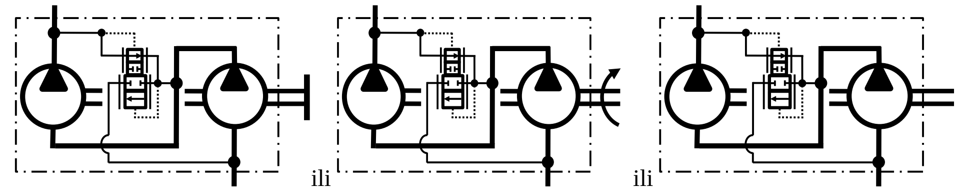


Tabela 5. Jednostepene pumpe jednosmernog dejstva, sa kompenzacijom pritiska.
Table 5. Fixed volume, single-stage, unidirectional hydraulic pumps with pressure compensation .

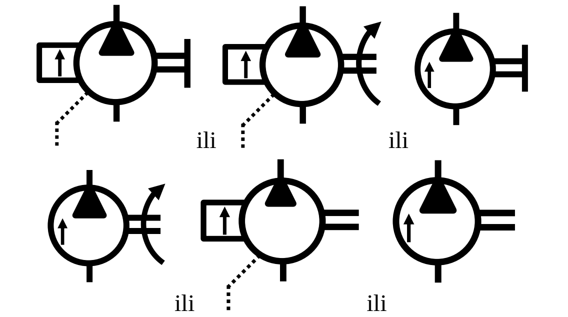
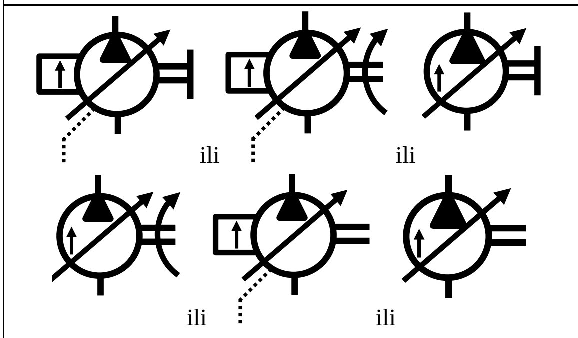
	**Jednostrujna jednostepena pumpa stalnog protoka i jednosmernog dejstva sa kompenzacijom pritiska**.
	**Jednostrujna jednostepena pumpa promenljivog protoka i jednosmernog dejstva sa kompenzacijom pritiska**.

Tabela 5 prikazuje alternativne hidrauličke simbole za predstavljanje jednostrujnih jednostepenih pumpi stalnog i varijabilnog protoka, sa drenažom. Isprekidana linija označava drenažni vod.

GRAFIČKI SIMBOLI HIDRAULIČKIH IZVRŠNIH ORGANA

Hidraulički izvršni organi su važne funkcionalne komponente hidrauličkih sistema, namenjene pretvaranju hidrauličke energije radne tečnosti u mehaničku energiju koja se koristi za vršenje mehaničkog rada.

Zavisno od kinematičkog tipa (vrste) kretanja radnog elementa, hidraulički izvršni organi se dele u tri osnovne grupe:

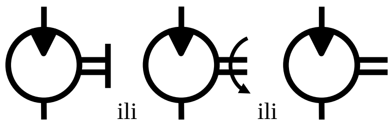
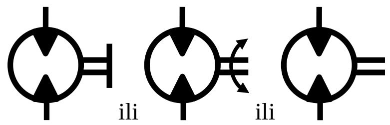
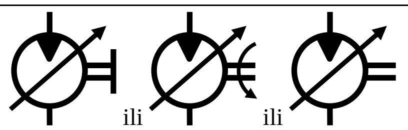
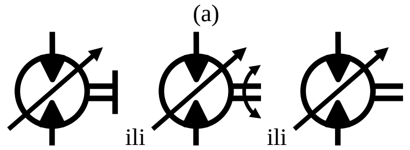
1. Obrtni hidraulički izvršni organi, sa obrtnim kretanjem radnog elementa, koji se nazivaju hidromotori;
2. Translatorni hidraulički izvršni organi, sa linearnim kretanjem radnog elementa, koji se nazivaju hidraulički radni cilindri i
3. Zakretni hidromotori, sa oscilatornim kretanjem radnog elementa.

Zakretni motori imaju ograničeni ugao zakretanja, a zakretno (oscilatorno-obrtno kretanje) pri vršenju mehaničkog rada prenose na izlaz direktno ili indirektno. Direktno zakretanje se ostvaruje pomoću krila (analogno tzv. krilnom motoru sa jednim krilom – radnim elementom unutar cilindra sa fiksnom radijalnom pregradom između potisnog i usisnog dela motora. Maksimalni ugao zakretanja takvog motora iznosi oko 300^0. Indirektno zakretanje se ostvaruje se pomoću cilindra preko zupčaste letve i zupčanika.

Grafički simboli hidrauličkih izvršnih organa predstavljeni su u tabelama 5 - 12, uz napomenu da dvostruke pune linije označavaju izlazna vratila za predaju snage potrošačima.

Simboličke grafičke oznake obrtnih hidrauličkih izvršnih organa sa kontinualnim obrtanjem radnog elementa, odnosno hidromotora, predstavljeni su u tabeli 6. Obuhvaćeni su motori jednosmernog i dvosmernog dejstva (koji se mogu obrtati u jednom ili oba smera, respektivno), stalnog ili varijabilnog protoka.

Tabela 6. Hidromotori sa kontinualnom radnom zapreminom.
Table 6. Fixed volume hydromotors.

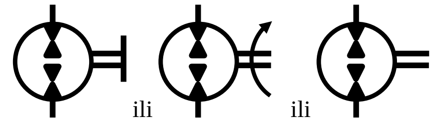
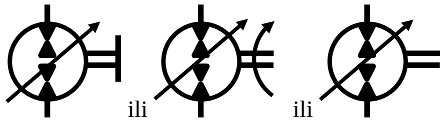
 (a)  (b)	**Obrtni motori stalnog protoka radne hidrauličke tečnosti i stalne učestanosti obrtanja radnog kola i izlaznog vratila sa:** (a) jednim smerom obrtanja i strujanja radne tečnosti, i (b) dva smera obrtanja i strujanja radne tečnosti.
 (a)  (b)	**Obrtni motori sa promenljivim protokom hidrauličke radne tečnosti i varijabilnom učestanošću obrtanja radnog kola i izlaznog vratila sa:** (a) jednim smerom obrtanja i strujanja radne tečnosti i (b) dva smera obrtanja i strujanja radne tečnosti.

Simboli dvosmernih hidrauličkih pumpi sa kontinualnim obrtanjem, koje mogu da rade i u režimu hidromotora, prikazani su u tabeli 7. Ove hidrauličke komponente se prema podesivosti protoka radne tečnosti dele u dve osnovne grupe.

Prva grupa radi sa stalnim protokom i učestanošću obrtanja radnog elementa, a druga ima mogućnost kontrolisane promene protoka radne tečnosti i učestanosti obrtanja.

Tabela 7. Dvosmerne reverzibilne hidrauličke pumpe koje funkcionišu i kao hidromotori, sa kontinualnim brojem obrtaja.

Table 7. Bidirectional reversible rotational hydraulic pumps that operates also as hydromotors.

	**Dvosmerne hidrauličke pumpe/motori stalnog protoka.**
	**Dvosmerne hidrauličke pumpe/motori promenljivog protoka.**

Zakretni motori predstavljaju posebnu grupu hidrauličkih izvršnih elemenata. Oni pretvaraju hidrauličku energiju radne tečnosti, dobijenu radom pumpe, u mehaničku energiju (rad) obrtnog izlaznog (radnog) vratila. Ugao zakretanja radnog vratila je ograničen u oba smera, zbog čega se nekada kaže da omogućavaju ograničeno oscilatorno kretanje radnog vratila. Njihove alternativne grafičke oznake-simboli predstavljene su u tabeli 8.

Tabela 8. Zakretni motori sa ograničenim oscilatornim kretanjem

Table 8. Semi-rotary actuators with limited oscillatory motion.

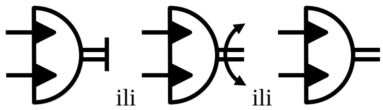
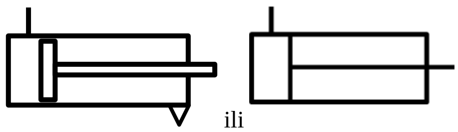
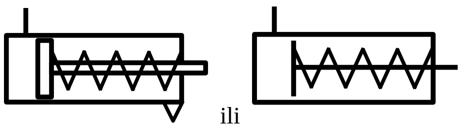
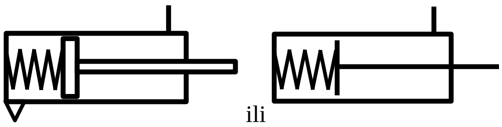
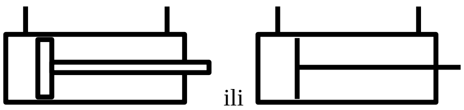
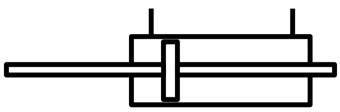
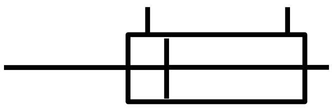
	**Zakretni motor, sa limitiranim oscilatornim obrtnim kretanjem.**

Tabela 9 prikazuje simbole hidrauličkih radnih cilindara jednosmernog i dvosmernog dejstva, sa jednostrukom klipnjačom i bez prigušivanja. Termin "prigušivanje" u ovom slučaju označava samokočenje – automatsko usporavanje klipa u blizini krajnjih položaja, koje se ostvaruje zahvaljujući posebnim konstruktivnim zahvatima kod cilindara sa prigušivanjem.

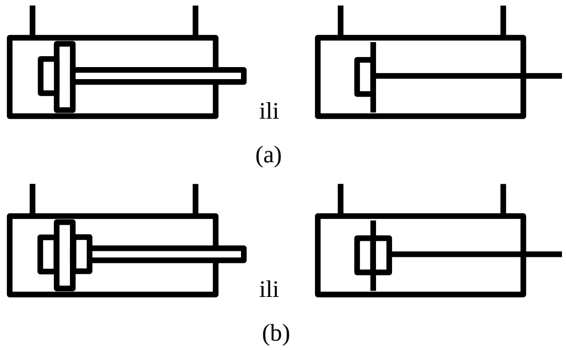
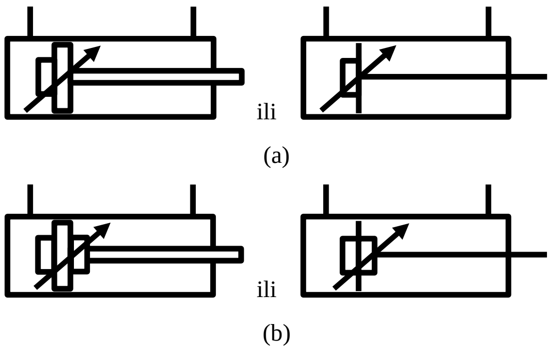
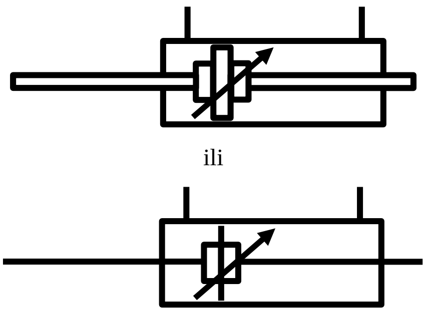
Nedostatak je, da samokočenje može predstavljati i važan nedostatak radnih hidrauličnih cilindara bez prigušivanja, jer zbog toga pri njihovom radu mogu nastati udarne sile manjeg ili većeg intenziteta, zavisno od radnih uslova. Za razliku od jednosmernih cilindara (cilindara jednosmernog dejstva) aktivnih samo u jednom smeru, cilindri dvosmernog dejstva po potrebi mogu vršiti rad u oba smera.

Tabela 9. Hidraulički radni cilindri bez prigušivanja.
Table 9. Hydraulic cylinders without cushions.

 ili	**Jednosmerni cilindar bez prigušivanja**. Pomeranje klipnjače i obavljanje rada vrši se pod dejstvom radne tečnosti povišenog pritiska na klip. Za uvlačenje klipa korisnik mora obezbediti spoljašnju silu, ili se to obavlja dejstvom npr. podignutog tereta.
 ili (a)  ili (b)	**Jednosmerni cilindar sa oprugom**: (a) klipnjača vrši rad pri izvlačenju, koje se obavlja pod uticajem hidrauličke tečnosti povišenog pritiska, a uvlači je opruga; (b) klipnjaču izvlači opruga, a vršeje rada se odvija pri njenom uvlačenju pod dejstvom radne hidrauličke tečnosti povišenog pritiska.
 ili	**Dvosmerni cilindar bez prigušivanja sa jednostranom klipnjačom**, postavlje-nom samo sa jedne strane klipa.
 ili 	**Dvosmerni cilindar bez prigušivanja sa dvostranom klipnjačom**, postavlje-nom sa obe strane klipa.

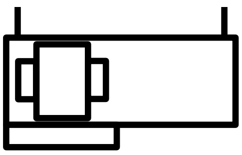
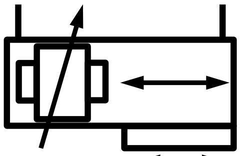
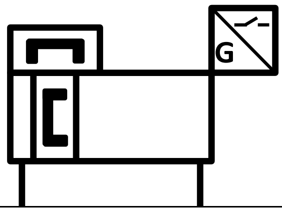
Grafički simboli dvosmernih radnih cilindara (cilindara dvosmernog dejstva) sa jednostranom i dvostranom klipnjačom, kao i fiksnim ili podesivim (varijabilnim) prigušivanjem, prikazani su u tabeli 10. Kod cilindara ove grupe, hidraulička tečnost povišenog pritiska izvlači i uvlači klipnjaču, a pri tome po potrebi može vršiti i rad. Dakle, aktivni su u oba smera. Kretanje klipa i klipnjače se konstruktivno hidraulički usporava (samokočenje) u zonama kada se približe graničnom položaju, radi sprečavanja pojave udarnih sila.

Tabela 10. Hidraulički radni cilindri dvostrukog dejstva, sa prigušivanjem.
Table 10. Bidirectional hydraulic cylinders with cushions.

	**Dvosmerni radni cilindri sa konstruktivno predpodešenim fiksnim prigušivanjem (samo-kočenjem):** (a) jednostranim i (b) obostranim.
	**Dvosmerni radni cilindri sa promenljivim prigušivanjem (samokočenjem):** (a) jednostranim i (b) obostranim.
	**Dvosmerni radni cilindri sa dvostranom klipnjačom i obostrano podesivim prigušivanjem (samokočenjem).** Hidraulička tečnost povišenog pritiska izvlači i uvlači klipnjaču, a pri tome po potrebi može vršiti i rad. Cilindri mogu biti aktivni u oba smera, sa mogućnošću podešavanja intenziteta usporavanja klipa u obe zone približavanja krajnjim položajima.

Kod jedne posebne grupe hidrauličnih cilindara, radni klip (tzv. “plunžer” – *engl. plunger*) istovremeno obavlja i funkciju klipnjače. Konstruktivno se izvode sa ili bez prigušivanja (samokočenja) klipa u blizini njegovih graničnih (krajnjih) položaja. Pri tome, prigušivanje može biti predpodešeno (fiksno) ili podesivo (varijabilno). Simboli plunžerskih cilindara prikazani su u tabeli 11.

Tabela 11. Hidraulički radni cilindri sa klipom bez kljipnjače – tzv. „plunžerski“ cilindri.
Table 11. Plunger (ram, rodless) hydraulic cylinders.

	**Jednosmerni “plunžerski” cilindri bez prigušivanja (samokočenja) klipa.**
 ili  (a) (b)	**Dvosmerni “plunžerski” cilindri sa prigušivanjem (samokočenjem klipa):** (a) obostrano predpodešeno (stalno) prigušivanje i (b) obostrano podesivo (promenljivo) prigušivanje klipa.
	**Dvosmerni magnetni hidraulički radni cilindar sa prekidačem u krajnjem položaju na jednoj strani.**

Višestepeni hidraulički radni cilindri se sastoje iz nekoliko cilindara koji se uvlače jedan unutar drugog. Stoga se nazivaju još i teleskopski. Osim spoljašnjeg cilindra najvećeg prečnika, ostali (unutrašnji) istovremeno obavljaju funkciju i klipa i klipnjače. Ukupan hod teleskopskih cilindara je veći od dužine tela spoljašnjeg cilindra. Mogu biti jednosmernog ili dvosmernog dejstva, u zavisnosti od konstrukcije. Pripadajuće simboličke oznake teleskopskih cilindara prikazane su u tabeli 12.

Tabela 12. Višestepeni (teleskopski) hidraulički radni cilindri.
Table 12. Telescoping hydraulic cylinders.

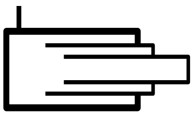
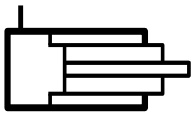
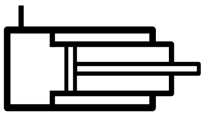
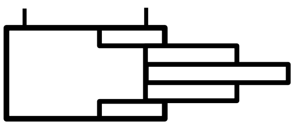
 ili  ili 	**Višestepeni radni cilindar jednosmernog dejstva.**
	**Višestepeni radni cilindar dvosmernog dejstva.**

Tabela 13. Membranski hidraulički radni cilindri.
Table 13. Hydraulic cylinders with diaphragm.

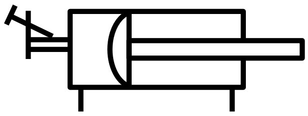
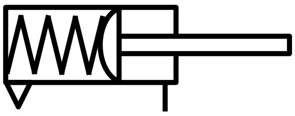
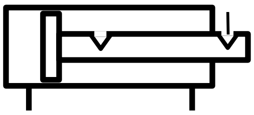
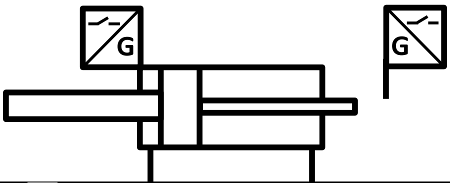
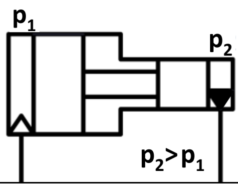
	**Dvosmerni membranski radni cilindar sa ograničenjem hoda.**
	**Jednosmerni membranski radni cilindar sa povratnom oprugom.**

Tabela 14. Specijalni hidraulički radni cilindri.
Table 14. Special hydraulic cylinders.

	**Dvosmerni hidraulički radni cilindar sa mehaničkom blokadom u oba krajnja položaja klipa i klipnjače.**
	**Dvosmerni hidraulički radni cilindar sa dvostranom klipnjačom i prekidačima u krajnjim položajima na obe strane.**
	**Jednosmerni pojačavač pritiska,** koji transformiše pneumatski pritisak u viši hidraulički pritisak radne tečnosti.

Simboli membranskih hidrauličkih radnih cilindara prikazani su u tabeli 13, a specijalnih cilindara u tabeli 14. Time je predstavljanje grafičkih simboličkih oznaka hidrauličkih radnih cilindara u ovom radu završeno.

ZAKLJUČAK

Napredak savremene poljoprivredne tehnike suštinski je povezan sa širokom primenom elektronski kontrolisanih hidrauličkih sistema spregnutih sa mehaničkim elementima prenosa snage i upravljanja. Ovaj rad predstavlja logičan nastavak prvog dela rada, pod nazivom „Hidraulički simboli - deo I: opšti simboli i oznake mernih instrumenata i indikatora“. Zato je drugi deo rada posvećen prikazivanju i opisivanju hidrauličkih simbola pumpi i račitih tipova izvršnih hidrauličkih organa: linearnih, rotacionih i oscilatornih.

Pored toga, prikazani su i grafički simboli reverzibilnih uređaja kombinovane namene, koji opciono mogu funkcionisati u dva različita radna režima, kao pumpe ili motori. Simboli svih grupa hidrauličkih komponenata, koje su u fokusu ovog rada, definisani su ISO industrijskim standardima.

LITERATURA

[1] Anonimous: ISO 1219-1:2012(en), Fluid power systems and components - Graphical symbols and circuit diagrams - Part 1: Graphical symbols for conventional use and data-processing applications, 3-rd ed., p. 178. Reviewed and confirmed in 2017. Technical Committee: ISO/TC 131 Fluid power systems. Link: https://www.iso.org/standard/60184.html .

[2] Anonimous: ISO 1219-2:2012(en), Fluid power systems and components - Graphical symbols and circuit diagrams - Part 2: Circuit diagrams, 2-nd ed., p. 42. Reviewed and confirmed in 2018. Technical Committee: ISO/TC 131 Fluid power systems. Link: https://www.iso.org/standard/51200.html .

[3] Anonimous: ISO 1219-3:2016(en) Fluid power systems and components - Graphical symbols and circuit diagrams - Part 3: Symbol modules and connected symbols in circuit diagrams, 1-st ed., p. 23. Technical Committee: ISO/TC 131/SC 1 Symbols, terminology and classifications. Link: https://www.iso.org/standard/62614.html .

[4] Barać, S., Petrović, D., Vuković, A., Biberdžić, M., Đikić, A., Đokić, D. 2017. Rezultati ispitivanja ratarskih prskalica u uslovima centralne Srbije: Savremena poljoprivredna tehnika, 43(1), pp. 17-26. Link: https://scindeks.ceon.rs/article.aspx?query=ISSID%26and%2614285&page=2&sort=8&stype=0&backurl=%2fissue.aspx%3fissue%3d14285 .

[5] Cerović, B., V., Petrović, V.D. 2018. Hidrostatički sistemi prenosa snage poljoprivrednih mašina: zapreminske pumpe. Poljoprivredna tehnika. 43(1): pp.12-21. Link: http://www.jageng.agrif.bg.ac.rs/files/casopis/PT_01-2018.pdf .

[6] Cerović, B., V., Petrović, V.D. 2018. Ventili kao upravljačke komponente hidrostatičkih sistema. Poljoprivredna tehnika. 43(3): pp.11-25. Link: http://www.jageng.agrif.bg.ac.rs /files /casopis/PT_03-2018.pdf .

[7] Cerović, V., Petrović, V.D., Radojević, L.R. 2016. Simulacije procesa raspršivanja. Zbornik radova 18. naučno-stručnog skupa sa međunarodnim učešćem „Aktuelni problemi mehanizacije poljoprivrede“, Beograd, 9. Decembar 2016., Srbija: pp. 14-21.

[8] Majdič, F. 2013. Hidravlični Simboli - Povzeto po standardu ISO 1219-1 (2006-10-15). Laboratorij za pogonsko-krmilno hidravliko (LPKH). Link: http://lab.fs.uni-lj.si/lft/img/material/SW-Hidra-simboli-vse.pdf .

[9] Miodragović, R., Petrović, D., Mileusnić, Z., Dimitrijević, A. 2011. Energy and distribution parameters of the mobile wheel line sprinkler system. Proceedings of the 39-th International symposium on agricultural engineernig „Actual Tasks on Agricultural Engineering“, pp. 299-305, 22-25 Februar, 2011, Opatija, Hrvatska.

[10] Miodragović, M.R., Petrović, V.D., Mileusnić, I.Z., Dimitrijević, Ž.A., Radojević, L.R. 2012: Water distribution uniformity of the traveling rain gun. African Journal of Agricultural Research 7(13), pp. 1988-1996. Link: https://academicjournals.org/journal/AJAR/article-full-text-pdf/326F84638540 .

[11] Petrović, V. D., Cerović, B., V. 2019. Hidraulički simboli - deo I: opšti simboli i oznake mernih instrumenata i indikatora. Poljoprivredna tehnika. 44(1): pp. 45-56. Link: http://www.jageng.agrif.bg.ac.rs/files/casopis/PT_01-2019.pdf .

[12] Petrović, V.D., Radojević, L.R., Vukša, P., Golubović, Z.Z. 2012. Droplet size distributions of conventional and air-induced nozzles. Proceedings of the DAS-29, 29-th Danubia-Adria Symposium, 26-th - 29-th , pp. 166-169, September, University of Belgrade, Serbia.

[13] Petrović, V. D., Urošević, M., Radojević, L. R., Mileusnić, I. Z., Petrović, S., 2017. Razvoj hidrauličko-mehaničkog sistema automatske nivelacije berača maline i kupine. Poljoprivredna tehnika. 42(2): pp.1-10. Link: http://www.jageng.agrif.bg.ac.rs/files/casopis/PT_02-2017.pdf .

[14] Trinkel, E., Fluid Power Basics 2017. First eBook edition Penton Media, Inc., https://www. hydraulicspneumatics.com/.

HYDRAULIC SYMBOLS – PART TWO: PUMPS AND ACTUATORS

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Abstract: At the current level of technological development, it is widely accepted that survival and progress of modern agricultural technology (among other things) is based on the widespread application of electronically controlled hydraulic systems, supported by mechanical elements of power transmission and control. This paper is a logical continuation of the first part, entitled "Hydraulic symbols - part I: general symbols and designations of measuring instruments and indicators". Therefore, the current second part of the paper is devoted to the presentation and description of hydraulic symbols of pumps and various types of actuators: linear, rotary and oscillatory. Symbols of the combined-function devices, which can optionally function in two different operating modes, such as pumps or motors, are also shown. Standard symbols of all groups of hydraulic components, which are in the focus of this paper, are standardized and defined by ISO industry standards.

Key words: *hydraulics, system, symbol, scheme, pump, actuator*

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AUTOMATIZATION AND DIGITALIZATION IN AGRICULTURE

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Summary. The fourth industrial revolution, which has begun couple of years ago, covers not only "smart" and interconnected machines and systems. It also coincides with further discoveries in various areas, from determining the genome sequence to nanotechnology and from renewable sources to quantum computing. The correlation between these technologies and their interaction in the physical, digital and biological field is what makes the fourth industrial revolution significantly different from the previous ones. The events should be faster, more extensive and radical, which will require the transformation of entire systems through (and within) countries, businesses, industries and society as a whole. We are already talking about switching from financing innovative projects to Comprehensive Innovation Ecosystems (AKIS).

The paper describes some important research work from the field of automatization and digitalization of Slovenian agriculture.

Key words: *precision farming, smart farming, agricultural robotics.*

INTRODUCTION – PRECISION FARMING

If we want Slovenian agriculture to become more competitive, we need to introduce modern agricultural technologies into our agricultural environment. Modern technology includes satellite navigation, which is intensively used in neighbour developed countries.

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The main factors in precision agriculture represent precise guidance, precise sowing, fertilizing and spraying. And with that we get a better realization of plant production. The use of precision agriculture technologies allows us to plan better and analyse the working procedures. In foreign literature there is a lot of researches on this topic. The structure of land in agri - developed countries is completely different than in Slovenia, and the use of RTK (Real Time Kinematic) navigation comes to a different perspective than on our fragmented land. In the task we want to check the actual saving of time and fuel, which consequently influences the reduction of variable production costs.

Faculty of Agriculture and Life Sciences made some very interesting field navigation experiment (Vajda, 2018). In order to save time and money, we have tested various ways of turning the tractor enabled by RTK technology. The purpose is also to determine the human accuracy of driving the tractor in the field and compare it with the use of RTK precision (± 2cm). We used tractor Fendt 828, which was equipped with the RTK navigation system.

We compared how much fuel and time we saved, and the width of overlap using manual driving. The experiment was conducted on two areas of land size of 172 x 58 meters, and the two working machines wide 3 and 6 meters. When the experiment was done, we saved 15,7% of the time and 8,66 % of the fuel on a working machine of 3 meters wide, and 12,6 % of the time and 8,28% of the fuel on a working machine of 6 meters wide. The width of the overlap represents 10% of the working width of the machine, and with the method of turning, which RTK navigation allows, we saved additional time.

Our findings are consistent with the Hege research [14]. He demonstrated the positive characteristics of RTK autonomous tractor driving in mechanical weed control in the production of onions and spinach.

A reference or base station is indispensable to determine the accuracy of the position less than one meter. This could be your own mobile or permanent reference station owned by an operator and used by several users. A permanently operating reference station is permanently located where there are no disturbing factors, such as large reflecting surfaces or radio transmitters. Since the coordinates of the reference station are precisely determined, the receiver can determine observation corrections from observations and known satellite positions. Through the communication channels (GSM, UMTS, NTRIP), the reference station in the form of standardized records sends such data to mobile receivers in the field, in our case on the tractor. Using the obtained data, the receiver, together with its data from observations or corrections of the reference receiver, determines its precise position in real time. The receiver determines its position by measuring the distances to satellites in the universe, creating a replica of the signal it receives from the satellite, and comparing it with the signal generated in the receiver. Because the signal on the Earth is very weak, special signalling is required. The locally-determined signal receiver delays so long that the cross-fermentation function reaches full alignment with the source signal. Signal is ready for further processing. The receiver decodes the position of satellites. The precise position of the receiver is determined by measuring the distances of the four satellites. The position is determined by the method of the smallest squares between pseudo-satellite distances. More available satellites we have, the better and more precise is the quality of locating the position (GNSS, 2018).

In Slovenian only general theoretical information literature dominates. And that is because this type of technology in Slovenia is new and investment is expensive.

Furthermore, the practical data is still too small for the technology to expand. Most information can be found on the websites of authorized dealers or importers. One such website is Geoservis d.o.o., where we can obtain a sufficient amount of data on the operation and usability of GPS in agriculture [7].

The method of capturing spatial data was first described at the University in Maribor. It was described how to use GPS technology and GPS systems to accurately determine the position in the space, measure the surfaces, ranges and paths, and simultaneously monitor agricultural machines in work tasks. It also provides information on GPS operation, signals, faults, measuring instruments and software [26].

The Global Information System (GPS) was very detailed described [14]. He described in detail the composition of GPS, its purpose, accuracy and mistakes. He also devoted much attention to the description of Geographic Information Systems. In the task they monitored the working procedure of ploughing and recorded satellite data with data that were later processed and used for precise calculation of the costs of ploughing. With the help of evidence, a working hypothesis was confirmed that with the aid of the GPS system, we can more accurately assess the costs of ploughing in comparison with the simulation model.

Different GPS systems were compared among each other, differing primarily in their ability to control precision. In the first treatment, a classic manual drive was compared, in the second manual drive in combination with GPS guidance, the third was autonomous driving, and in the last, fourth, autonomous driving with RTK system. The difference between the stated accuracy indicated by the manufacturers and the actual measured accuracy was compared in one experiment in Germany. At first and second treatment, the actual accuracy was worse than stated, namely, the accuracy was indicated for a manual run of 20 cm and the actual one was 22 cm.

In the second treatment, the accuracy was 10 cm and the actual one was 12 cm. For the following two systems, the actual accuracy was better than indicated. In the autonomous run without RTK, the accuracy was 5 cm, the actual 3.5 cm, and the RTK 2 cm and the actual 1.2 cm. In the continuation of this research, the productivity of automatic and manual driving was demonstrated, where productivity was increased by about 8% in automatic driving, which is 0.5 ha per hour [22].

At the Universität für Bodenkultur in Austria was made interesting study. Three different systems were used to guide the tractor: manual driving, manual GPS-assisted driving, and automatic driving system. With the working width of 15 m and 3 m, the actual width of the working machine was compared. For a working width of 15 m, the actual working width of the hand-held vehicle was 14.29 m, for GPS assistance and manual driving 14.92 m, and for automatic driving 14.91 m. At a working width of 3 m, the actual working width of the manual drive was 2,775 m, and for GPS assistance and automatic driving 2,906 m. Researchers studied the time needed to process parcels in the size of 3,186 ha. A hand-guided ride was compared to each other, where 29 passes were required to process the plot and 39.38 minutes, of which turning time was 8.4 minutes.

With the help of the GPS system and the ring ride, 28 passages were needed, and 34.12 minutes and a turning time of 4.77 minutes. In automatic driving, 28 passes were needed. 36.05 minutes and 6.02 minutes for turning. For manual driving, the average turning time was 13.39 seconds, while using the GPS system was significantly shorter. 13.38 seconds were used on average for the autonomous driving system and 10.61 seconds for the manual hand-held GPS system.

Differences in the turning time between the GPS systems were separated due to the longest distance travelled in autonomous driving.

As a matter of interest, at the end of this study, it was stated that with the help of the GPS system, in addition to working area of 5 m, work surface of up to 9 ha can be processed within 12 hours. [16].

Lopez [19], showed the savings in manual drive and RTK system in crop production. The savings in the production of silage maize with the GPS system is around 13 € / ha, 22 € / ha of sugarcane, 22 € / ha of sugar beet and 23 € / ha for cereals. The highest hectare savings, 61 € / ha, was in the production of potatoes. They also showed average hectare savings in all the aforementioned crops, except for potatoes. Using an accuracy of 0.30 m, we can save 4-5 € / ha, with an accuracy of 0.15 m 9-12 € / ha and using the RTK system 20-23 € / ha.

The Slovenian national network that goes by the name SIGNAL is the GNSS (Global Navigation Satellite System) network, which is made up of 16 uniformly distributed permanent stations throughout the country. The stations are arranged in such a way that the distance between them is less than 70 km, while the borders of the country complement the stations of the neighbouring countries (5 Austrian, 6 Croatian and 1 Hungarian). Network operation of the SIGNAL is provided by the GNSS Service under the auspices of the National Geodetic Authority at the Geodetic Institute of Slovenia. Access to network data Signal is also possible through the DGPS service provided by Telekom Slovenia. In this way, we can access RTK data via the GSM (Global System for Mobile communications) network where the user needs a GSM-modem connected to a mobile server (Ministry of Environment and Space, [20]).

Geoservis d.o.o. Slovenia is the main manager of permanent GNSS stations (Figure 1), where besides own stations, they also take care of partner stations. In Slovenia there are 7 permanent stations, and 4 additional permanent stations will be installed (GNSS, [7]).

Figure 1: Map stations of the company Geoservis, d.o.o.

SMART AGRICULTURE

The spectral composition of light reflected from vegetation depends on the condition of vegetation (plant height and canopy density, nutrient supply, water availability, damage due to pests or mechanical factors). This, theoretically, allows a non-destructive evaluation of the physiological and structural condition of the vegetation and to forecast crop yield. Eler&Co present in his study the potential and limitations of multispectral measurements in three field experiments, where relatively simple and less precise measures (vegetation index) to assess the vegetation condition were used. Correlation of vegetation indices with agronomical relevant vegetation parameters was the highest for the grassland experiment with r = 0.67 between normalized difference vegetation index (NDVI) and yield.

For maize irrigation experiment, he found significant differences between irrigated and non-irrigated area, but it was difficult to estimate the contribution of higher leaf area index and higher concentration of chlorophyll in irrigated areas to these differences. The vegetation index was the lowest in the experiment with winter barley, where only minor correlations with the physiological status of the crop were found, however some variety-specific reflectance of spectra and their interaction with N side dressing was detected during vegetative development [4].

Data acquisition with high resolution multispectral aerial survey in agriculture is increasingly gaining ground.

Multispectral aerial photography makes it possible to get enough objective and, above all, up-to-date documents containing information for further use and transition to precise farming. With the obtained data, which we record with the unmanageable. It is possible to provide aircraft with access to information on production conditions, development and real-time healthcare, allowing timely and appropriate response to the actual situation in the fields [2].

Unmanned aerial systems and related new systems for more precision farming are becoming standard in modern food production. Newer technologies allow faster monitoring and precise plant stress control, soil quality and more accurate assessment of vegetation of cultivated plants. Right interpretation results of high resolution multispectral aerial photography present basis for more precise farming. In order to follow the trend of modern production technologies introduction, the Agricultural Institute of Slovenia purchased unmanned aerial systems with a multispectral camera adapted for agricultural use. The first experimental year with new research equipment showed, enormous potential for further development and research in all agricultural fields Such equipment allows acquiring new and different kind of data which enable better understanding of plant response to various stressful circumstances (drought, nutrition, weeds), which will allow easier transition into precision farming [6].

Satellite images with better temporal and spatial resolution are allowing significant progress in the introduction of systems for the timely detection of drought and mitigation of its effects in agriculture. For greater reliability of satellite images interpretation in the initial stage the knowledge of soil water and its spatial variability is necessary. The experiment by Pintar&Co was made at four locations in Prekmurje area, further divided into four plots of 20 m x 20 m ten repetitive measurements of soil - water content in the nine time periods in 2016 were made. The measurements were carried out using a portable TDR probe TRIM FM-1.

Variability of measurements within individual plots and between the plots was very similar. The coefficient of variation has reached a value between 0.1 and 0.7 %. Variations in the water content between the plots at a single location were statistically significant in several dates, but only a few have been relevant and reached a value of 5 to 10 vol. %. The amount of water in the soil at the time was as a rule up to 25 vol. %. Due to the low variability, in the following experiment we can reduce the sampling from the current ten to five or six and four or five on the heavy and on light soils, respectively [21].

On the Faculty of Agriculture and Life Sciences, Department for Biosystems Engineering the main research work in last years was made in the field of autonomous robots in agriculture and specially in the field of machine vision and autonomous orientation in space. One of the goals of this work was to investigate the possibility of using two non-costly 2D LIDAR scanners to reconstruct a 3D scene, instead of using a more expensive multi-channel sensor, by applying an alternative SLAM approach. To test the approach a small field robot was fitted with two 2D sensors and the tests were conducted in indoor as well as outdoor environment.

An accurate 3D model of an outdoor scene can be used in many different scenarios of precision agriculture, for instance to analyse the silhouette of a tree crown canopy for precision spraying, to count fruit for fruit yield prediction or to simply navigate a vehicle between the plant rows. Instead of using stereovision, limited by the problems of different light intensities, or by using expensive multi-channel 3D range finder (LIDAR scanner), limited by the number of channels, this work investigates the possibility of using two single channel LIDAR scanners mounted on a small robot to allow a real-time 3D object reconstruction of the robot environment. The approach used readings captured by two LIDAR scanners, SICK LMS111 and SICK TiM310, where the first one was scanning horizontally and the second one vertically. In order to correctly map the 3D points of the readings from the vertical sensor into a 3D space, a custom SLAM algorithm based on image registration techniques was used to calculate the new positions of the robot. The approach was tested in an indoor and outdoor environment, proving its accuracy with an error rate of 0.02 m ± 0.02 m for vertical and -0.01 m ± 0.13 m for the horizontal plane [18].

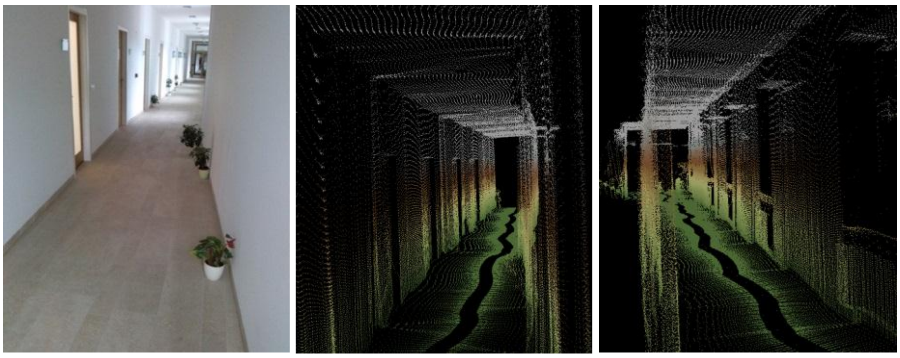

Figure 2: Indoor environment – a corridor. The left image depicts a real scene, while image in the centre and on the right depict their representation in 3D space

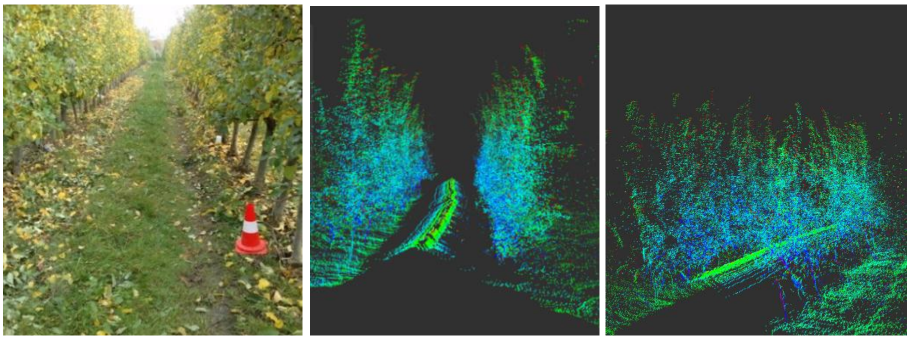

Figure 3: Outdoor environment - apple orchard. The left image depicts a real image, while in the centre and on the right, it shows their representation 3D reconstruction

A 3D map of objects of an environment is useful in many issues of precision agriculture. For instance, it could be used to localise a robot on the field, to prevent it from bumping into obstacles or to plan a trajectory the robot would take to reach its destination [23]. Next, a 3D model could be used to get information about the plant development [5], to evaluate the shape / density of a tree silhouette for precision spraying application [27]. And finally, a 3D model could even be used to pick fruits [3], to measure the size of the trees [4] or to distinguish weed from maize plants [1].

To make an autonomous filed robot it has to include all necessary sensors and logic in order to localise itself, to build a map of the environment and to possibly plan a path it would take to move to a new position. The environment sensing step can be accomplished by using simple ultrasonic or infra-red sensors that produce trivial readings, but if we want to get a more accurate results, more complex sensors should be used, such as cameras, depth cameras, or single/multi-channel LIDAR scanners that produce more detailed results.

Some limitations can be overlooked if we know that the robot will only have to avoid obstacles that are on the ground, where a simple 2D LIDAR can be used to drive between them. The problem is more complex environment, where parts of the objects hang and obstruct the robot. In these cases, it is necessary to build a 3D model of the scene. An example of such approach was described by Ben-Tzvi et al., 2010., where two cameras were used to calculate a depth information by analysing corresponding pixel pairs. The work from Jung et al. [13] is based on the use of digital camera and a projector that emits structured light on to the target and depth information is recorded by measuring the intensity of the reflected light. The closer the object is, the bright the colour and vice versa. The sensors with the highest prices at the moment are 3D LIDAR scanners [23]. They used laser light to measure the distance from the scanner to a point of the scene. In comparison to the ordinary 2D models, the 3D version has multiple channels. This means they take measurements on different planes, but are limited with the number of channels, for instance 16, 32 or 64.

If a 3D LIDAR scanner is used on a field robot it would make possible for such a robot to sense the environment and navigate between the obstacles [23] . It would be able to detect the crop lines when placed in a field and navigate between them without destroying the plants.

Next, it could detect fruits or crops with an intent to then harvest them by focusing on the shapes measured by a 3D depth sensor [3] or it could record the shape of the tree crown canopy [27] to adjust the dosage rate of pesticides based on the thickness of the tree crown. If there are no branches, the valves are shut, if there are the valves are open and if there are just a few, the valves are partly open.

It is useful to know the size of fruit or plants. If a fruit producer wants to make a prognosis about the yield of the harvest [24], he has to know the number and size of fruit. If a forester wants to estimate the biomass [4] of a tree it has to know its high and diameter or a volume. In all these cases having a 3D model of the scene would be useful and the system like this could be a part of an autonomous farming robot.

One of the most important parts of the software for such a robot would represent a SLAM (simultaneous localisation and mapping) algorithm. The most well-known SLAM algorithms are Gmapping [10, 11] and Hector mapping [15]. To localize and create a map of the environment Gmapping relays on the use of Rao-Black wellized particle filter that minimizes the number of particles to reduce local uncertainty. The approach is optimised for long-range data captured by a LIDAR scanner and therefor suitable for large areas. But in order to work it needs additional data from the robots' odometry.

As tested in a previous work by [17], Hector mapping is not proven to be the best choice for outdoor environments due to changing conditions and unstructured pattern of the surrounding objects. Instead, an image analysis-based approach is suggested utilising image registration techniques done in the frequency domain. In comparison to G-mapping the presented approach works without any odometry data.

CONCLUSION

Technology, Artificial Intelligence (AI) and Machine Learning will change the game across the entire food system. On farms, AI and machine learning can deliver greater reliability in forecasting, such as weather conditions, pests and fluctuations in commodity prices. Cameras and applications can help detect illnesses, pathogens and weeds in a matter of seconds. Through a smart platform, the consumer can supply fresh and healthy food, and merchants can reduce the amount of discarded food. The consequences are improving general health, disease tracking, etc. Of course, we must be aware that achieving food security requires political and economic solutions to issues such as poverty and racial inequality. Innovation must reach the hands of those who need it the most - leaders must provide everyone with accessible, user-friendly and accessible technology. This must be our goal to which we strive. However, the paths that are going to the destination will, as always, be quite different.

REFERENCES

[1] Andujar, D., Rueda-Ayala, V., Moreno, H., Rosell, J. R., Escola, A., Valero, C., Gerhards, R., Griepentrog, H. W. 2013. Discriminating crop, weeds and soil surface with a terrestrial LIDAR sensor. Sensors 13 pp.14662-14675.

[2] Chaerle, L., Van Der Straeten, D. 2000. Imaging techniques and the early detection of plant stress. Trends in Plant Science 5, pp. 295-500.

[3] Dzitac, P., Mazid, A. M. 2012. A depth sensor to control pick-and-place robots for fruit packaging, 12th International Conference on Control Automation Robotics & Vision (ICARCV), pp. 949 – 954.
[4] Eler, K., Turk, B., Čop, J., Lazarevič, B., Vodnik, D. 2017. Multispektralni posnetki visoke prostorske ločljivosti v raziskavah v agronomiji – trije primeri uporabe. SAD, Novi izivi v agronomiji, Zbornik simpozija, Laško: 258-264.
[5] Garrido, M.; Paraforos, D. S.; Reiser, D.; Vazquez Arellano, M.; Griepentrog, H. W.; Valero, C. 2015. 3D Maize Plant Reconstruction Based on Georeferenced Overlapping LiDAR Point Clouds. Remote Sensing 7(12) 17077-17096.
[6] Germšek, B., Knapič, M. 2017. Uporaba brezpilotnih zrakoplovov v kmetijstvu. SAD, Novi izzivi v agronomiji, Zbornik simpozija, Laško: pp. 252-257.
[7] GNSS Geoservis. 2018. Retrieved on 18. October 2018 at: http://www.gnss.si/kako-deluje
[8] Gonzalez RC and Woods RE 2001. Digital image processing, 2nd edition, P.Hall, Upper Saddle River, New Jersey.
[9] GPS visualiser. 2018. Retrieved on 22. October at: http://www.gpsvisualizer.com
[10] Grisetti, G., Stachniss, C., Burgard, W. 2007. Improved Techniques for Grid Mapping with Rao-Blackwellized Particle Filters, IEEE Transactions in Robotics, Volume 23, pp. 34-46.
[11] Grisetti, G., Stachniss, C., Burgard, W.2005. Improving Grid-based SLAM with Rao Blackwellized Particle Filters by Adaptive Proposals and Selective Resampling, Proceedings of the IEEE Int.Conf. on Robotics and Automation.
[12] Hege, D. 2014. Retrieved on 11 September 2018 at: https://www.landwirtschaft.sachsen.de/landwirtschaft/6779.htm
[13] Jung, H., Lyou, J. 2014. 3D map building using the kinect mounted on a mobile robot, IEEE International Conference on Industrial Technology (ICIT), pp. 604 – 608.
[14] Kašman, I. 2003. Diplomsko delo - Dokumentiranje in analiza stroškov delovnega postopka z uporabo satelitske navigacije. Univerza v Mariboru.
[15] Kohlbrecher, S., Meyer, J., Graber, T., Petersen, K., Klingauf, U., Stryk O. 2013. Hector Open Source Modules for Autonomous Mapping and Navigation with Rescue Robots, Dep. of Computer Science, TU Darmstadt, Germany.
[16] Landerl, G. 2009. Untersuchungen zum Nutzen und zu Genauigkeiten von GPS-gestützten Parallelfahrsystemen (Lenkhilfe, Lenkas- sistent und Lenkautomat) bei Traktoren. Wien, Universität für Bodenkultur.
[17] Lepej, P., Rakun, J. 2016. Simultaneous localization and mapping in a complex field environment, Biosystems Engineering, Volume 150, pp. 160–169.
[18] Lepej, P., Lakota, M., Rakun J. 2017. Robotic real-time 3D object reconstruction using multiple laser range finders. Advances in Animal Biosciences, Conference on Precision Agriculture (ECPA 2017), John McIntyre Centre, Edinburgh, UK, July, (8), 2: 16–20.
[19] Lopez, H. 2013. Retrieved on 25. October 2018., at: https://www.landwirtschaftskammer.de/duesse/rueckblick/pdf/2013-06-19-rentabilitaet-pf.pdf
[20] Ministrstvo za okolje in proctor. 2018. Retrieved on 26. October 2018 at: http://www.gu-signal.si/node/1
[21] Pintar, M., Đurič, N., Nedog, M., Kastelec, D. 2017. Preliminarne meritve količine vode v tleh za potrebe interpretacije satelitskih slik. SAD, Novi izzivi v agronomiji, Zbornik simpozija, Laško: 189-195.
[22] Reckleben, Y. 2010. Vorzüge und Schwachstellen von Lenksystemen in der Landwirtschaft. Fachhochschule Kiel.
[23] Roh, H.C., Sung, C.H., Chung, M.J. 2013. Rapid SLAM using simple map representation in indoor environment, 19th Korea-Japan Joint Workshop on Frontiers of Computer Vision, pp. 225 – 229.

[24] Stajnko, D., Lakota, M., Hocevar, M. 2004. Estimation of number and diameter of apple fruits in an orchard during the growing season by thermal imaging. Computers and Electronics in Agriculture, 42, 31-42.

[25] Vajda, N., Kelc, D., Vindiš, P., Berk, P., Rakun, J., Stajnko, D., Lakota, M. 2018. Increase of soil tillage efficiency with using of RTK – navigation. 46th International Symposium "Actual Tasks on Agricultural Engineering" 27th February – 2nd March 2018, Opatija, Croatia

[26] Vaukan, T. 2001. Diplomsko delo - Satelitska navigacija kot osnova za geoinformacijske sisteme v kmetijstvu. Univerza v Mariboru.

[27] Wellington, C., Campoy, J., Khot, L., Ehsani, R. 2012. Orchard tree modeling for advanced sprayer control and automatic tree inventory. In: Proc. IROS Workshop on Agricultural Robotics.

AUTOMATIZACIJA I DIGITALIZACIJA U POLJOPRIVREDI

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Sažetak. Četvrta industrijska revolucija, koja je započela pre nekoliko godina, danas pokriva i "pametne" i međusobno povezane mašine i sisteme (u poljoprivredi) . Takođe se poklapa sa daljim otkrićima u različitim oblastima, od određivanja sekvenci genoma do nanotehnologije i iz obnovljivih izvora do kvantnog računarstva.

Korelacija između navedenih tehnologija i njihove interakcije u fizičkoj, digitalnoj i biološkoj oblasti čini ono što četvrtu industrijsku revoluciju znatno razlikuje od prethodnih.

Događaji bi trebali biti brži, opširniji i radikalniji, što zahteva transformaciju čitavih sistema kroz (i u okviru) pojedinih zemalja, biznisa, industrije i kompletnog društva.

Danas se već govori o prelasku sa finansiranja Inovativnih projekata (IP) na sveobuhvatne inovativne ekosisteme (AKIS).

Rad opisuje danas važne istraživačke radove iz oblasti automatizacije i digitalizacije poljoprivrede u Republici Sloveniji.

Ključne reči: precizno farmerstvo, pametna poljoprivreda, roboti u poljoprivredi.

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SAVREMENI SISTEMI UPRAVLJANJA FLOTOM VOZILA

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Sažetak. Savremeni sistemi upravljanja flotom vozila omogućavaju menadžerima efikasno upravljanje i optimizaciju prevoza, koji po svojim efektima značajno prevazilaze tradicionalni pristup za upravljanje flotom vozila.

Ovi sistemi omogućavaju efikasnu kontrolu korišćenja različitih vozila i potrošnje goriva, pregled istorijskih podataka o kretanju vozila, praćenje ponašanja vozača tokom vožnje i rada motora, evidentiranje pojedinih prekršaja (prekoračenje brzine, nekorišćenje sigurnosnih pojaseva i dr.), praćenje održavanja vozila, smanjenje direktnih i indirektnih troškova i evidentiranje specifičnih događaja.

Ključne reči: *flota, upravljanje, sistem, teretno vozilo, bezbednost, troškovi, transport, kontrola, optimizacija, centar.*

UVOD

U radu je objašnjena veza između primene savremenih sistema za upravljanje flotom motornih vozila i mogućnosti optimizacije prevoza kroz nadzor i upravljanje ponašanjem vozača i kontrolu korišćenja vozila u realnom vremenu.

Ovi sistemi omogućavaju i praćenje potrošnje goriva, rada motora, pregled istorijskih podataka o kretanju vozila, evidentiranje pojedinih prekršaja, praćenje održavanja vozila. Primena ovih sistema doprinosi smanjenju direktnih i indirektnih troškova i evidentiranje specifičnih događaja kao osnove za pravilan izbor i primenu adekvatnih mera i aktivnosti za unapređenje upravljanja flotom motornih vozila.

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Primenom savremenih sistema upravljanja flotom vozila može se značajno unaprediti poslovanje kompanije, smanjiti troškovi, izbeći neželjeni događaji, i tako uticati na vozače da budu kvalitetniji i bezbedniji u saobraćaju. Na ovaj način može se doprineti uspostavljanju sistema upravljanja bezbednošću saobraćaja u kompaniji, smanjiti zagađenje životne sredine, i što je najvažnije, mogu se sačuvati mnogi ljudski životi.

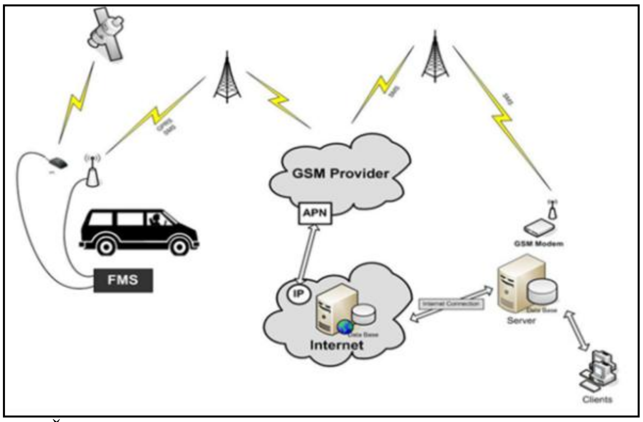
Efekti primene savremenih sistema upravljanja flotom motornih vozila, u vidu odgovarajućih ušteda, dati su kroz primer statističke analize prikupljenih informacija i parametara za određenu flotu vozila. Ovi podaci su praćeni u realnom vremenu, na posmatranom području i obrađeni od strane kontrolnog centra.

PRIMENA SAVREMENIH SISTEMA UPRAVLJANJA FLOTOM VOZILA

Oblasti primene savremenih sistema upravljanja flotom vozila

a) Praćenje stanja i pozicije vozila

Zahvaljujući savremenoj tehnologiji, praćenje flote vozila sada je moguće u svakom trenutku, korišćenjem globalnog položaja satelita. Ovo rešenje daje mogućnost menadžmentu kompanije da održava kontakt sa uređajima u vozilu u svakom trenutku, gde god da se vozilo nalazi u svetu. U cilju određivanja i prenosa informacije o stanju i poziciji vozila koja su u sistemu praćenja, odgovarajuća jedinica (uređaj) prima signal od GPS satelita, procesuira informacije i šalje ih preko lokalne GSM mreže ili satelita (Sl. 1).



Slika 1. Šematski prikaz rada sistema upravljanja flotom vozila, [2]

Fig. 1. Schematic overwiev of the operation of the fleet management system, [2]

b) Bezbednost saobraćaja

„Saobraćajne "nezgode" nisu "nesreće", tj. stradanje u saobraćaju nije slučajnost, već je rezultat sistemskih grešaka i nerada. Trend porasta broja poginulih i povređenih u saobraćaju može se promeniti dobro organizovanim radom i sprovođenjem dobro osmišljenih i koordiniranih mera“ , [1].

Ovaj stav je suština savremenog pristupa uspostavljanju sistema upravljanja bezbednošću saobraćaja, delovanjem na bezbednost saobraćaja kao sistem ili na pojedine njegove elemente (čovek-vozilo-put-okruženje).

„Saobraćajne nezgode najčešće nastaju kao posledica nepoštovanja propisa ili zbog loše obuke vozača. Za mene je to bio izazov: Kako naći rešenje koje će sprečiti saobraćajne nezgode i biti korektivni faktor za vozače“ [2].

Kod mnogih osoba, kada se nađu za volanom, dolazi do promene ličnosti – osećaju se snažnijim i moćnijim. Često postaju mnogo agresivniji vozači u vožnji i visokorizični u saobraćaju, za sebe i druge.

Razlozi mogu biti mnogobrojni za ove promene u ponašanju: nedostatak znanja, nedostatak veština, manjak realizacije sopstvenih ciljeva i želja, jačanje negativne usvojene prakse, nedostatak nadžora (kontrole), sukob interesa i sl.

U mnogim, ako ne i svim slučajevima, nedostatak znanja, veština, (ne)shvatanja rizika i sl. može se prevazići nadzorom, odnosno adekvatnim posmatranjem i kontrolom. Međutim, i pored sve veće primene sistema praćenja i drugih vidova kontrole ponašanja vozača u saobraćaju, upravljanje motornim vozilom je često bez nadzora. Zato su razvijena savremena rešenja za bezbednost na putevima, koja se baziraju na vozaču, njegovim stavovima i ponašanju. Osvajanje srca i uma vozača je ključ za uticaj na njegovo ponašanje u saobraćaju.

Da bi se ovaj cilj ostvario, neophodan je kvalitetan i pouzdan izvor informacija tj. dobar IVMS *(In Vehicle Monitoring System)*. Osnovna poruka u sferi upravljanja flotom vozila, odnosno vozačima jeste: - Budite fer prema vozaču; nagradite njegove dobre navike u vožnji, a sprovodite propisane postupke za (ne)odgovornost vozača u vožnji i kada krši propise.

v) Telematika

Savremena tehnologija praćenja vozila oslanja se na vodeće provajdere „*Machine-to-Machine*“ (M2M) mrežnih usluga, koja nudi globalnu konekciju vozila preko GSM, CDMA i *Satelit-tehnologija*.

Lociranje vozila i tržište praćenja flote vozila pomogli su rađanju rastuće „mašina u mašini“ (M2M) industrije, kako je optimizacija ruta flote vozila i mogućnost da se prati ranjivi tovar postala opšteprihvaćena realnost i potreba. Ovo tržište danas je jedan od najvažnijih korisnika M2M sistema sa naširoko rasprostranjenom primenom u teretnim i dostavnim vozilima i *Rent a Car* floti. Uz inovativna i prilagodljiva rešenja koja se nude i bivaju podržana od provajdera aplikacija, ovo tržište nastavlja da se širi, bazirajući se na uštedi, velikoj pokrivenosti i opšteprisutnom mobilnom mrežnom pristupu.

g) Zaštita vozila

Krađe vozila su česte. U cilju zaštite skupocenih vozila od krađe, dobro je investirati u najbolji protiv-provalni sistem koji može da se nađe na tržištu. Ipak, nijedan uređaj ne daje potpunu zaštitu. Ako je automobil veoma ranjiv (zbog cene, izgleda, opreme, okruženja i sl.) često se praktikuje opremanje vozila sa dva ili više različitih tipova zaštitnih uređaja.

d) Upravljanje vrednostima

Savremene tehnologije upravljanja flotom vozila nude optimalne performanse i iskorišćenost sredstava (vozila, uređaji i oprema), tako što unapređuju njihov rad i održavanje, povećavajući njihovu produktivnost, istovremeno produžavajući životni vek. Ove tehnologije omogućavaju upravljanje životnim vekom ovih sredstava.

Upravljanje vrednostima *(Asset Management)* pomaže kompanijama i organizacijama da jasno definišu politiku održavanja i strategije: povećanja vrednosti sredstava i povećanja produktivnosti. Ove strategije uključuju proaktivno održavanje programa kao što su praćenje stanja, centralizovano održavanje i pouzdani procesi za unapređenje pogona.

đ) Potrošnja goriva

Gorivo je jedan od najvećih troškova sa kojim se transportne kompanije suočavaju u svom radu. Cene se brzo menjaju, što zahteva proaktivno upravljanje kompanijskim troškovima (troškovima goriva). Ovo podrazumeva stalnu potrebu za usaglašavanjem dve suprotstavljene vrednosti(smanjenje troškova i povećanje profita).

Različiti faktori, uključujući vreme, aerodinamiku, tip vozila, otpornost guma i usvojena praksa održavanja vozila mogu uticati na potrošnju goriva, ali postoje i drugi faktori koji se, uz primenu savremene tehnologije, mogu kontrolisati:

- prazan hod
- loše menjanje brzina
- preveliki broj obrtaja kolenastog vratila motora
- ubrzavanje
- krađa goriva.
- potrošnja goriva

Stavljanje pod kontrolu ovih parametara, omogućava transportnim i drugim kompanijama koje imaju flotu vozila, ogromne uštede u radu (do 30%).

e) Javni prevoz putnika

Savremeni sistemi upravljanja integrišu upravljanje autobuskim voznim parkom sa sistemom pojedinačne naplate karata kao i dodatnih sistema plaćanja (npr. mesečna karta) u jedan pogodan, bezbedan, integrisan i lak za upravljanje *(on-line)* transportni sistem.

Savremeno upravljanje javnim gradskim prevozom bazirano je na novom EFS data sistemu koji omogućava generisanje ugrađenih redovnih i *on-line* operacija.

Korišćenjem sistema *wireless data network* (GPRS) dobijenim od GSM operatera, podaci se kontinuirano prenose u glavnu kontrolu sobu dajući potrebne informacije pouzdano i tačno, u realnom vremenu, što omogućava efikasno upravljanje javnim gradskim prevozom.

ž) Prevoz dece – školski autobus

Primena savremenih rešenja za praćenje vozila omogućava obrazovnim instituicijama da upravljaju školskim autobusima i da adekvatno reaguju, po potrebi.

Time se sa lakoćom prati kretanja svih školskih autobusa i istovremeno primaju sva upozorenja za određene prekršaje (čekanje više od 15 minuta, nagla kočenja, nagla ubrzavanja, prekoračenje brzine i dr. (preko *e-pošte* ili SMS-a).

Ugradnjom savremenih uređaja za praćenje u autobuse, uključujući i autobuse sa đačkim ekskurzijama, omogućava se školama da lako identifikuju zloupotrebljena vozila, neautorizovana putovanja ili ulazak u oblast za koju autobus (vozač) nema ovlašćenje.

z) Održavanje vozila

Savremena rešenja za praćenje i upravljanje flotom vozila pružaju niz korisnih softverskih alata kako bi pomogli menadžerima flote vozila da ostvare efikasnu zaštitu, preventivno održavanje vozila i blagovremene popravke kritične za održavanje vozila i drugih sredstava voznog parka.

Savremena rešenja održavanja flote vozila omogućavaju da se snimaju, prate i analiziraju svi relevantni pokazatelji eksploatacije vozila, kao što su: vreme vožnje, troškovi koji nastaju operacijama flote, kontrolni zahtevi, potrošnja goriva, informacije o vozilu, nagla kočenja, nagla ubrzavanja, održavanje vozila, i dr.

Primena softvera kod upravljanja flotom vozila, posebno je značajna kod upravljanja u logističkom lancu (*supply chain management*), razvijenom po iskustvu 4PL-operacija *(Fourth Party Logistics) - četvorostranački posrednici kao potpuni logistički operateri, koji pokrivaju celokupni lanac isporuka – snabdevanja* [3].

Primena softvera omogućava efikasnije upravljanje javnim prevozom putnika, *Rent a Car* flotom vozila, *Taxi* - prevozom i dr.

Efekti primene savremenih sistema upravljanja flotom vozila

Flota vozila (vozni park) je skup svih prevoznih sredstava (vozila) auto transportne kompanije ili druge organizacije koja u svom sastavu ima prevozna sredstva (automobili, autobusi, teretna motorna vozila, vučna motorna vozila, prikolice i poluprikolice).

Savremeni sistemi upravljanja flotom vozila *(Fleet Management Systems)* zasnovani su na praćenju i kvalitetnoj obradi prikupljenih podataka od uređaja za praćenje instaliranih u vozilo - *IVMS (In Vehicle Monitoring System).* Ovi sistemi omogućavaju praćenje i snimanje ponašanja vozača tokom vožnje, u realnom vremenu, uz automatizovanje radnih procesa, što kompanijama omogućava povećanje prihoda, ali i smanjenje troškova.

U zavisnosti od vremena u kome se mogu pratiti i obrađivati podaci u procesu upravljanja, postoje *Off-line* i O*n-line* sistemi upravljanja flotom vozila, pri čemu su u svetu sve više prisutni savremeni sistemi praćenja i upravljanja flotom vozila u realnom vremenu (*On-line Fleet Management System*).

Za kvalitetno planiranje transportnih procesa i efikasno upravljanje flotom vozila neophodno je:

- poznavanje potražnje za transportnim uslugama,
- upravljanje radnim vremenom vozača (vreme vožnje i odmori vozača),
- upravljanje radom vozila, odnosno motora,
- kontinuirano održavanje i praćenje pouzdanosti flote vozila.

U okviru praćenja pouzdanosti flote vozila, neophodno je sukcesivno vršiti analizu pojedinih parametara:

- pređeni put vozila - pod opterećenjem i bez opterećenja,
- brzina kretanja vozila (saobraćajna brzina, prevozna brzina, brzina obrta).
- iskorišćenost i opterećenje vozila.

Osnovni efekti primene savremenih sistema upravljanja flotom vozila su:

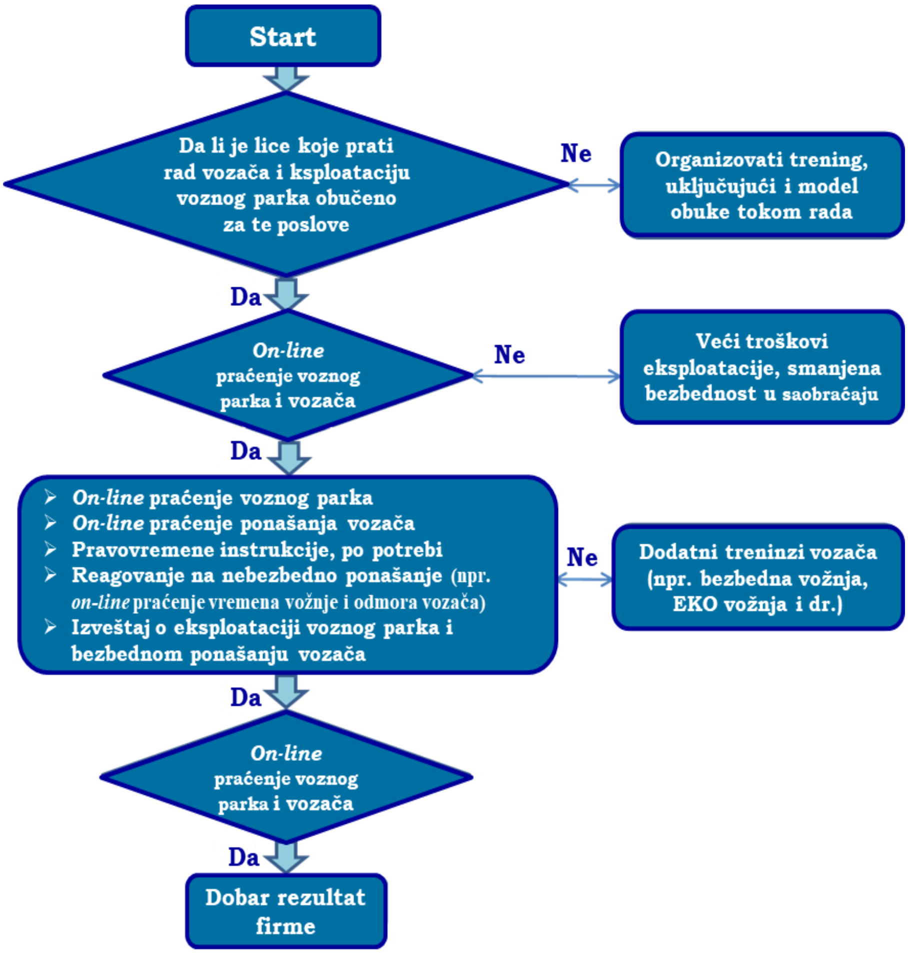
- unapređeno upravljanje flotom, odnosno transportom: mogućnost stalnog praćenja vozila u realnom vremenu, uz stalne povratne informacije („vozila koja komuniciraju“) i mogućnost korekcije prevoza (relacije i ponašanja vozača),
- veća bezbednost u saobraćaju (stvaranje uslova za smanjenje broja saobraćajnih nezgoda i posledica),
- unapređena opšta bezbednost i kontrola,
- brz i optimalan izbor rešenja (odluka) u složenim situacijama,
- povećanje produktivnosti, efikasnosti i profita,
- smanjenje troškova (optimizacija: *potrošnje goriva, održavanja vozila i grešaka tokom vožnje*),
- povećanje prihoda (optimizacija rute, bolja iskorišćenost flote vozila - bez suvišnih vožnji, mogućnost dodatnog korišćenja vozila, redukcija praznog hoda, omogućavanje prevoza različitih vrsta tereta),
- unapređeno snabdevanje i efikasan logistički lanac,
- zaštita životne sredine (smanjenje emisije SO2),
- snimljeni dokazi isporuke, automatizovani radni procesi, poboljšanje usluga i smanjenje opterećenja vozača.

PRIMERI RADA KONTROLNOG CENTRA I POSTIGNUTI REZULTATI

Poslovi i zadaci osoblja kontrolnog centra

Osoblje kontrolnog centra obavlja sledeće poslove:

- Prati kretanje vozila i bezbedno ponašanje vozača u saobraćaju;
- Prati putovanja prema zadatim parametrima i identifikuje sve neželjene radnje (npr. promena itinerera, nepoštovanje vremena vožnje i odmora itd.);
- Identifikuje: poštovanja brzine, (ne)korišćenje pojasa, naglo kočenje, naglo ubrzavanje, neželjeno zadržavanje itd.;
- Proverava da li sistem (IVMS) ispravno radi;
- U slučaju ugrožene bezbednosti vozača, prima signal i reaguje pravovremeno kako bi se obavestile službe za pružanje pomoći;
- Prati posebne uslove *(potrošnja goriva, temperatura u tovarnom prostoru*);
- Prati vremenske uslove i daje pravovremene informacije i savete vozačima i partnerima u logističkom lancu;
- Beleži sve aktivnost i vodi radni dnevnik učinka;
- Sačinjava ciljane i automatizovane izveštaje koji menadžerima daju jasnu sliku o iskorišćenosti i statusu flote vozila.

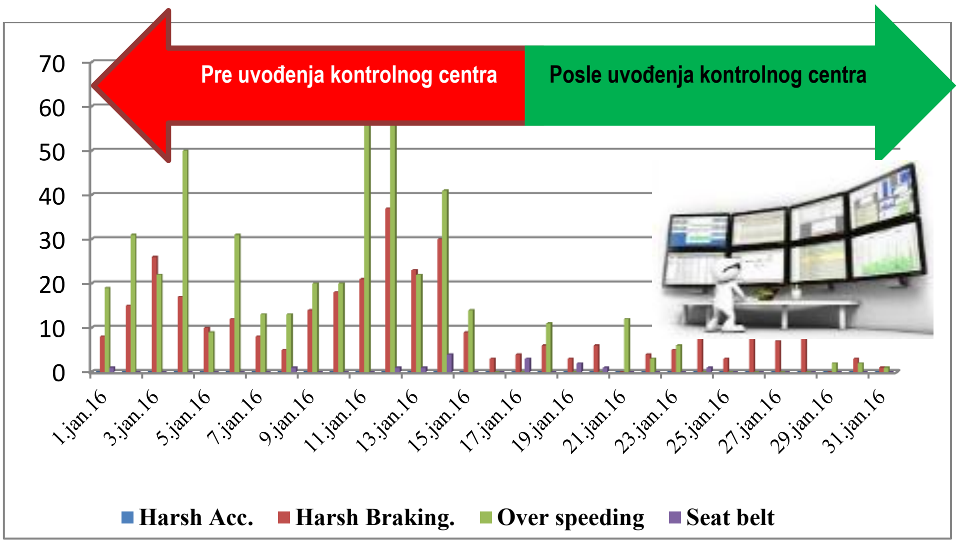


Slika 2. Algoritam rada kontrolnog centra, [4]
Figure 2. Algoritham of control centre operation, [4]

U slučaju nepoštovanja zadatih parametara ili nepoštovanja propisa u saobraćaju, odgovorno lice zaduženo za praćenje (ne) bezbednog ponašanja vozača u saobraćaju prati i vrednuje njihovo ponašanje i na osnovu ostvarenih rezultata nagrađuje savesne i odgovorne vozače ili preduzima mere u cilju unapređenja bezbednosne kulture vozača (edukacija, savetovanja, treninzi, kaznene mere i dr. (Sl. 2).

3.1. Primeri najbolje prakse u radu kontrolnog centra

Primer 1. *Flota od 90 teretnih vozila,* [5] *i 150 vozača*. Posmatrani parametri (greške ili prekršaji): naglo ubrzanje, naglo kočenje, prekoračenje brzine i (ne)korišćenje sigurnosnog pojasa.

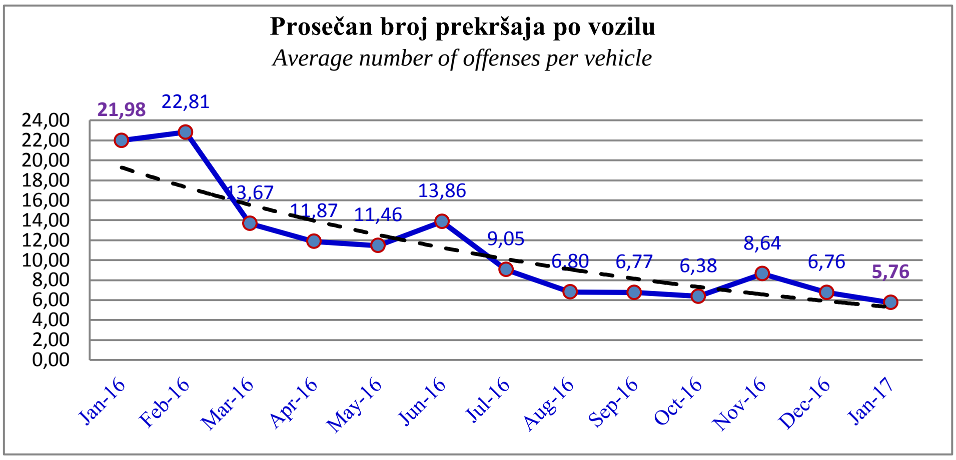


Grafik 1. Primer uspostavljanja rada kontrolnog centra. Rezultat: unapređeno bezbedno ponašanje vozača za 95 % u drugoj polovini meseca, [4]

Graph 1. Exapmle after establiscment of Control centre. The result: improved safety behavior for drivers by 95% in the second half of the month, [4]

Grafik 1. daje prikaz posmatranih parametara ponašanja vozača (greške ili prekršaji) tokom meseca januara 2016. godine, na floti od 90 teretnih vozila i 150 vozača. Vidi se da je posle uspostavljanja rada kontrolnog centra unapređeno bezbedno ponašanje vozača za 95 % u drugoj polovini meseca januara [4] .

Primer 2. *(7.500 motornih vozila* [5], *i 14.730 vozača - dat je prosečan broj prekršaja, po vozilu, na mesečnom nivou).*



Grafik 2. Unapređeno bezbedno ponašanje vozača za 74 % , [4]

Graph 2. Improved safety behavior for drivers by 74% , [4] Na *Grafiku 2.* dat je prikaz posmatranih parametara ponašanja vozača (greške ili prekršaji): *naglo ubrzanje, naglo kočenje, prekoračenje brzine i (ne)korišćenje sigurnosnog pojasa*, u periodu: januar 2016. – januar 2017. godine, na 7.500 motornih vozila [5] i 14.730 vozača. Vidi se da je za 13 meseci rada kontrolnog centra unapređeno bezbedno ponašanje vozača za 74% [4].

ZAKLJUČAK

Savremeni sistemi upravljanja flotom vozila *(Fleet Management Systems)* baziraju se na telematici, odnosno na podacima dobijenim od uređaja za praćenje instaliranih u vozilo (IVMS). Ovi sistemi omogućavaju praćenje i snimanje ponašanja vozača tokom vožnje i automatizovanje radnih procesa, što je osnova za efikasno upravljanje i optimizaciju prevoza.

Zahvaljujući primeni telematike, omogućeno je efikasno upravljanje flotom vozila, radom (ponašanjem) vozača (nagla kočenja, nagla ubrzavanja, vreme vožnje i odmori), radom vozila, odnosno motora, održavanjem vozila i praćenjem pouzdanosti flote vozila.

Primenom savremenih sistema upravljanja flotom vozila *(Fleet Management Systems)* stvaraju se preduslovi za bolju organizaciju rada, veću bezbednost u saobraćaju, povećanje produktivnosti i prihoda, smanjenje troškova (optimizacijom: potrošnje goriva, održavanja vozila i grešaka - prekršaja u saobraćaju) i drugih faktora .

Efekti primene sistema upravljanja flotom vozila, u vidu odgovarajućih ušteda, dati su kroz primer statističke analize prikupljenih informacija i parametara za određenu flotu vozila, na određenom području.

Prikazani rezultati u ovoj analizi, praćeni i obrađeni od strane kontrolnog centra, ukazuju da se primenom savremenih sistema upravljanja flotom vozila može značajno uticati na unapređenje bezbednog ponašanja vozača, što kompanijama podiže ugled i donosi velike uštede.

LITERATURA

[1] Strategija bezbednosti saobraćaja na putevima Republike Srbije za period od 2015. do 2020. g. *("Sl. glasnik RS", br. 64/2015, str. 1).*

[2] Alkassar, B. 2017. Osnivač i generalni direktor Kompanije FMS Tech. Dallas, Texas, USA; (Profil Kompanije FMS Tech. - *Fleet Management Systems & Technologies)*, Beograd.

[3] Drašković M. 2008. *Evolucija sistemskih logističkih provajdera,* Montenegrin Journal of economics, N^{o}8. str.119 – 127. Podgorica.

[4] Hadžić D. 2017. *Kompanija „Petroleum Development Oman"; Istraživanje integrisanog upravljanja putovanjima (primer dobre prakse),* Maskat, Oman.

[5] Zakon o bezbednosti saobraćaja na putevima; član 7. tačke 33 i 44; *("Sl. glasnik RS", br. 41/2009, 53/2010, 101/2011, 32/2013 - odluka US, 55/2014, 96/2015 - dr. zakon, 9/2016 - odluka US i 24/2018)*

MODERN FLEET MANAGEMENT SYSTEMS

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Abstract: Modern fleet management systems allow managers to effectively manage and optimize transport, which by its effects go way beyond the traditional approach to fleet management.

These systems allow efficient control of vehicle use and fuel consumption, a review of historical data on the vehicles movements, monitoring driver behavior while driving and the engine running, the recording of certain offenses (speeding, non-use of safety belts, etc.), tracking vehicle maintenance, reducing direct and indirect costs and the recording of specific events.

Key words: *fleet management systems, heavy vehicle, safety, cost, transport, control, optimization.*

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FIELD PERFORMANCE ANALYSIS OF A TRACTOR-DRAWN TURMERIC RHIZOME PLANTER

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Abstract: A field performance analysis of a developed prototype tractor-drawn turmeric planter is presented. The experiment was randomized in a factorial design of three planter levels of rhizome lengths (30, 45 and 60 mm) and operational speeds of 8, 10, and 12 kmh^{-1}. An average mass of 3 kg of wholesome turmeric rhizomes were introduced into the hopper of the planter and planted in 90 m^2 of experimental plot. During field evaluation of the machine, the effective field capacity, field efficiency, missing index, multiple index and planting depth were considered; whereas laboratory tests were conducted to evaluate the planter's seed rate, percentage rhizome bruise wheel slippage and fuel consumption. Results obtained show that the maximum seed rate was 0.283 th^{-1}. The maximum percent bruised turmeric rhizome was found to be 30.08%. The mean effective field capacity varied between 0.63 - 0.96 hah^{-1}, at operational speeds of 8 and 12 kmh^{-1}, respectively and 45 mm rhizome length. The mean field efficiency was obtained to be 65.8%. The maximum wheel slippage of 4.37% and fuel consumption of 3.8 lha^{-1} were obtained at the machine speeds of 8 kmh^{-1} and 12 kmh^{-1}, respectively; whereas the minimum wheel slippage of 3.14% and fuel consumption of 2.2 lha^{-1} were obtained at the machine speeds of 12 kmh^{-1} and 8 kmh^{-1}, respectively for the range of the studied turmeric rhizome length. The highest and lowest percentage turmeric rhizome miss index of 35% were recorded for turmeric rhizome length of 30 mm at a speed of 10 kmh^{-1} and 8 kmh^{-1}, respectively. An average planting depth of 68 mm was obtained. The numerical optimization approach was adopted to obtain an optimal operational parameters of 12 kmh^{-1} speed and 45 mm turmeric rhizome grading size with an overall desirability index of 0.73. An economic evaluation was calculated using the principle of payback period which was obtained to be very small (1.64 years) compared to the life of the planter of 17 years. Prospects for future works were suggested.

Keywords: *Turmeric rhizome, field evaluation, optimization, performance parameters, planter.*

INTRODUCTION

Turmeric (*Curcuma Longa Linn*) is a stem tuber crop. It belongs to the same family as ginger (Zingiberaceae) and grows in the same hot and humid tropical climate. In Nigeria, turmeric is cultivated mostly on subsistent bases in about 19 states and given different local names depending on the area.

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It is called *atale pupa* in Yoruba; *gangamau* in Hausa; *nwandumo* in Ebonyi; *ohu boboch* in Enugu (Nkanu East); *gigir* in Tiv; *magina* in Kaduna; *turi* in Niger State; *onjonigho* in Cross River (Meo tribe) [1]. It is native to India and Southeast Asia. India is the largest producer, consumer and exporter of turmeric. Indian turmeric has been known to the world since ancient times. It has been used as a dye, medicine and flavoring since 600 BC [2]. To most people in India, from housewives to Himalayan hermits, turmeric is affectionately called the 'Kitchen Queen', the main spice of kitchen [3]. It has many nutritional and medicinal advantages [4 - 6].

In spite of increasing demand for derived products of turmeric in Nigeria which makes its large scale production attractive, it is still cultivated mainly in small plots around homes. In Nigeria, turmeric has not gained the desired attention that will boost its large scale production. From researches carried out, turmeric has little or no mechanization in its production processes from planting to harvesting in Nigeria.

The only mechanization of turmeric production in Nigeria is the land preparation (ploughing and harrowing). Turmeric, if fully mechanized, will ensure timeliness of operation in the farm and reduce cost and drudgery associated with planting, mulching and harvesting. There is a strong research support for cultivation of turmeric on scientific lines, as National Root Crops Research Institute Umudike, Nigeria and its Research Stations located in many states in Nigeria are conducting a multi-locational trial of many turmeric accessions to ensure official release for cultivation by Nigerian farmers.

Planting of turmeric has been a challenge to the farmers in Nigeria due to lack of planting machines. The farmers are left to the traditional method of planting with hoes and cutlasses. This method is time consuming, labour intensive, and associated with human drudgery and human energy intensive. It was noted that farm operations are timely by nature, and whatever help shortens the time required for planting operation will help circumvent the effect of adverse weather conditions [7]. To achieve food security through large scale production of crops with high prospects such as turmeric, there is much need to provide a planting aid to Nigerian farmers to alleviate their suffering and improve the dignity of farm work. However, the recent climatic change which results in delayed early rain and short duration of annual rainfall affects the maturity of the turmeric rhizomes due to the long time taken in manual planting of turmeric. In most cases, turmeric does not attain 7 – 9 months maturity before rainy season elapses due to delay as a result of time spent in the use of manual operation. Bearing in mind the above points, this study was carried out with the objective of analyzing the field performance of a developed tractor-drawn turmeric planter, optimizing its operational parameters as well as the economic evaluation.

MATERIAL AND METHODS

Experimental design and optimization

To evaluate the performance of the planter, three levels of rhizome length (30, 45 and 60 mm) and planter speed variables (8, 10, and 12 kmh^{-1}) were randomized in a general factorial design to carry out the field experiment. The relative contributions of each of the independent variables to response variables (V_r) were determined as shown in Table 1.

Table 1. Levels of experimental independent variables of the randomized factorial design layout.

Independent variables	***Symbols***		***Levels***	
	Actual	***Coded***	***Actual***	***Coded***
			8	*-1*
Speed (kmh^{-1})	*S*	*A*	*10*	*0*
			12	*1*
			30	*-1*
Rhizome grade (mm)	R_g	*B*	*45*	*0*
			60	*1*

The data were subjected to analysis of variance (ANOVA) using design expert software. Optimization of operational parameters of the tractor-drawn turmeric planter was done using the technique of multivariate response of numerical optimization, referred to as desirability index [8, 9] expressed in Eq. (1) as:

$$D_i = [\sum_{i=1}^{n}(V_r)]^{\frac{1}{n}} \tag{1}$$

Where: D_i = desirability index; V_r is the response variable (planted rhizome, missing, bruise, and multiple); n is the total number of responses = 4; $0 \leq D_i \leq 1$; with 0 and 1 representing the minimum and maximum desirable coded levels, respectively.

D_i shows the degree of compatibility or how desirable the response variables are at any given experimental input variable. The goal of numerical optimization is to maximize planted rhizome, minimize missing, bruise, and multiple indices. This study considered the goal for the independent variables (operational speed and grading size) at any process level within the ranges of the design values, whereas the response variables have minimum missing, bruises, and multiple planting as the goal. The optimal solution of the system, which represents the best functions of the planting process is indicated by the high value of D_i. The optimum experimental factor values were obtained from the four response variables that maximize D_i [9, 10].

Experimental Procedure

Calibration

Calibration was necessary to ascertain optimal performance of the planter. The hopper units were loaded with turmeric rhizomes. The ground wheel was jacked up for free turning of the drive wheels. Marks were made on the drive wheels and the body of the planter for easy and convenient counting of the drive wheel complete revolution. The numbers of turmeric rhizomes dropped within five revolutions of the drive wheel were recorded for three different turmeric rhizome lengths. The turmeric rhizomes were also investigated for visible damages.

A 90 x 90 m^2 field located at the Federal University of Technology, Minna farm site, was ploughed and harrowed in readiness for the testing operation. The field was sub divided into smaller plots of 30 x 30 m^2. Cleaned turmeric rhizomes were obtained from National Root Crops Research Institute (NRCRI) Nyanya sub-station, Abuja - Nigeria. The rhizomes were sorted into 30, 45 and 60 mm lengths to determine the required length for optimum performance. The planter was hitched to Eicher 5660 tractor make, loaded with turmeric rhizome and then planted on the 30 x 30 m^2 sub plots at three different operational speeds of 8, 10 and 12 kmh^{-1} (Fig. 1). The different field performance evaluation tests of the tractor-operated turmeric planter involved:

1. Test for seed rate and percent rhizome bruise/damage.
2. Evaluation of the viability of the planter through field performance tests to measure the miss index, multiple index, planting depth, effective field capacity (E_{fc}), field efficiency (E_f), fuel consumption and wheel slippage.

Figure 1. Field test of the turmeric planter.

Rhizome bruise test

The test for percent rhizome was achieved by loading 0.5 kg of turmeric rhizome in the hopper and planting without the furrow closing device for physical observation of the rhizomes. The number of discharged turmeric rhizomes that were damaged mechanically including any significant bruise to the bud or crushing were recorded. The procedure was repeated for three times and their percentage was calculated as the seed bruise percentage using Eq. (2) [11]:

$$R_b\% = \frac{Rb_n}{N_R} \times 100 \quad (2)$$

Where: R_b = turmeric rhizome bruise (%); Rb_n = number of turmeric rhizome bruise; N_R = total number of turmeric rhizomes.

Miss index

The miss index is the ratio of the number of spacing greater than 1½ times the theoretical spacing (set spacing and total number of measured spacing) [11]. Misses were recorded along a randomly selected 10 m length of each planted row with the covering devices removed. Misses or skips were created when seed grooves fail to pick and deliver seeds to the delivery funnels. The missing percentage is expressed in Eq. (3) as [11]:

$$M_I = \frac{n_s}{N} * 100 \quad (3)$$

Where: M_I = Missing index (%); n_s = number of skips; N_t = total number of spacing.

Multiple index

The multiple index (D_I) is the percentage of spacing that are less than or equal to half of theoretical (nominal) spacing and indicates the percentage of multiple rhizome drop. Multiples were created when more than one turmeric rhizome is delivered by the groove. Multiples were also counted along a randomly selected 10 m segment of each planted row. This was measured from 10 m of planted rows and calculated using the Eq. (4) [12]:

$$D_I = \frac{n_d}{N} * 100 \quad (4)$$

Where: D_I (%); n_d = number of multiple dropping at the same spot; N = total number of spacing.

Planting depth

Depth of planting was monitored and measured along the row at a distance of 5m at four randomly selected locations. For good sprouting, planting depth of turmeric rhizome ranges from 5 - 10 cm [13]. However, this was done by adjusting the furrow opener to accommodate depth of 5 to 10 cm and lifting the furrow closer in order for the machine to be operated without the furrow covering mechanisms. The depth at which the rhizomes were placed was estimated vertically upward to the soil surface with the aid of a measuring rule.

Effective field capacity and field efficiency

The time taken to cover the field was recorded and the planter width was measured using a steel measuring tape. The effective field capacity (C_{eff}), theoretical field efficiency (C_{th}) and field efficiency (E_f) were calculated using Eqs. (5) to (7), respectively [11]:

$$C_{eff} = \frac{A_f}{T} \tag{5}$$

$$C_{th} = \frac{S * W_e}{10{,}000} \tag{6}$$

$$E_f = \frac{C_{eff}}{C_{th}} * 100 \tag{7}$$

Where: A_f = area of field covered (m^2); T = total time of operation (hr); C_{eff} = effective field efficiency (hah^{-1}); C_{th} = theoretical field efficiency (hah^{-1}); E_f = field efficiency (%).

Fuel consumption

The fuel tank of Eicher-5660 tractor was filled to the brim prior to field test. After planting, the tractor fuel tank was refilled to the brim using a graduated cylinder to estimate the quantity of diesel required. The quantity of fuel consumed per hectare was calculated using Eq. (8):

$$F_t = \frac{F_c}{A*1000} \tag{8}$$

Where: F_t = total quantity of fuel consumed (lha^{-1}), Fc = fuel consumed (ml), A = area of field covered (ha).

Wheel slippage

The amount of slippage in the drive wheels of the planter was measured by recording the distance travelled by the drive wheels at five revolutions on no load. Thereafter, three replications of the number of revolutions were recorded when operated under load and the average calculated. The percent wheel slippage was calculated as expressed in Eq. (9):

$$S_w = \frac{L_1 - L_2}{L_1} \tag{9}$$

Where: S_w = wheel slippage (%); L_1 and L_2 = distance travelled under no-load (m) and theoretical distance travelled under load (m), respectively.

RESULTS AND DISCUSSION

Seed rate and percent rhizome damage

The result of the effect of operational speed at varying turmeric rhizome lengths on the mean seed discharge rate is presented in Figure 2. Increase in machine operational speed and turmeric length increased the seed discharged rate. At reduced operational speed and longer rhizome lengths, the rhizomes blocked the hopper discharge chute as there was insufficient vibration due to reduction in speed to cause agitation of the rhizomes in the hopper.

The maximum and minimum seed rate of 0.283 th^{-1} and 0.147 th^{-1}, respectively were obtained at machine speeds and rhizome lengths of 12 and 8 kmh^{-1}, and 60 and 30 mm, respectively.

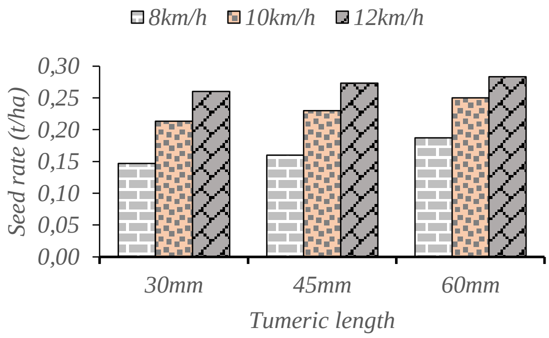

Figure 2. Effect of turmeric lengths at varying speeds on seed discharge rate.

Analysis of variance (ANOVA) conducted indicates that the machine operating speed has significant effect on the seeding rate of the turmeric rhizome planter ($P < 0.05$) as shown in Table 2. Increase in machine speed increases the seed rate as reported by Kalay and Moses [17]. The result further suggests that the interaction between the operating speed of the machine and the turmeric rhizome length has a good significant effect on the seeding rate of the turmeric planter ($P < 0.05$), whereas as rhizome grade was statistically insignificant to seed rate at $P < 0.05$.

Table 2. Analysis of variance for evaluation of seed rate.

Source	Sum of Squares	Df	Mean Square	F-value	P-value (Prob > F)	Remark
A- Speed	21.407	2	10.704	5.255	0.0159	*
B- Rhizome grade	1.407	2	0.704	0.345	0.7125	ns
A*B	33.925	4	8.481	4.164	0.0147	*
Residual	36.667	18	2.037			
Cor. Total	93.407	26				

** and ns denote significant and non-significant effects at P < 0.05, respectively.*

The percent bruised turmeric rhizome was affected by machine operational speed (Figure 3). The percent turmeric damage increases with increase in the operational speed of the machine for the 30 mm rhizome length. At maximum operational speed of 12 kmh^{-1}, the percent rhizome damage decreased to 15%. This is because, at higher speed the machine's metering device tends to pick turmeric rhizomes at a quicker rate, thus reducing sharing force between adjacent rhizomes in the hopper which results in bruises. ANOVA results obtained from field test (Table 3) indicate that machine operating speed and turmeric rhizome lengths as well as their interaction effect did not affect the planting operation at 5% level of probability.

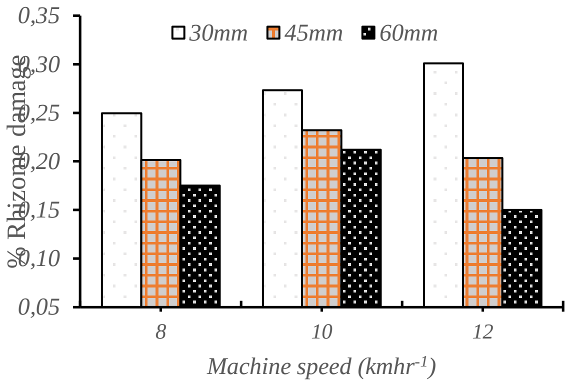

Figure 3. Effect of machine speed on percentage rhizome damage at varying rhizome lengths.

Table 3. ANOVA result for evaluation of percent turmeric rhizome damage.

Source of variation	Sum of Squares	Df	Mean Square	F-value	P-value (Prob > F)	Remark
A - Speed	1.407	2	0.704	0.297	0.7467	ns
B – Rhizome length	12.074	2	6.037	2.547	0.1062	ns
A*B	5.926	4	1.481	0.625	0.6507	ns
Residual	42.667	18	2.370			
Cor. Total	62.074	26				

ns denotes non-significant effects at P < 0.05.

Effect of rhizome length and operational speed on effective field capacity and field efficiency of the turmeric planter

The effective field capacity of planters depends on the operational speed [11, 15]. Field test results (Table 4) show that increase in the machine operational speed resulted in an increase in field capacity of the machine at constant turmeric rhizome length, which agrees with the report of Kalay and Moses [17]. It was observed that the mean effective field capacity of the turmeric planter ranges between 0.63 - 0.96 hah^{-1}. The maximum and minimum field capacities were obtained at 12 kmh^{-1} and 8 kmh^{-1}, respectively at 45 mm rhizome length. This could be as a result of decreased wheel slippage of the planter which increases its operational speed which resulted in increased effective field capacity. Researchers [11, 14]; Mohamed et al. [11] reported that reducing planter's wheel slippage increases its operational speed. Table 3 further illustrates that the best field capacity of the studied turmeric planter was obtained when the rhizome length of 45 mm was planted at the operational speed of 12 kmh^{-1}. ANOVA results show that turmeric rhizome length and its interaction effect with speed were not statistically significant ($P < 0.05$) to the effective field capacity of the planter (Table 5). This was as a result of the close range of mean field capacity values for 45 and 60 mm rhizome lengths at maximum operational speed of 12 kmh^{-1}.

Table 4. Turmeric planter field test for all observed parameters at varying rhizome lengths and operational speeds.

Rhizome length (mm)	Machine speed (kmh^{-1})	Mean field capacity (hah^{-1})	Efficienc y (%)	Fuel consumption (lha^{-1})	Whee l slippage (%)
	8	0.65	62.4	2.5	4.19
30	10	0.82	64.6	3.2	3.71
	12	0.92	68.3	3.8	3.26
	8	0.63	60.5	2.3	4.22
45	10	0.68	62.9	2.8	3.86
	12	0.96	69.8	3.4	3.26
	8	0.64	63.4	2.2	4.37
60	10	0.84	64.2	3.0	3.62
	12	0.95	67.3	3.5	3.14

The mean field efficiency was higher at increasing operational speed. It ranges between 60.5 to 69.8%, with the maximum value obtained at operational speed of 12 kmh^{-1}for rhizome length of 45 mm. The average field efficiency obtained from the field is 65.8%. This is an indication of a satisfactory performance as it is within the 50 – 75% range of field efficiency of row-crop planters [7]. Analyses of variance (Table 6) indicated no significant difference between operational speeds of the planter at varying rhizome lengths as well as speed-rhizome length interaction effect on the field efficiency. Similar findings were observed by Mohamed et al. [11], Oduma et al. [15] and Raghavendra and Veerangeouda [16].

Table 5. Analysis of variance table for effective field capacity.

Source	*Df*	*Sum of Squares*	*Mean Square*	*F-value*	*P-value (Prob > F)*	*Remark*
Rep	*2*	*9.487*	*4.7435*	*-*	*-*	
A - Speed	*2*	*17.452*	*8.6710*	*0.297*	*0.0371*	***
B - Rhizome length	*2*	*3.957*	*1.9735*	*2.547*	*0.1852*	*ns*
*A*B*	*4*	*22.703*	*5.6758*	*0.625*	*0.4962*	*ns*
Residual	*18*	*48.922*	*2.7179*			
Cor. Total	*28*	*102.521*				

** and ns denote significant and non-significant effects at P < 0.05, respectively.*

Table 6. Analysis of variance table for field efficiency.

Source	*Df*	*Sum of Squares*	*Mean Square*	*F-value*	*P-value (Prob > F)*	*Remark*
Rep	*2*	*7.926*	*3.963*	*-*	*-*	
A - Speed	*2*	*10.502*	*5.251*	*0.642*	*0.451*	*ns*
B - Rhizome length	*2*	*5.327*	*2.664*	*1.971*	*0.502*	*ns*
*A*B*	*4*	*18.931*	*4.733*	*1.203*	*0.921*	*ns*
Residual	*18*	*38.792*	*2.155*			
Cor. Total	*28*	*81.480*				

ns denotes non-significant effect at P < 0.05.

Effect of rhizome length and operational speed on wheel slippage and fuel consumption of the turmeric planter

Table 4 indicates that wheel slippage varies inversely with fuel consumption and operational speed. The maximum wheel slippage and fuel consumption (4.37% and 3.8 lha^{-1}, respectively) were obtained at the operational speeds of 8 kmh^{-1} and 12 kmh^{-1}, respectively; whereas the minimum wheel slippage and fuel consumption (3.14% and 2.2 lha^{-1}, respectively) were obtained at the operational speeds of 12 kmh^{-1} and 8 kmh^{-1}, respectively for every rhizome length. However, the range of the wheel slippage values obtained from this study is adequately close to the recommended slippage value of 5.7% [11, 16]. Statistical analysis (Table 7) shows that no significant effect exists in the wheel slippage and rhizome lengths, as well as their interaction ($P < 0.05$). Table 8 shows that variation in operation speed and the interaction effect of speed and rhizome lengths were statistically significant ($P < 0.05$) on fuel consumption rate, whereas varying rhizome lengths had no significant effect ($P < 0.05$). It is pertinent to point out that an average of 32.37% of fuel was consumed at varying wheel speeds of the planter at all rhizome lengths.

Table 7. Analysis of variance table for wheel slippage of the turmeric planter.

Source	*Df*	*Sum of Squares*	*Mean Square*	*F-value*	*P-value (Prob > F)*	*Remark*
Rep	*2*	*2.083*	*1.0415*	*-*	*-*	
A - Speed	*2*	*0.982*	*0.491*	*1.431*	*0.716*	*ns*
B - Rhizome length	*2*	*1.512*	*0.756*	*1.621*	*0.862*	*ns*
*A*B*	*4*	*11.053*	*2.7633*	*0.225*	*0.287*	*ns*
Residual	*18*	*22.608*	*0.8074*			
Cor. Total	*28*	*38.238*				

ns denotes non-significant effects at P < 0.05.

Table 8. Analysis of variance table for fuel consumption of the turmeric planter.

Source	Df	Sum of Squares	Mean Square	F-value	P-value (Prob > F)	Remark
Rep	2	6.213	3.1065	-	-	
A - Speed	2	3.263	1.6315	13.523	0.0279	*
B - Rhizome length	2	5.042	2.521	7.231	0.0634	ns
A*B	4	16.114	4.029	10.541	0.0311	*
Residual	18	34.108	1.8949			
Cor. Total	28	64.74				

** and ns denote significant and non-significant effects at P < 0.05, respectively.*

Effect of operational speed on miss index at varying rhizome lengths

Figure 4 shows the variation of missing index with increasing operational speed of the planter. Miss percentage tend to decrease with increase in turmeric rhizome length at constant operational speed except for a speed of 8 kmh^{-1} where an increase in the miss index was observed. Increasing the operational speed to 12 kmh^{-1} at increasing rhizome lengths reduces the percent miss index of the planter. This observation is contrary to the findings of Singh and Gautam [12] for planting of corms. The highest percentage turmeric rhizome miss index of 35% was recorded for turmeric rhizome length of 30 mm at machine operational speed of 10 kmh^{-1}, whereas the lowest percentage turmeric rhizome miss index of 15% was obtained for turmeric rhizome length of 60 mm at the machine operational speed of 12 kmh^{-1}. This is because shorter rhizome lengths tend to fall out much easily than the longer ones, as more than one turmeric rhizome tend to fall from the hopper to the metering system. ANOVA result (Table 9) indicates that the machine operating speed has significant effect on the miss index of the turmeric rhizome ($P < 0.05$), whereas rhizomes lengths were non-significant to miss index (at $P > 0.05$). The results of the analysis also suggest that the interaction between the operating speed of the machine and the turmeric rhizome lengths were significant on the miss index of the turmeric planter ($P < 0.05$).

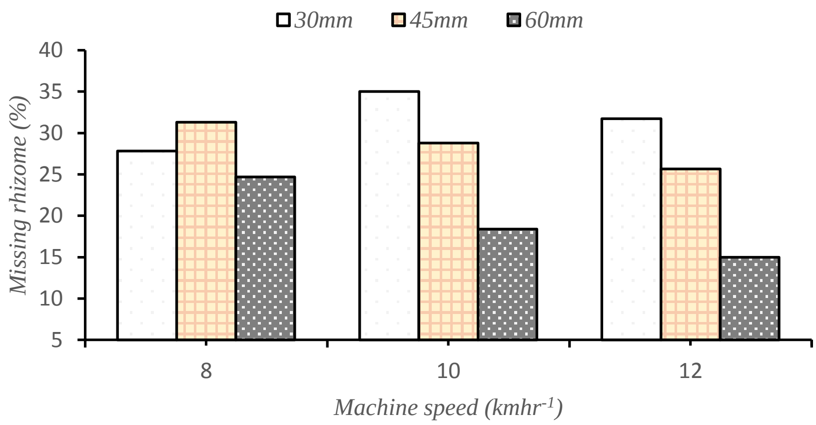

Figure 4. Influence of operational speeds and rhizome lengths (grade) on missing

Table 9. Analysis of variance table for missing index of the turmeric planter.

Source	Df	Sum of Squares	Mean Square	F-value	P-value (Prob > F)	Remark
A - Speed	2	15.630	7.815	3.576	0.0492	*
B - Rhizome length	2	3.630	1.815	0.831	0.4519	ns
A*B	4	32.370	8.093	3.703	0.0228	*
Residual	18	39.333	2.185			
Cor. Total	26	90.963				

** and ns denote significant and non-significant effects at P < 0.05, respectively.*

Multiple index

The results of the test conducted on the effect of operational speed of the planter on the multiple index for various levels of turmeric rhizome length is shown in Figure 5. The multiple index of the machine decreases with increase in the turmeric rhizome length and operational speed. The highest multiple index of 35% was recorded for turmeric rhizome length of 30 mm at lowest operational speed of 8 kmh^{-1} This implies that as the rhizome length increases, the multiple index reduces. The smaller size of rhizomes tends to metered out faster than the longer lengths due to their short length which enables them to fall out freely. This result is not in accordance with the observations of Kalay and Moses [17], and Singh and Gautam [12] for okra seed and corm planters, respectively. The results of analysis of variance (Table 10) shows that both operational speed and rhizome length as well as the interaction effect of speed and rhizome length were all statistically significant at 5% level of probability.

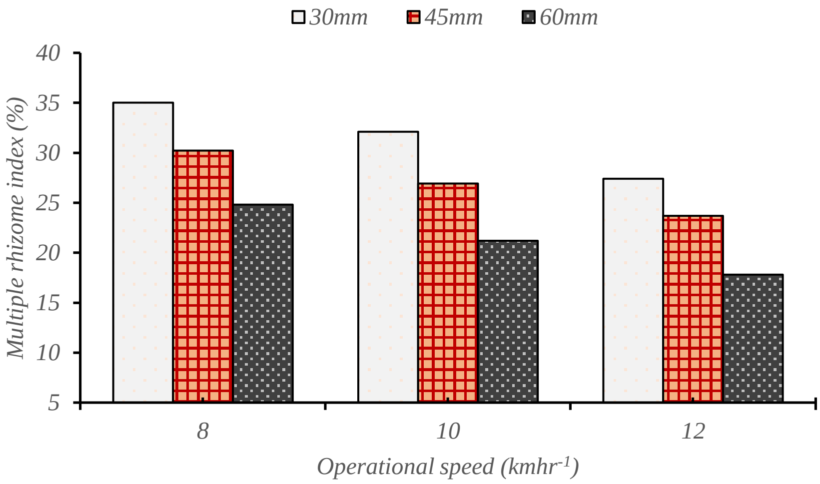

Figure 5. Influence of operational speeds and rhizome lengths (grade) on multiple index.

Table 10. Analysis of variance table for multiple index of the turmeric planter.

Source	Df	Sum of Squares	Mean Square	F-value	P-value (Prob > F)	Remark
A - Speed	2	6.740741	3.37037	8.2727	0.0028	*
B – Rhizome length	2	20.96296	10.48148	25.727	0.0001	*
A*B	4	1.703704	0.425926	1.0454	0.04114	*
Residual	18	7.333333	0.407407			
Cor. Total	26	36.74074				

* denotes significant effect at $P < 0.05$.

Planting depth

The results of planting depth of the machine are as shown in Table 11. The mean depth of planting observed and measured was 68 mm for all operational speeds and rhizome lengths. This depth of planting is within the agronomists' recommended range of 50 -100 mm for turmeric by agronomist [13].

Table 11. Result of planting depth

Replication	Planting Depth (mm)
I	73
II	56
III	82
Total	272
Mean	68

Optimization of Planter Parameters

The result for the optimization of operational parameters of the tractor-drawn turmeric planter is shown in Table 12. Constraints were set before optimizing the planter parameters. These constraints include the optimization goal to obtain the best planting operation across the range of speed of 8 to 12 kmh^{-1}, turmeric grading size between 30 to 60 mm and to minimize missing, bruises and multiple planting. Nine (9) optimize solutions were generated by the Design Expert software for all possible combinations to achieve all goals set for the optimization. The best optimized range of solutions recommended for using the developed turmeric rhizome planter is at machine operational speed of 12 $kmh^{-1}$and turmeric rhizome grading size of 45 mm with a maximum desirability index of 0.73 at 95% confidence level, represented with a bar chart (Figure 6), which further illustrates the best operating input variables of the planter.

At these optimal input conditions of 12 kmh^{-1} and 45 mm of speed and rhizome length, respectively, the goals of the corresponding response variables (depth of planting, missing, bruised, and multiple) were achieved within the limits with different desirability indexes as shown in Table 13. As the desirability index approaches unity, the better are the treatment combinations for optimizing the operating parameters of the turmeric planter [18]. The desirability index illustrates how desirable the response variables are at any given experimental input variable. It indicates the optimal solution of the turmeric planter, which represents the best functions of the planting process.

Table 12. Conditions for optimal operational parameters of turmeric planter.

Name	*Goal*	*Lower limit*	*Upper limit*	*Lower weight*	*Upper weight*	*importance*
Speed (kmh^{-1})	*In range*	*8*	*12*	*1*	*1*	*3*
Rhizome grading (mm)	*In range*	*30*	*60*	*1*	*1*	*3*
Planted	*Maximize*	*9*	*17*	*1*	*1*	*3*
Missing	*Minimize*	*3*	*11*	*1*	*1*	*3*
Bruised	*Minimize*	*2*	*8*	*1*	*1*	*3*
Multiple	*Minimize*	*2*	*7*	*1*	*1*	*3*

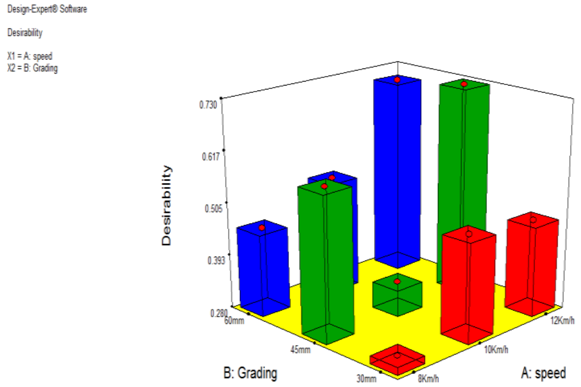

Figure 6. Desirability chart of the optimal operating conditions of turmeric planter.

Table 13. Desirability index at optimum values of the input and response variables of turmeric planter.

Speed (kmh^{-1})	*Rhizome grading (mm)*	*Planted*	*Missing*	*Bruised*	*Multiple*	*Desirability*
12	*45*	*14.66*	*5.33*	*3.00*	*3.66*	*0.73*
12	*60*	*13.67*	*6.33*	*3.00*	*2.67*	*0.70*
8	*45*	*14.00*	*6.00*	*4.00*	*4.67*	*0.59*
10	*60*	*12.00*	*8.00*	*3.67*	*3.33*	*0.52*

Economic Evaluation

Cost analysis

The cost analysis for the tractor drawn turmeric planter is classified into three [20]: cost of material, labour cost, and overhead cost. The overhead cost includes the cost of feeding, transportation and miscellaneous expenses incurred during the construction of the equipment which is taken as 60% of labour cost [19]. The total cost of materials is estimated at N 181,470. The labour cost is taken as 30% of material cost = N 54, 441 [20]; whereas the overhead cost is estimated at 60% of labour cost = N 32, 664.60. The total cost of planter fabrication is the sum of the three costs = N 268,575.60.

Payback analysis

The soil condition of Minna, Niger State, located in the Southern Guinea Savanna of Nigeria allows the use of tractor-drawn turmeric planter for planting of turmeric rhizomes between the months of April and June (78 days). This is the basis for the payback analysis of the turmeric planter. The associated costs of planting turmeric rhizomes in Minna and economic variables based on the current Nigeria's economic situation are presented in Table 14. Applying these data, the payback period was estimated using Eq. (10) expressed as [20, 21]:

$$\text{Payback period} = \frac{\text{Initial investment}}{\text{Annual net undiscounted benefits}} \tag{10}$$

The payback period is calculated as the time needed for the cost of investment to equal the return. In the case of the turmeric planter, a very small payback period of 18 months (1.64 years) was estimated compared to the planter life span of 17 years. This implies that the planter would plant turmeric rhizomes at no cost for almost its entire life time.

Table 14. Payback period of the tractor-drawn turmeric planter.

Cost of planter	*$ 504.08*
Planter hopper capacity (39.22kg x 3)	*117.7kg*
Depreciation	*$ 50.41*
Planter life	*17 years*
Cost of maintenance (for three months)	*$8.33*
Cost of labour (30% of planter cost)	*$ 151.23*
Cost of diesel during planting ($ 4.17 x 78 days)	*$ 325.36*
Cost of raw turmeric rhizome ($0.13 x 117.7kg x 78 days)	*$ 1,285.28*
Total cost	*$ 1, 810.05*
Total income (83 x 117.7 x 78days)	*$ 2, 116.64*
Net income	*$ 306.59*
Note: 1 USD = N 360	

$$payback\ period = \frac{504.08}{306.59} = 1.64\ years$$

CONCLUSION

Field performance analysis of a tractor-drawn turmeric planter was carried out to evaluate its effective field capacity, field efficiency on actual filed conditions, whereas laboratory tests were conducted to evaluate the planter's seed rate, percentage rhizome bruise, wheel slippage and fuel consumption. The seed rate ranges between 0.283 - 0.147 th^{-1}. The maximum percent bruised turmeric rhizome was obtained to be 30.08% at operational speed and rhizome length of 12 kmh^{-1} and 30 mm, respectively. The mean effective field capacity varied between 0.63 - 0.96 hah^{-1}, at operational speeds of 8 and 12 kmh^{-1}, respectively and 45 mm rhizome length. The mean field efficiency was obtained to be 65.8%.

The maximum wheel slippage of 4.37% and fuel consumption of 3.8 lha^{-1} were obtained at the machine speeds of 8 kmh^{-1} and 12 kmh^{-1}, respectively; whereas the minimum wheel slippage of 3.14% and fuel consumption of 2.2 lha^{-1} were obtained at the machine speeds of 12 kmh^{-1} and 8 kmh^{-1}, respectively for the range of the studied turmeric rhizome length.

The highest percentage turmeric rhizome miss index of 35% was recorded for turmeric rhizome length of 30 mm at a speed of 10 kmh^{-1}, whereas the highest multiple index of 35% was recorded for turmeric rhizome length of 30 mm at lowest operational speed of 8 kmh^{-1}. A mean planting depth of 68 mm was obtained. Numerical optimization of operational parameters of the planter was conducted. The optimal operating condition of the planter was obtained at machine operational speed of 12 $kmh^{-1}$and turmeric rhizome grading size of 45 mm, with an overall desirability index of 0.73. Economic evaluation was carried out using the criteria of cost and payback analyses which vary with product and location. A total production cost was estimated at $ 746.04, whereas a very small payback period of 1.64 years compared to the estimated planter's life of 17 years. Further research is required to determine the field performance and optimized operational conditions of a similar planter handling different crops.

REFERENCES

[1] Nwaekpe, J.O., Anyaegbunam, H.N., Okoye, B.C. and Asumugha, G.N. 2015. Promotion of Turmeric for the Food/Pharmaceutical Industry in Nigeria. American Journal of Experimental Agriculture 8(6): 335-341, 2015, Article No.AJEA.2015.177.

[2] Srinivasan, K. and Dhandapani, C. 2013. Turmeric: The Golden Spice.

[3] Lal, J. 2012. Turmeric, Curcumin and Our Life: A Review. Bulletin of Environment, Pharmacology and Life Sciences. Bull. Environ. Pharmacol. Life Sci.; Vol. 1[7] June 2012:11 -17.

[4] Balakrishnan K. V. 2007. Postharvest technology and processing of turmeric. In: Ravindran P. N, Nirmal Babu K, Sivaraman K, editors. Turmeric: The Genus Curcuma. Boca Raton, FL: CRC Press, pp. 193–256.

[5] Sahdeo Prasad and Bharat B. Aggarwal. 2011. Turmeric, the Golden Spice. https://www.ncbi.nlm.nih.gov/books/nbk9272/

[6] Hatcher H., Planalp, R., Cho, J., Torti, F.M., Torti, S.V. 2008. Curcumin: From Ancient Medicine to Modern Clinical Trials. Cell.Mol. Life Science. 1-22 http://wwww.birkhauser.ch/CMLS.

[7] Ajit, k. Srivastara, Carroll, E. Goering, Roger P. Rohrbach, Dennis, R. Buckmaster. 2006. Engineering Principles of Agricultural Machines, Second Edition. ASABE Publication SO1M0206.

[8] Afolabi, T.J., Akintunde, T.Y. and Oyelade, O.J. 2014. Influence of drying conditions on the effective moisture diffusivity and energy requirements of ginger slices: *J. of Food Research,* 3: 103 – 112.

[9] Minaei, S., Chenarbon, H.A., Motevali, A. and Arabhosseini, A. 2014. Energy consumption, thermal utilization efficiency and hypericin content in drying leaves of St. John's Wort (Hypericum Perforatum): *Journal of Energy in South Africa, 25*: 27 – 35.

[10] Beigi, M. 2016. Energy efficiency and moisture diffusivity of apple slices during convective drying. Food Sci. Tech. 36:145-150. https:// doi:10.1590/1678-457X0068.

[11] Mohamed, M.A., Kheiry, A.N., Rahma, A.E., Yousif, H.A. 2016. Performance evaluation of two planter makes as affected by forward speeds. *J. of Agricultural Science and Practice,* 2: 16 -22.

[12] Singh, T.P. and Gautam Vijay (2015). Development and Performance Evaluation of a Gladiolus Planter in Field for Planting Corms. International Journal of Agricultural and Biosystems Engineering Vol. 9, No: 12 pp 1243-1248.

[13] Nwakor, E.N., Asumugha, G.N., Nwokocha, C.C., Ekedo, T.O. 2014. Guide to Turmeric Production, Processing and Marketing in Nigeria. Extension Guide No. 28, Extension Service Programme, National Root Crops Research Institute Umudike, Nigeria.

[14] Albushari,S.A. 2016. Effect of different seed drill covering devices on forage sorghum seed emergence and machine performance. A research project, College of Agricultural Studies, Sudan University of Science and Technology.

[15] Oduma, O., Nwakuba, N.R. and Igboke, M.E. 2014. Performance evaluation of a locally developed pigeon pea thresher. *Int.J. of Applied Science, Technology and Engineering research* 3(2):20 – 31.

[16] Raghavendra, M. and Veerangeouda, K.V. 2013. Development and evaluation of ridge planter for cotton. *Karnataka Journal of agricultural Sciences,* 26(1): 88 – 91.

[17] Kalay K. and Moses, S.C. 2017. Performance evaluation of manually operated multi-crop planter for okra. Journal of Pharmacognosy and Phytochemistry SPI: pp. 264-269.

[18] Nwakuba, N.R.; Chukwueize, O.C.; Asoegwu, S.N.; Nwandikom, G.I.; Okereke, N.A.A. A Prediction Model of Energy Requirements for Drying of Okra Slices in a Hybrid Solar-Electric Dryer. UJET, 2018, 4(1) 155-163.

[19] Ugwuishiwu, B.O. and Onwualu, A.P. (2009). Sustainability and Cost of Agricultural Mechanization in Nigeria as Affected by Macro-Economic Policies. . *Journal of Agricultural Engineering and Technology*, 17 (2), December, 2009.
[20] Boughali, S., Benmoussa, H., Bouchekima, B., Mennouche, D., Bouguettaia, H., and Bechki, D. 2009. Crop drying by indirect active hybrid solar-electrical dryer in the eastern Algeria Septentrional Sahara. *Solar Energy*, 83: 2223 – 2232.
[21] Neufville, R.1990. Applied System Analysis. McGraw-Hill Pub.Company, N. York, USA

ANALIZA PERFORMANSI AGREGATA TRAKTOR - SADILICA RIZOMA KURKUME

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Sažetak: Rad prikazuje ispitivanja terenski razvijenog prototipa sadilice za kurkumu *(Curcuma Longa Linn)*. Ispitivanja su randomizirana u faktorskom dizajnu sa tri različite dužine rizoma kurkume od 30, 45 i 60 mm, i radnih brzina agregata traktor – sadilica je 8, 10 i 12 kmh^{-1}. U ispitivanju je prosečna masa od 3 kg celih rizoma kurkume ubačena u spremište – levak sadilice i posađena na 90 m^2 eksperimentalne površine. Tokom terenskog ispitivanja mašine-sadilice razmatrani su: efektivni učinak, statistička greška, višestruki indeks i dubina sadnje rizoma kurkume. Laboratorijska ispitivanja su obavljena kako bi se procenila potrebna količina materijala rizoma za sadnju, % proklizavanja točkova traktora i količina potrošenog goriva. Dobijeni rezultati pokazuju da je maksimalna količina utrošenih rizoma kurkume bila 0,283 th^{-1}. Utvrđeno je da maksimalni % modificiranog rizoma kurkume iznosi 30,08 %. Srednji efektivni učinak varirao je između 0,63 - 0,96 hah^{-1}, pri stvarnoj operativnoj brzini rada agregata od od 8 i 12 kmh^{-1}, odnosno dužini rizoma kurkume od 45 mm. Dobijen srednji učinak na polju od 65,8%. Maksimalno proklizavanje točkova traktora bilo je od 4,37%, a potrošnja goriva od 3,8 lha^{-1} dobijeni su pri brzinama agregata od 8 kmh^{-1} odnosno 12 kmh^{-1}. Najmanje proklizavanje točkova traktora je 3,14% i potrošnja goriva 2,2 lha^{-1} dobijeni su pri brzinama agregata od 12 kmh^{-1} i 8 kmh^{-1}. Najviši i najniži % prolaska rizoma kurkume kroz aparat sadilice je 35% , a konstatovan je za dužinu rizoma od 30 mm pri brzini agregata od 10 kmh^{-1} odnosno 8 kmh^{-1}. Dobijena prosečna dubina sadnje rizoma kurkume je od 68 mm. Numerički optimizacijski pristup usvojen je da bi se dobili optimalni operativni parametri rada agregata brzine od 12 kmh^{-1} i veličine dubine sadnje rizoma kurkume od 45 mm sa ukupnim indeksom ostvarljivosti od 0,73. Ekonomska procena isplativosti izračunata je primenom načela povrata investicije, koja je dobijena kao vrlo mala (1,64 godine) u odnosu na mogući vek sadilice od 17 godina. Predloženi su zadaci i mogućnosti za buduće radove.

Ključne riječi: *rizom kurkume, procena polja, optimizacija, parametri izvođenja ogleda, sadilica*

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MAPIRANJE TRETMANA HEMIJSKE ZAŠTITE U PROIZVODNJI JEČMA KORIŠĆENJEM TEHNIKA PRECIZNE POLJOPRIVREDE

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Sažetak: Hemijska zaštita je nezaobilazna agrotehnička mera u svim segmentima konvencionalne poljoprivredne proizvodnje. Značaj pravilnog izvođenja hemijske zaštite na kvalitet i prinos gajenih useva je veliki, isto kao i finansijski troškovi koja ova mera ima u strukturi ukupnih troškova. Ustaljena tehnika kontrole, praćenje kvaliteta rada i efikasnosti mašina za zaštitu bilja u ratarskoj proizvodnji ima brojne nedostatke. Različite tehnike precizne poljoprivrede nam omogućavaju evidentiranje i detekciju kritičnih tačaka u različitim proizvodnim procesima, pa se slične tehnike mogu primeniti u kontroli hemijske zaštite ječma.

U ovom radu je korišćena lokacijski notirana baza podataka ostvarenih protoka prskalica koje su radila hemijski tretmane u ječmu. Na parceli veličine 52 ha, odstupanje od zadate norme tretiranja, za više od 10%, je obavljeno na 3,61 ha. Utvrđeno je da ostvarena norma tretiranja, prilikom korišćenja istog agregata, u značajnoj meri zavisi od samog rukovaoca, gde su odstupanja u pojedinim tretmanima i preko 100%. Utvrđena su značajna odstupanja u normama tretiranja koja značajno utiču na cenu koštanja utrošenih hemijskih sredstava, gde su u hemijskoj zaštiti ječma na preko 454 ha prekoračene zadate norme, što je povećalo troškove upotrebljenih hemijskih sredstava za 10,33%.

Kljične reči: *norma tretiranja, tehnička ispravnost, merač protoka, mapa tretiranja, troškovi.*

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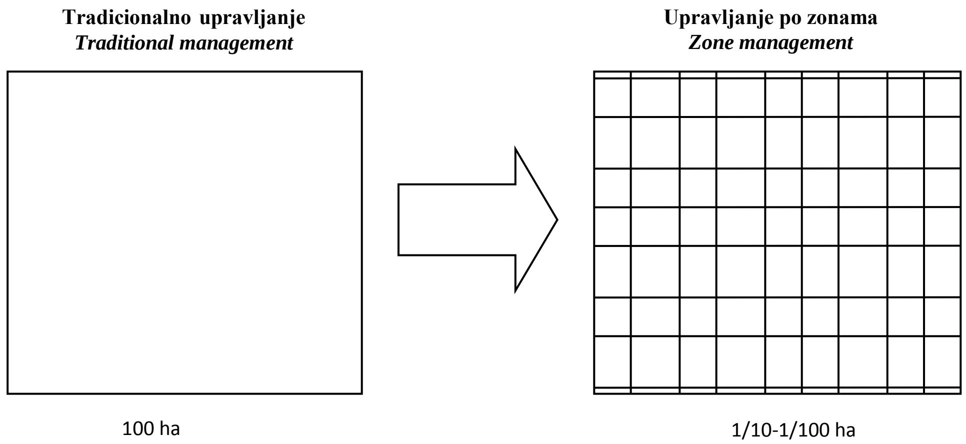
UVOD

Rastuća potreba za hranom, dovela je do razvoja poljoprivrede prevashodno se oslanjajući na primenu mehanizacije i hemijskih sredstava. Prekomerna, nekontrolisana i nestručna upotreba zaštitnih hemijskih sredstava (pesticida) u konvencionalnoj proizvodnji je vrlo čest slučaj. U nameri ostvarivanja što viših prinosa i profita, primenjuju se ne odgovarajuće norme tretiranja, ne poštuju se osnovna načela hemijske zaštite bilja, što za uzrok ima umanjenje kvalitet i plodnost zemljišta, pri čemu se zanemaruje uticaj takve prakse na kvalitet i bezbednost hrane po zdravlje ljudi i životinja [1], [3], [5].

Kao jedan od odgovora na ustaljenu praksu u oblasti hemijske zaštite bilja, precizna poljoprivreda je ponudila više različitih tehnika i tehnologija čijom se primenom mogu uspešno prevazići višedecenijski problemi. Precizna poljoprivreda kao koncept, temelji se na evidentiranju i selektivnom tretmanu manjih površina unutar nekog polja (slika 1). Precizna poljoprivreda se temelji na primeni informatičkih tehnologija, satelitske navigacije, sofisticiranih upravljačkih alata i mogućnosti usklađivanja poljoprivredne mehanizacije sa željenim pravcem menadžmenta proizvodnje. Pomoću različitih senzora se mogu u realnom vremenu utvrditi i evidentirati parametri proizvodnih procesa, na osnovu kojih se precizno mogu utvrditi razlozi efikasnog/neefikasnog delovanja [3], [5]. Prikupljene informacije se koriste za izradu karata (mapa) koje pokazuju varijacije posmatranih parametara poput prinosa, zakorovljenosti, plodnosti zemljišta, razvoja bolesti i sl. Cilj precizne poljoprivrede je stvoriti optimalne uslove za rast i razvoj gajenih biljaka, na svakom od delova parcele pojedinačno. Takvim pristupom se pored podizanja proizvodnih rezultata utiče i na smanjenje negativnih uticaja na životnu sredinu od prekomerne upotrebe hemijskih sredstava [5].

Potpuni efekat primene precizne poljoprivrede vidljiv je kroz ekonomičnost proizvodnje, optimizaciji troškova angažovanih inputa u proizvodnji, i racionalizaciji angažovanja sredstava poljoprivredne mehanizacije i ljudske radne snage.



Slika 1. Različiti pristupi upravljanja parcelom
Figure 1. Different approaches to parcel management

Hemijska zaštita bilja je jedna od veoma važnih, možda i presudnih agrotehničkih mera na kvalitet i kvantitet ratarskih kultura. Dobrom i pravilnom hemijskom zaštitom može se u značajnoj meri uticati na pojavu i intenzitet bolesti na gajenom usevu, pa time i na obim hemijske zaštite. Što je hemijska zaštita izvedena bolje i pravovremeno, manje su potrebe za dodatnim hemijskim merama, a sama zaštita je uspešnija. Hemijska zaštita ratarskih kultura daje dobre efekte ako favorizuje rast i razvoj gajenih biljaka, a ometa ili ne doprinosi razvoju korovskih biljaka, patogena, odnosno bolesti. Presudan faktor na efekat hemijske zaštite ratarskih kultura jeste odabir odgovarajućeg pesticida i njegova pravilna primena. Pri svemu ovome, potrebno je imati u vidu štetno dejstvo pesticide na životnu i radnu okolinu. Zbog svega iznetog, pesticide se moraju racionalno koristiti čime se eliminiše ili u znatnoj meri umanjuje njihovo štetno dejstvo. Racionalno korišćenje pesticida podrazumeva primenu u tačno zadatoj normi tretiranja.

Ustaljena praksa podešavanja i kontrolisanja prskalica prilikom hemijske zaštite ratarskih useva, podrazumeva odokativnu vizuelnu proveru ispravnosti svih rasprskivača, kao i podešavanje radnih parametara prskalice (izbor rasprskivača, radni pritisak, brzina kretanja agregata) prilikom započinjanja procesa hemijske zaštite. Vrlo često dolazi do odstupanja od željenih ili podešenih vrednosti koje pre svega zavise od: tehničke ispravnosti prskalice i odgovornosti rukovaoca traktorskog agregata. Upravo su u ovom radu analizirana ova dva uticajna faktora, gde su uz pomoć različitih tehnika merenja, sakupljanja i obrade podataka utvrđena određena odstupanja. Primenom različitih tehnika precizne pljoprivrede omogućeno je evidetiranje ovih anomalija u proizvodnom procesu, kao i preduzimanje mera za njegovo brzo i efikasno otklanjanje.

MATERIJAL I METODE RADA

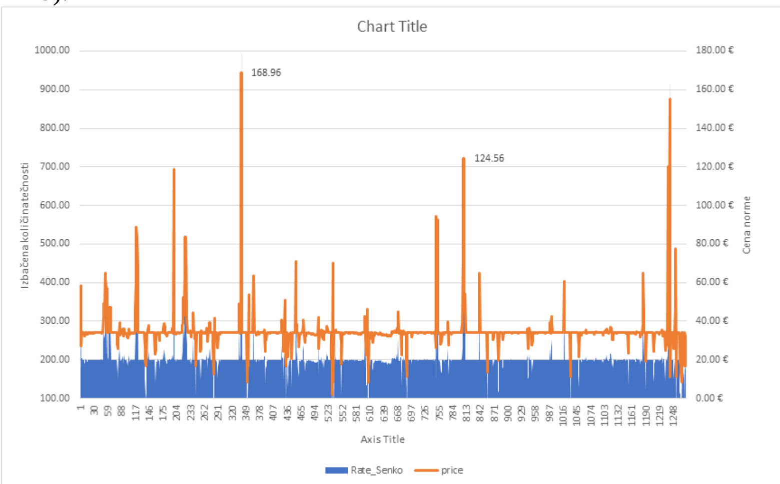
Istraživanje je sprovedeno na proizvodnim poljima kompanije Alrawafed Srbija, gde su prikupljani podaci dobijeni iz proizvodnje više ratarskih kultura, dok je reprezentativna analiza rađena za proizvodnju ječma koja se obavljala na površini od 454 ha. U proizvodnim uslovima je korišćena savremena poljoprivredna mehanizacija, ne starija od 4 godine [2], [4]. Samohodne prskalice i traktorski agregati praćeni u ovom istraživanju su bili sa instaliranim navigacionim sistemima preciznosti 2,5 cm, koje su podržavale primenu tehnike “kontrola sekcija”. Sva praćena sredstva poljoprivredne mehanizacije su opremljena modemima, kao standardnim delom navigacione opreme. Modem omogućava dvosmerna komunikaciju između mašine i centralnog računara, posredstvom oblaka podataka (cloud), na kome se kasnije vršila obrada i analiza prikupljenih podataka.

Zbog automatizovanog podešavanja norme prskanja, prskalice kao standardnu opremu imaju merač protoka ka diznama, Podaci koji se dobijaju od merača protoka se šalju u ECU prskalice. ECU prskalice je povezan sa monitorom navigacije, koji služi kako za upravljanje navigacijom tako i za kontrolu rada prskalice. Ovim povezivanjem, je omogućeno geografsko lociranje postignute norme na delovima parcele. Jedna “tačka” zapisa ostvarene norme je veličine 20 m dužine x radni zahvat prskalice. U slučaju samohodne prskalice to je 20 x 36 m, a u slučaju vučene prskalice 20 x 30 m. U istraživanju je korišćena prskalica Hardi Alfa radnog zahvata 36 m (prskalica A), i prskalica Hardi Commander radnog zahvata 30 m (prskalica B).

“Trimble Ag softvera”, verzija desktop [6], izvršena je preliminarna analiza podataka, izvršeno je kreiranje mapa za svaku obrađenu parcelu, i pripremljen je grafički prikaz analiziranih podataka. Svi sakupljeni podaci su obrađeni statističkim metodama uz primenu softverskog paketa SPSS 17.0. Analiza troškova primenjene mešavine hemijskih sredstava je urađena u programu MS Excel.

REZULTATI ISTRAŽIVANJA I DISKUSIJA

Tehnička ispravnost prskalica ima presudan uticaj na pravilnu distribuciju i efikasnost hemijske zaštite gajenih useva. Praćenjem podataka je ustanovljeno da i pored kalibrisanja i provere tehničke ispravnosti prskalica, tokom eksploatacije dolazi do određenih promena protoka, a sa time i promene norme tretiranja. Ova odstupanja nisu izazvana ljudskim faktorom, već su čisto tehničke prirode, jer su praćeni višednevni podaci korišćenja oba tipa prskalice sa istim i različitim rukovaocima. Utvrđeno je da prskalica A ostvaruje veća odstupanja norme tretiranja od zadatih u odnosu na prskalicu B (slika 2 i 3).



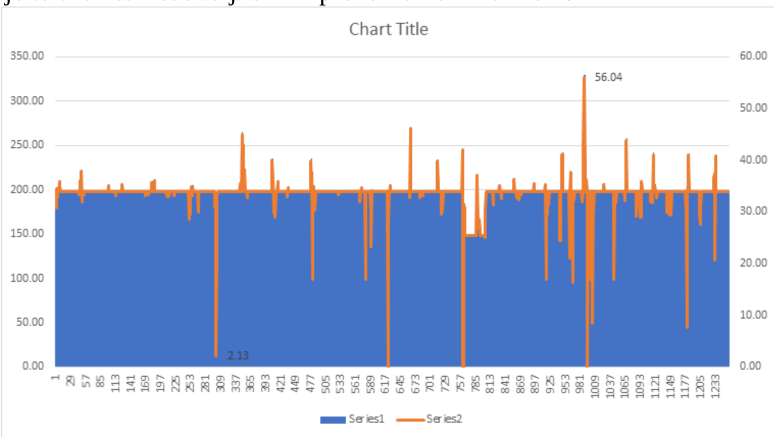
Slika 2. Distribucija norme tretiranja i troška korišćenog miksa pesticida kod prskalice A

Figure 2. Distribution of the treatments norm and the costs of pesticide mixes (sprayer A)

Ispitivane prskalice (A, B) radile su u indentičnim uslovima i zadatim parametrima rada, na parceli veličine 52 ha. Zadata norma tretiranja je bila 200 l/ha, dok su tokom eksploatacije izmerena često manja, dok u pojedinim momentima značajno veća odstupanja. Ove oscilacije su više bile izražene kod prskalice A (slika 2).

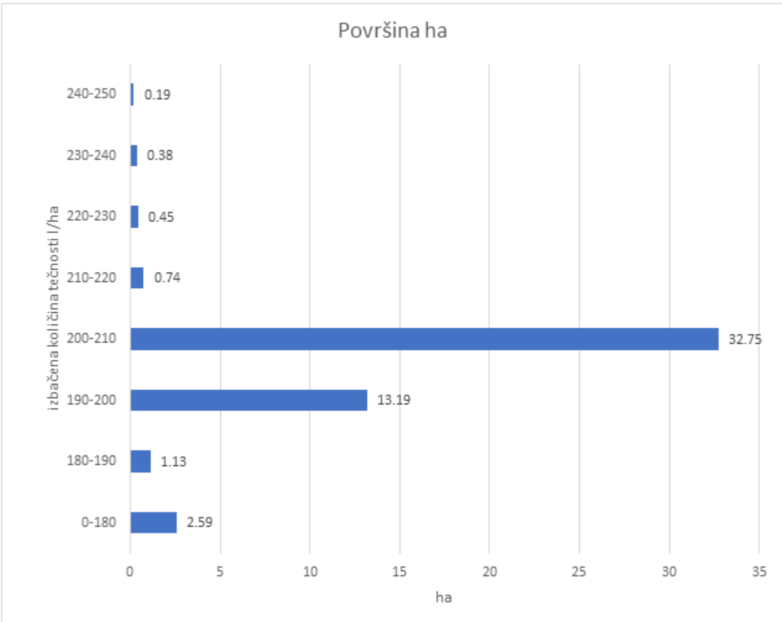
Pored oscilacija u realizovanoj normi tretiranja, izračunate su i oscilacije troškova korišćenih pesticide u zadatom miksu. Naime, cena korišćene mešavine pesticide (tank mix-a) je iznosio 0,17 EUR/l zaštitne tečnosti, što je prema zadatoj normi tretiranja od 200 l/ha iznosilo 34 EUR/ha. Prateći oscilacije norme tretiranja, prskalica B je ostvarila značajno manje troškove hemijskih sredstava (slika 3). Kod prskalice B, oscilacije troškova tank mix-a se kretao u granicama od 0 do 56,04 EUR/l, dok se kod prskalice A ove osilacije kretale u rasponu od 0 do 168,96 EUR/l.

Prateći efikasnost nanošenja odabranog tank mix-a pomoću angažovanih prskalica, utvrđena je sledeća raspodela normi tretiranja na površini od 52 ha (slika 4). Uzevši u obzir dozvoljena odstupanja od zadate norme tretiranja, od 52 ha tretirane površine, 3,61 ha (7%) je tertiran sa nedovoljnom ili prekomernom normom.



Slika 3. Distribucija norme tretiranja i troška korišćenog miksa pesticide kod prskalice B

Figure 3. Distribution of the treatments norm and the costs of pesticide mixes (sprayer B)



Slika 4. Histogram ostvarene distribucije norme tretiranja na parceli veličine 52 ha (zadata norma tretiranja 200 l/ha)

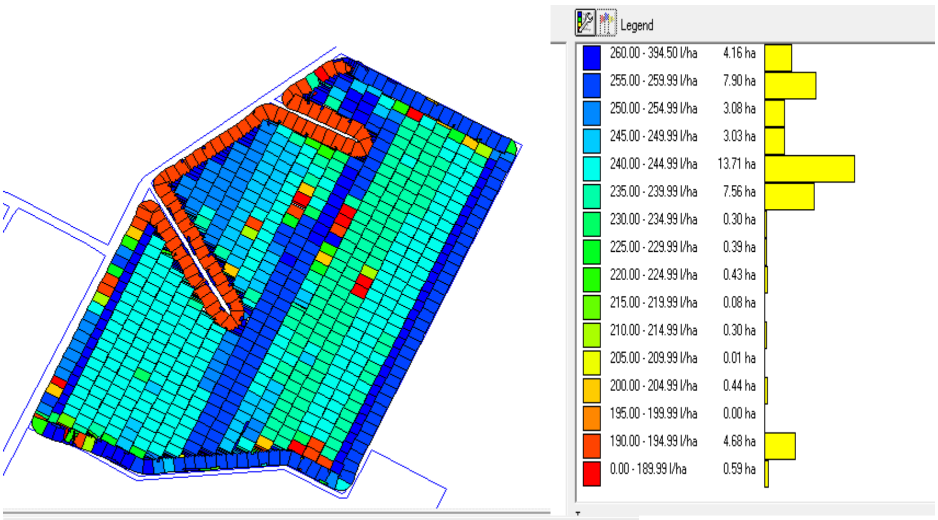
Figure 4. Histogram of the achieved distribution of the treatment norm (the set treatment norm is 200 l/ha)

Tabela 1. Uticaj povećanja norme prskanja na povećanje troškova prskanja

Table 1. The influence of the increase of tretment norms on increasing spraying costs

Hem. Sredstvo Pesticide	***Planirana norma The set pesticide norm [l/ha]***	***Planirana potrošnja The set treatment norm [l]***	***Stvarna norma Realized pesticide norm [l/ha]***	***Stvarna potrošnja Realized treatment norm [l]***	***Razlika Remainder [l]***	***Cena hem. sredstva The price of pesticides [€/l]***	***Povećanje troška Increase of pesticide costs [€]***
A	*1.70*	*152.80*	*2.00*	*179.75*	*26.96*	*11.28*	*304.09 €*
B	*3.50*	*314.58*	*4.12*	*370.08*	*55.50*	*2.40*	*133.20 €*
C	*1.20*	*107.86*	*1.41*	*126.89*	*19.03*	*10.00*	*190.29 €*
D	*1.00*	*89.88*	*1.18*	*105.74*	*15.86*	*4.28*	*67.87 €*
						Suma Total	*695.45 €*

U tabeli 1 je dat prikaz tretiranja na parceli površine 90 ha. Planirana norma je bila 150 l/ha i tank-mix se sastojao od 4 hemijska sredstva. Ostvarena prosečna norma je iznosila 176 l/ha, Za tretiranih 90 ha, povećanje utroška hemijskih sredstava je bilo 695.45 €. U hemijskoj zaštiti ječma na preko 454 ha prekoračene su zadate norme u 15 slučajeva od 22 tretiranja, Povećanje norme se kretalo od 2,5% do maksimalnih 29%, što je povećalo troškove upotrebljenih hemijskih sredstava za 10,33%.



Slika 5. Mapa norme hemijske zaštite ječma

Figure 5. Map of the chemicals treatment norm in barley production

Na slici 5 prikazana je mapa norme prskanja kao i histogram rasporeda normi po hektaru. Uočava se veliko odstupanje od zadate norme (200 l/ha) kao i velik broj ostvarenih različitih normi. Uzrok ovako lošeg rasporeda hemijskih sredstava može biti neispravnost prskalice, odnosno otkazivanje automatske kontrole norme prskanja ili pogrešno rukovanje.

Uticaj rukovaoca na proces hemijske zaštite nije mali. U ovom istraživanju je utvrđeno da rukovaoci imaju različit odnos prema hemijskoj zaštiti, u istim proizvodnim i eksploatacionim uslovima. Rukovaoc agregatom A je u većini tretmana izbacivao veće norme tretiranja u odnosu na zadate, a samim tim trošio i više zaštitnih sredstava.

Rukovaoc agregatom B je u većini hemijskih tretmana izbacivao normu tretiranja koja je približna zadatoj normi i time racionalno trošio veoma skupa hemijska sredstva (tabela 2).

Tabela 2. Potrošnja hemijskih sredstava u zavisnosti od spretnosti rokovaoca
Table 2. Consumption of chemicals depending on the skill of the operator

	Rukovaoc ***Operator***		***Zadata norma*** ***The set treatment norm***
Tank MIX -1	A	B	
Pesticid X *Pesticide X*	0,23	0,17	0,2
Pesticid Y *Pesticide Y*	0,70	0,52	0,6
Pesticid Z *Pesticide Z*	1,40	1,04	1,2
	Rukovaoc *Operator*		Zadata norma *The set treatment norm*
Tank MIX - 2	***A***	***B***	
Pesticid O Pesticide O	*3,07*	*1,67*	*1,50*
Pesticid X Pesticide X	*0,41*	*0,22*	*0,20*
	Rukavaoc Operator		*Zadata norma The set treatment norm*
Tank MIX - 3	***A***	***B***	
Pesticid X Pesticide X	*0,34*	*0,18*	*0,2*
Pesticid K Pesticide K	*1,02*	*0,84*	*0,8*
Pesticid G Pesticide G	*1,73*	*1,47*	*1,5*

ZAKLJUČAK

Savremena poljoprivredna proizvodnja se zasniva na nekoliko bitnih principa: racionalizacija troškova, maksimiziranje prinosa, efikasnost proizvodnje i visoka profitabilnost. Moderne prskalice su opremljene sa automaskim uređajima za održavanje zadate norme i njihovim povezivanjem sa navigacionim sistemom, čime je omogućeno mapiranje norme prskanja. Bilo je za očekivati da tehnička ispravnost ima veliki uticaj na normu prskanja, odnosno na povećanje kontrole utroška hemijskih sredstava, a samim tim i na troškove hemijske zaštite. Ta pretpostavka je potvrđena sa analizom prikupljenih podataka. Prikupljeni podaci za svako tretiranje, omogućili su da se kvantifikuje i uticaj svakog pojedinačnog rukovaoca prskalice, bio on pozitivan ili negativan.

Primena tehnologija precizne poljoprvrede u segmetu zaštite bilja nam omogućava kontrolu kvaliteta prskanja i kontrolu kvaliteta rada rukovaoca na način koji je do sada bio potpuno nov i nepoznat.

LITERATURA

[1] Donatelli, M., Magarey, R.D., Bregaglio, S., Willocquet, L., Whish, J.P.M., Savary, S. 2017: Modelling the impact of pests and diseases on agricultural systems. Agric. Syst. 15, pp. 213-224.

[2] Oparnica, S. 2018. Advanced use of crop yield maps and histograms. Adv. Agr. Environ. Sci. 1(2), 65−68.

[3] Prashant, K.N., Balikai, R.A., Anusha, Ch. 2016. Pest management strategies in precision farming. J.Exp. Zool.India, 19(1), 1-8.

[4] Stanković, V.S., Stanković, Z., Pajić, M., Pajić, V. 2016. Pregled potencijala primene IOT rešenja u poljoprivredi. 18. Aktuelni problemi mehanizacije poljoprivrede, Zbornik radova, ISBN 978-86-7834-262-2, Univerzitet u Beogradu, Poljoprivredni fakultet, Beograd, 9.12.2016., str. 163-171.

[5] Strickland R.M., Ess, D.R., Parson, S.D. 1998. Precision farming and precision pest management: the power of new crop production technologies. Journal of Nematology, 30(4) 431-435.

[6] Trimble Ag software user guide, Version 2017 Revision A. (2017).

MAPPING TREATMENTS OF CHEMICAL PROTECTION IN BARLEY PRODUCTION BY USING THE PRECISION AGRICULTURE TECHNOLOGY

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Abstract: Chemical protection is an indispensable agro-technical step in all segments of conventional agricultural production. The significance of proper chemical protection is large for the quality and yield of cultivated culture, as is the financial costs that this measure has in the structure of total costs. The established technique of control, monitoring the quality of work and the efficiency of plant protection machines in crop production has numerous shortcomings. Different techniques of precision agriculture enable us to record and detect critical points in various production processes, so similar techniques can be applied in the control of chemical protection of barley.

In this paper, a location database of actual flows of sprinklers that used chemical treatments in barley was used. On a plot of 52 ha, the deviation from the specified treatment rate by more than 10% was performed at 3.61 ha. It was found that the achieved norm of treatment when using the same aggregate, depends significantly on the operator itself, where the deviations in individual treatments and over 100%. Significant deviations in treatment standards have been identified that also significantly affect the cost of consumed chemicals, where the recommended standards have been exceeded in the chemical protection of barley production on over 454 ha, which increased the cost of used chemicals by 10.33%.

Key words: *treatment norm, technical accuracy, flow meter, treatment map, costs.*

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PERFORMANCE OF HYBRID PHOTOVOLTAIC/THERMAL CROP DRYER IN HOT HUMID NIGERIAN REGION

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Abstract: This paper presents a study carried out to investigate the performance of a hybrid photovoltaic/thermal crop dryer in hot humid region of Umuagwo-Ohaji in the South-east region of Nigeria, through energy and exergy analyses, drying, electrical and thermal efficiencies, energy utilization and energy utilization ratio, sustainability indicators such as waste energy ratio (WER), sustainability index (SI) and improvement potential (IP). Drying experiments were conducted at varying inlet air temperatures (50, 60 and 70^{o}C), airflow rates (1.14, 2.29 and 3.43 kgs^{-1}) and slice thicknesses (10, 15 and 20 mm) on 500g batch size of red pepper slices during sunshine periods. Results obtained show that the total and specific energy consumption for drying a batch of sliced red pepper samples varied between 2.08 – 34.91kJ and 7.04 – 62.76 kJkg^{-1}, respectively. The energy utilization and energy utilization ratio during the drying process ranged from 195.75 – 3013.21 Js^{-1} and 1.82 – 20.4%, respectively. The energy and exergy efficiencies varied between 15.67- 38.17% and 26% to 88%, respectively. The mean drying efficiency of the system ranged from 7.12 – 40.27%. The maximum electrical and thermal efficiencies of 23.86% and 93.03%, respectively were obtained. A waste energy ratio of 0.0827 - 0.1579 was obtained, whereas SI and IP values ranged between $1.137 \leq SI \leq 6.119$ and $0.198 \leq IP \leq 0.583$kW, respectively. There is certainly a wide range of improvement in the PV/T system as 12.1 – 18.4 % of the solar irradiance was consumed for drying. Prospects for improvement and recommendations for further studies were suggested.

Key words*: Energy, exergy, PV-T system, sustainability indicators, thermal conversion.*

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INTRODUCTION

Nigeria is a tropical country, characterized with seasonally damp and humid climate as well as four distinguishable climate types (tropical rainforest climate, tropical savannah climate, tropical dry climate and Alpine climate).

It is strategically located within the global high sunshine belt, receiving an estimated solar radiation in the range of 3.5 – 7.0 $kWm^{-2}day^{-1}$ and 3,000 hr of annual sunshine [1]. Nevertheless, this advantageously placed it to harness considerable amount of solar energy all year round for crop drying operation. Daily and seasonal variations in solar radiation as well as persistent absorption by rain and regular cloud cover in many parts of the country have negatively affected the effective use of the sun's energy for crop drying application [2]. Nevertheless, the high rainfall intensity, especially in the South-East region of Nigeria, as result of coastal influence causes great concern as it poses a great challenge to crop drying.

Food drying has recently become a common unit operation in the drying industries for preservation of end products of food materials as well as an intermediate operation [3]. Fresh fruits and vegetables are known for their high perishable nature as a result of their relatively high moisture content (70 to 95% wet basis) at harvest which requires long drying time, low thermal conductivity during the falling rate drying period which inhibits convective heat transfer to the inner sections of the product structure, relatively low energy efficiency of dryers, and high latent heat of water evaporation [4, 5]. Drying operation is considered to be the most energy intensive unit operation because of the high latent heat of vaporization of water and inefficient heat transfer by the air stream [6, 7]. Thus, reducing the cost of energy sources to enhance dryer efficiency for good quality dried food products is one of the major challenges in drying technology [7 – 9]. It is therefore, important to perform a thermal analysis of a forced convective thin layer drying process to provide energy savings and optimum operational conditions [3].

Convective hot air crop drying using artificial dryers requires substantial amount of energy input when compared to other production processes as a result of relatively low energy efficiency of the dryer (approximately 30%), inefficient heat transfer between convective air and food material, large quantity of energy loss through the exhaust air (even as temperature reaches the wet bulb temperature), and increased latent heat of vaporization of water [10 – 12]. In most developed nations, the energy consumption for drying operations accounts for 7 – 25% of the nation's total industrial energy demand [13]. In this regard, it is important to carry out an effective energy and exergy-based performance analyses of hybrid solar-electric drying process to provide energy savings and optimal process conditions. According to Nazghelichi et al. [3] and Aviara et al. [6], energy analysis is a basis for estimating different energy conservation processes as well as evaluating quantitatively the energy requirements of a drying system. Energy analysis applies the principle of energy conservation, that is, first law of thermodynamics; whereas exergy analysis considers the availability of energy at different points in the system. Exergy is defined as the maximum amount of work which can be produced by a quantity or stream of matter, heat or work as it comes to equilibrium with a reference environment [14].

Due to certain deficiencies and shortcomings of energy analysis, such as, inability to distinguish the different energy qualities which depends on temperature of the heat source, cannot explain the reason for the inability of conversion of heat to useful work by thermodynamic process, etc. Exergy analysis has become as a more useful tool for performing engineering evaluations [7]. It gives a clearer understanding of the effect of thermodynamic parameters on the process efficiency, to provide optimal process conditions and to decrease the impact of drying on the environment [7, 8, 16, 17]. In system design, exergetic analysis gives useful information on the selection of the most suitable component design and operation procedure. This is mostly beneficial in determining the plant cost of operation, energy conservation, fuel versatility and environmental impact [8, 9].

Solar photovoltaic converts the sun's energy into direct current. It is regarded as one of the most significant and rapidly developing renewable energy technologies, with notable future applications. Hegazy [18] classified solar energy applications into two categories, namely: thermal system (T) and photovoltaic system (PV) cell. In the later, high solar flux incident on the PV panel gives rise to high electrical output. This system is referred to as photovoltaic-thermal system or hybrid (PV/T) and has the advantage of generating both thermal and electrical energy simultaneously. During dry season with high solar radiation intensity, the solar panel temperature rises up to 50 to 60^{o}C which results in output power reduction of about 3 – 5% [19]. Increase in the surface temperature of PV panel, results in gross reduction in the efficiency of solar energy to electricity conversion rate, as not all the incident radiation on the PV panel can be converted to electrical energy [20]. In accordance to first law of thermodynamics, the remaining portion of the absorbed energy is converted to heat and leads to efficiency drop of the PV panel. In order to cushion this effect, researchers [18, 20, 21] have incorporated axial fans and fluid circulation channels to cool the panel temperature in order to achieve enhanced energy conversion rate of the incident solar flux. However, in humid environment, the PV panel surface can be left to be cooled by natural convective air. This paper therefore, investigates the performance of a hybrid photovoltaic/thermal system in hot humid region of Owerri, South-east Nigeria, through energy and exergy efficiencies and improvement potential factors so as to make comparison for practical applications.

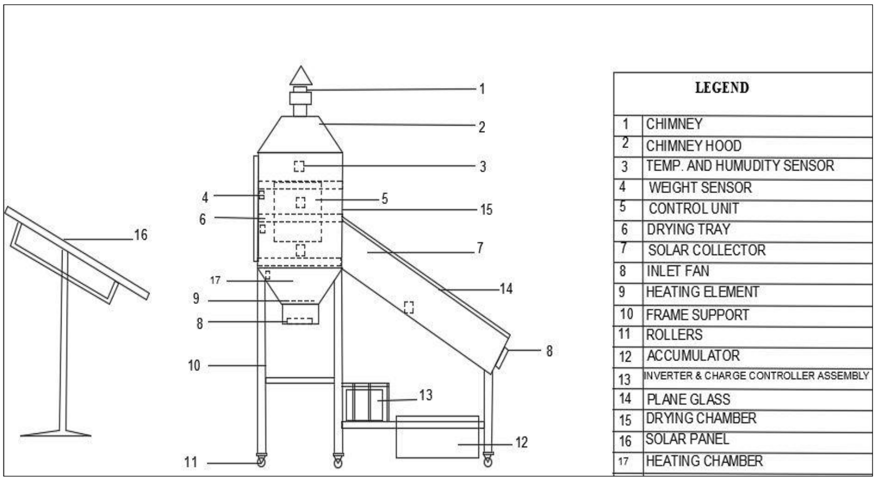
MATERIALS AND METHODS

System Description and Experimental Procedure

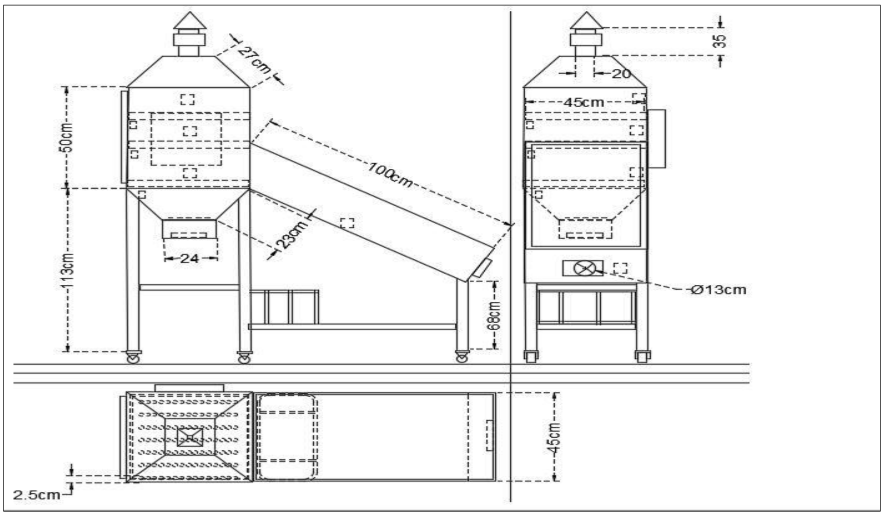
Figure 1a shows the prototype hybrid PV/T dryer, which comprises three major integral components namely: air heater units (solar collector and electrical resistance wire), solar module (with solar cells), solar batteries (deep cycle batteries), inverter and charge controller assembly, drying chamber (with two layers of drying rack made of wire mesh), and Arduino microprocessor (version C++, SPK16.000G). Solar radiation falls on the solar cells of the PV module during sunshine periods and gets converted into electrical energy and heat. The former is stored in deep cycle batteries, whereas the later was lost to convective air. This caused the PV modules to get heated up and results in loss of solar cells efficiency.

Table 1 shows the technical specifications system components. The air heater unit (flat plate solar collector) was constructed into the shape of a wooden box (laminated plywood board) with dimension: 100 x 65 x 30 cm^3. The solar box was lagged with 150mm thick fiberglass and was covered with a plain glass. An absorber plate of about 10mm steel sheet, painted dull black was formed and inserted in the solar collector box. The solar collector was judiciously designed to obtain the dimensions that will harness and effect the necessary enthalpy increase of the drying air stream to provide adequate drying air temperature. A circular opening (15cm diameter) was made in front of the solar collector box with an axial suction fan to draw in ambient air to the solar collector and subsequently into the drying chamber. A heating element was mounted directly under the drying chamber, on top a suction axial fan (Fig. 1b). The solar collector and the drying chamber units were jointed as an integral unit through a hood. The drying chamber was constructed with lagged metal sheet forming a dimension: 50 x 50 x 50 cm^3.

Transducer sensors were mounted beside the drying racks to measure and record the air temperature, relative humidity and mass loss. Temperature and humidity sensors were also placed at the different points of the dryer to measure the temperature and relative of the chimney, electric heating chamber, solar collector box and ambient environment (solar module). These transducers were connected to a control unit, housing Arduino micro-processor, which automatically displays insitu readings on a liquid crystal display (LCD).the control unit also has a 4 x 4 matrix keypad for inputting desired air temperature and air velocity thresholds. The integral hybrid system was mounted on angle-iron frame with the solar collector tilted at an angle of 15.54° and faced towards the North-South axis for maximum collection of solar radiation.



(a)



(b)

Figure 1. Isometric (a) and orthographic (b) views of the hybrid PV/T systems.

Table 1. *Technical specifications of hybrid dryer components.*

/N	***Component***	***Specification***
	Solar panel	*150 W*
	Deep cycle accumulator	*150 Ah., 12 V*
	Liquid crystal display (LCD)	*3 x 1.5 cm²*
	Pyranometer	*Apogee MP-200*
	Inlet and exhaust fans	*D.C, 12 V*
	Control unit	*Dual colour, 12 V*
	Plain glass	*4 mm thick; dim: 92 x 67 x17 cm³*
	Solar collector	*Laminated board (100 x 65 x 30 cm³)*
	Heating element	*1500 W, 240 V, 50 Hz.*
0	*Absorber plate*	*1 mm steel sheet (95.5 x 65.5 x 25.5 cm³)*
1	*Weight sensor*	*± 0.001 g*
2	*Temperature and relative humidity sensors*	*LM-35 transducers*
3	*Frame support*	*Angle iron*
4	*Rollers*	*3.5cm diameter, steel rollers*
5	*Inverter system*	*2.5 kVA, 50 Hz*
6	*Relays and contactor*	*30 Amps and 2hp, respectively*
7	*Fluid*	*Air*

A local variety of fresh red pepper was purchased from a nearby market in Owerri, Nigeria. The samples were sorted according to viability and fully red colour. A 500g sample batch size was selected using a digital weighing balance (± 0.01 g, Camry instruments, China) and sliced to three different thicknesses (10, 15 and 20 mm) using a stainless steel knife and a digital vernier caliper (accuracy ± 0.05mm) with the cutting direction at perpendicular to the sample vertical axis. An average initial moisture content of the samples (81.94% w.b) was determined gravimetrically by drying a 20 g representative sample at 105°C for 24 hours [4]. The samples were in thin-layers on the drying racks in the direction of axial flow of hot air stream uniform drying and increased drying rate.

The hybrid dryer was positioned in an open environment of Imo State Polytechnic, Umuagwo-Ohaji, South-eastern region of Nigeria; and the quantity of incident solar radiation and temperature on the solar collector was measured using a pyranometer (Apogee MP-200) to evaluate the solar collector thermal profile. Drying experiments were conducted during sunshine hours (9:00 – 17:00hrs) using the hybrid heat units. The dryer was switched to allow steady-state condition to be attained by the drying chamber. Sliced red pepper samples with initial moisture content of 81.94% w.b were introduced and dried at three varying air temperatures (50, 60 and 70°C), airflow rates (1.14, 2.29 and 3.43 kgs^{-1}) and slice thicknesses (10, 15 and 20 mm) using the 4 x 4 matrix keypad panel. The amount of moisture loss were recorded by the weight sensors in 30-minutes intervals. The total energy consumption and drying time per batch were recorded. The experiment was replicated three times at varying air temperatures, airflow rates, and sample thicknesses for the same batch size. Each experimental batch was ended when the samples attained a mass loss corresponding to a desired storage moisture level of 10% w.b. [22, 23].

Theoretical Principle

The total and specific energy consumption for drying a batch of red pepper slices were obtained as reported by Nwakuba et al. (2019). The performance analyses of the hybrid PV/T dryer is grouped into electrical and thermal performances. The electrical efficiency (η_e) is dependent upon the incident solar flux and the panel surface temperature, and is expressed as Eq. (1); whereas the thermal efficiency (η_{th}) at steady-state condition is a function of the incident solar radiation and airflow rate, expressed as Eq. (2) [24]:

$$\eta_e = \frac{I_m V_m}{AG} \tag{1}$$

$$\eta_{th} = \frac{\dot{m} c_p (T_o - T_i)}{AG} \tag{2}$$

Where: I_m and V_m = PV module current (A) and voltage (V) respectively; A = Area of PV module (m^2); G = incident solar radiation (Wm^{-2}); $\dot{m}$ = mass flow rate of air (kgs^{-1}); c_p = specific heat capacity of air ($Jkg^{-1}K$); T_i and T_o = inlet and outlet air temperatures (°C), respectively.

The overall system efficiency (η_o) is expressed as Eq. (3):

$$\eta_o = \eta_e + \eta_{th} \tag{3}$$

The energy efficiency (η_{en}) of the hybrid PV/T system, referred to as the ratio of the total (electrical and thermal) energy, Q_t to the solar energy incident on the PV module is expressed as Eq. (4) [21]:

$$\eta_{en} = \frac{Q_t}{GA} \tag{4}$$

The drying efficiency of a hybrid PV/T dryer (η_d), is defined as the ratio of total energy consumed for sample moisture evaporation to the quantity of energy supplied to by the hybrid system, as expressed in Eq. (5) as [25, 26]:

$$\eta_d = \frac{M_m L}{GA + F_p + Q_{PV/T}} \tag{5}$$

Where: M_m = amount of moisture evaporated (kg); L = latent heat of vaporization of moisture ($kJkg^{-1}$); F_p = power rating of the axial fan (W); $Q_{PV/T}$ = energy from PV/T system (kJ).

The energy utilization (E_u) was obtained using Eq. (6) [6, 8]:

$$E_u = M_a(h_{a1} - h_{a2}) \tag{6}$$

Where: h_{a1} and h_{2a} = enthalpies of the ambient dry air at inlet and outlet points, respectively ($kJkg^{-1}$).

The energy utilization ratio (EUR) defined as the ratio of energy used for moisture evaporation to energy supplied by the hybrid dryer heat source was calculated using Eq. (7) [6, 8]:

$$EUR = M_a \left(\frac{h_{a1} - h_{a2}}{h_{a1} - h_a}\right) \tag{7}$$

Where: h_a = enthalpy of the ambient dry air ($kJkg^{-1}$).

Exergy efficiency (η_{ex}) is important to evaluate the actual performance of PV/T system of the hybrid dryer. It is expressed as Eq. (8) [21]:

$$\eta_{ex} = \frac{\dot{E_x}}{S_{ex}} \tag{8}$$

Where: E_x and S_{ex} = exergy from PV/T system and exergy from solar radiation incident on the PV module surface (kJ), respectively. Eq. (6) can be further expressed as Eqs. (9) and (10) [21]:

$$\dot{E_x} = I_m V_m + \left(1 - \frac{T_a}{T_m}\right)[h_{am} A(T_c - T_a)] \quad (9)$$

$$S_{ex} = \left(1 - \frac{T_a}{T_m}\right) GA \quad (10)$$

Where: T_a and T_m = ambient and module temperatures (^oC), respectively; h_{am} = convective heat coefficient from ambient to module temperature (^oC).

Sustainability indicators

Drying operations involve heat generation, utilization and transfer; its influence on the surrounding environment is considered for sustainable development. Sustainability indicators vary air temperature and air velocity during drying process [22, 26, 27]. This study considers the following sustainability indicators: improvement potential (IP), waste exergy ratio (WER) and sustainability index (SI). They were calculated using Eqs. (11) – (13), respectively:

$$WER = \frac{Ex_l}{Ex_i} \quad (11)$$

$$SI = \frac{1}{1 - \eta_{ex}} \quad (12)$$

$$IP = (1 - \eta_{ex}) E_{Xl} \quad (13)$$

Where: η_{ex} = overall exergy efficiency expressed in Eq. (14) as:

$$\eta_{ex} = \frac{Ex_i - Ex_l}{Ex_i} \quad (14)$$

Where: E_{xl} = exergy loss of the drying chamber = $E_{xi} - E_o$ (kJs^{-1}); E_{xi} and E_{xo} = exergy inlet and exergy outlet of the drying chamber (kJs^{-1}), respectively.

In this study, the ambient air temperature and relative humidity were measured as T_m = 295.7K and $\varphi = 35\%$, respectively.

RESULTS AND DISCUSSION

System performance efficiency

The electrical (η_e), thermal (η_{th}) and overall (η_o) efficiencies of the hybrid PV/T dryer were calculated with Eqs. (1) to (3) at different hourly time and solar irradiance during sunshine period, as presented in Fig. 2. It was observed that both electrical and thermal efficiencies depend on the solar radiation intensity which is a function of hourly time. Increase in the temperature of the PV module decreases the electrical and thermal efficiencies of the dryer as a result of the system's low energy conversion rate of the incident solar flux at high module surface temperatures.

The maximum electrical (23.86%) and thermal (69.16%) efficiencies were obtained at 10:00am at solar radiation intensity of 644.95Wm^{-2}. Whereas the maximum thermal efficiency (were obtained may reach 60% to 70% during the system operation. Maximum solar irradiance (959.26Wm^{-2}) was obtained at 1:00pm with corresponding low electrical and thermal efficiencies of 14.3% and 59.43%, respectively. The overall efficiency of the system during operation varied between $71.81\% \leq \eta_o \leq 93.03\%$. This is an indication of satisfactory performance since the PV module is cooled by natural convection [20].

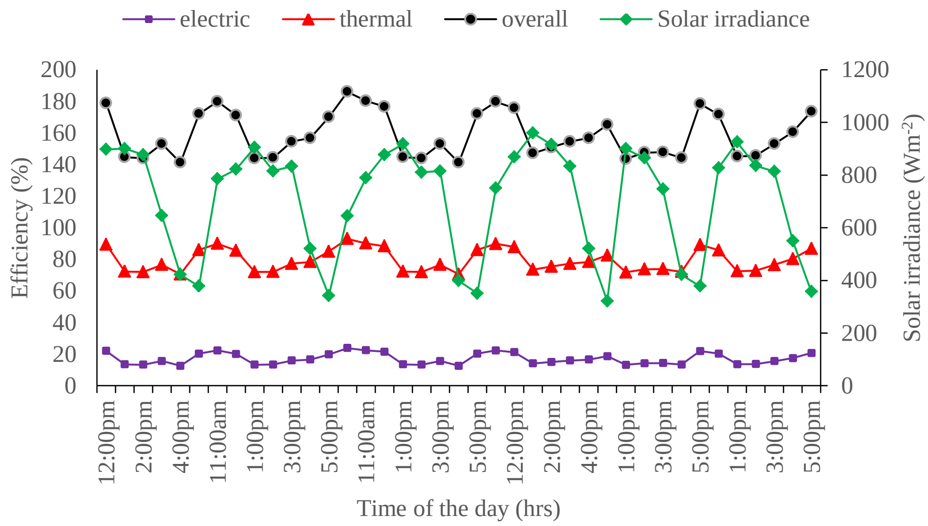


Fig. 2. Mean electrical, thermal and overall efficiencies at varying time and solar irradiance during sunshine periods.

The energy efficiency of the drying system is referred to as the ratio of energy utilized for removal of moisture to the total energy consumed during drying process. It then indicates that more energy was used increasing drying air temperature and product slice thickness at constant airflow rate (Figure 3). The energy efficiency reduces with increase in mass flow rate of the drying air; which varied between 15.67 to 38.17% as the drying air temperature and slice thickness increased from 50 to 70^{o}C, and 10 to 20mm, respectively at airflow rates of 3.43kgs^{-1} and 1.14 kgs^{-1}. Similar results have been reported for cassava starch drying and apple slices [6, 10], respectively.

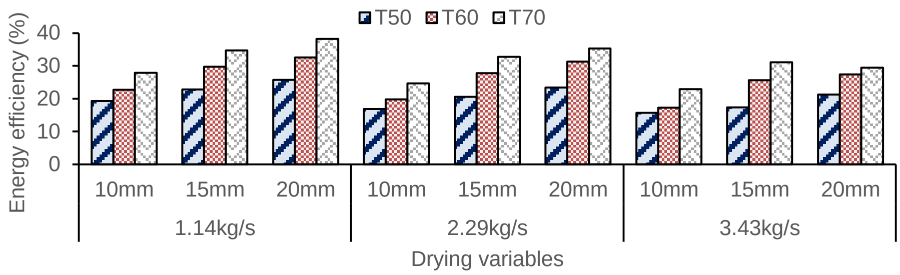


Figure 3. Variation of energy efficiency with drying air temperature, airflow rate and slice thickness.

However, at constant airflow rate, increasing the drying air temperature and slice thickness increases the drying efficiency of the system (Table 2). This was attributed to higher evaporative power of the drying air at increasing air temperatures, which reduce the water vapour pressure within the sample product, thus enhancing the drying rate. Increasing the airflow rate of the drying air increases the heat transfer rate within the system [29], as well as heat removal factor of the solar collector absorbing plate and electric heating unit. However, heat removal increases from these two heating units which yields an increase in the total useful heat of air, which enhances drying efficiency [30, 31]. From Table 2, the mean drying efficiency of the hybrid system varied between 7.12 – 40.27%. This agrees with [10, 25, 32] who reported drying efficiency values ranging between 2.50 – 54.37%.

Table 2: Mean values of drying efficiency at varying drying conditions.

Slice thickness (mm)		*10*			*15*			*20*	
Airflow rate (kgs^{-1})	*1.14*	*2.29*	*3.43*	*1.14*	*2.29*	*3.43*	*1.14*	*2.29*	*3.43*
Drying air temp. (^oC)					*Drying efficiency (%)*				
50	*7.12*	*12.42*	*15.45*	*13.66*	*17.54*	*21.43*	*20.27*	*25.12*	*29.75*
60	*10.72*	*14.92*	*17.63*	*16.51*	*20.82*	*24.71*	*25.41*	*30.41*	*34.53*
70	*12.81*	*16.61*	*18.38*	*19.77*	*22.49*	*28.37*	*29.94*	*33.12*	*40.27*

Energy performance

The total energy consumption for drying a batch of red pepper slices is shown in Figure 4. Increase in drying air temperature and airflow rate at constant slice thickness decreased the total energy consumption due to rise in kinetic energy of the product sample for rapid moisture diffusion and evaporation which increased the heat transfer rate and vapor pressure deficit for less intra-particle resistance to moisture taken place; drying time was reduced, thus reduction in the total energy consumption. Also as sample thickness increases, more energy was consumed for heat transfer to take place in the interior of sample due to large capillary distance. Increase in airflow rate. Energy consumption increased when drying thicker samples at increasing airflow rate due to longer time taken by internal moisture to diffuse trough the capillary structure, thus increased drying time. Generally, less energy was consumed at increased air temperature and airflow rate at any given slice thickness to dry the sliced pepper sample to the desired moisture level. The total energy consumption varied between 2.08 – 34.91kJ. These were obtained at drying air temperatures, air mass flow rates and slice thicknesses of70°C, 3.43kgs^{-1}, 10mm and 50°C, 1.14kgs^{-1}, 20mm, respectively.

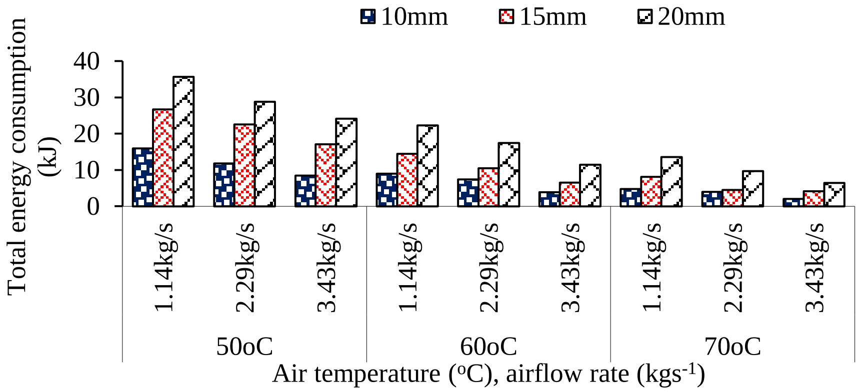


Fig. 4. Effect of drying air temperature and airflow rate at varying slice thicknesses on the total energy consumption for drying of red pepper slices.

Increase in the air temperature reduces the specific energy consumption at decreasing sliced simple thickness (Fig. 5). This is because of increased temperature gradient between the drying air and sample product which resulted in reduction in drying time, thus decreased specific energy consumption. Increasing the air temperature and airflow rate reduce the specific energy consumption due to increased heat transfer rate and water vapour pressure deficit in the sliced samples. Also increasing the airflow rate at constant air temperature decreases the specific energy consumption whereas increase in slice thickness increases it. The specific energy consumption ranged between 7.04 – 62.76 kJkg^{-1}.

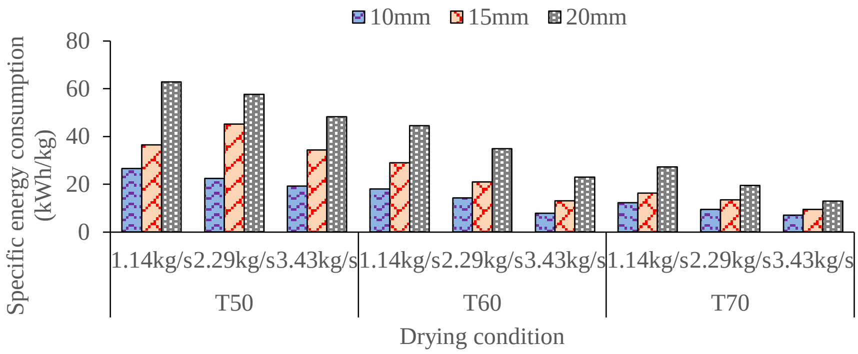


Fig. 5. Effect of air temperature and airflow rate at varying slice thicknesses on the specific energy consumption for drying of red pepper slices.

Variation in energy utilization (EU) during drying process of sliced red pepper samples at varying air temperatures, airflow rates and slice thicknesses is shown in Fig. 6. The energy consumption at constant airflow rate increases with temperature increase. This gave rise to further moisture removal in larger sample thickness because of increase in kinetic energy of the drying air that EU value. Also, EU increases with decrease in in sample slice thickness (at constant air temperature and airflow rate), because of short intra-particle capillary transfer of heat and moisture. At constant sample thickness, increasing the air temperature and airflow rate gave rise to increased EU because of increased rate of surface moisture evaporation. Similar observations were reported by [3, 10, 32, 33]. The energy utilization obtained for drying of red pepper slices ranged from 195.75 – 3013.21 Js^{-1}. Similar results for eggplant slices, ball pepper slices and okra slices in a hybrid solar-electric dryer were reported by [33 – 35].

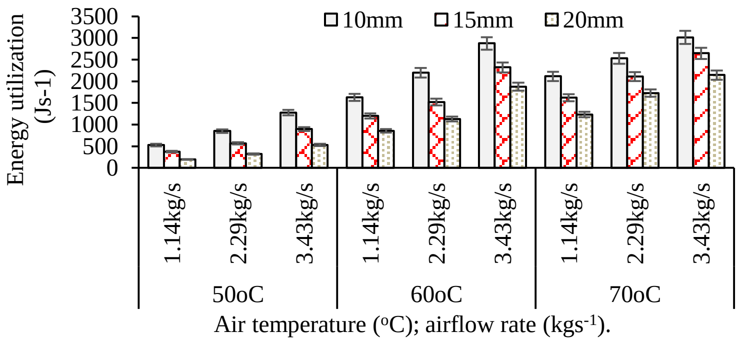
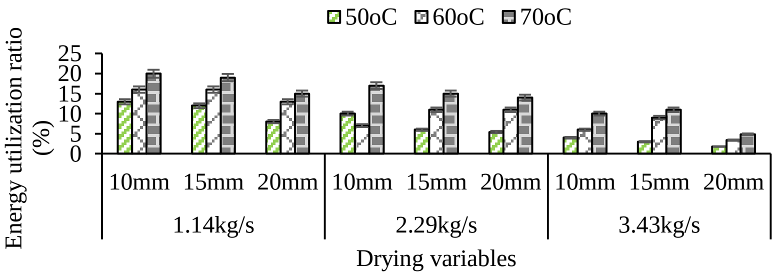


Fig. 6. Energy utilization at varying drying parameters.

The energy utilization ratio (EUR) at varying drying conditions of red pepper slices is presented in Fig.7. Increase in air temperature increases EUR but decreases it with increase in airflow rate. Increasing the slice thickness (at constant drying air temperature and airflow rate) decreases EUR, as a result of low kinetic energy of the drying air which gave rise to reduced heat and mass transfer rate. The EUR values obtained varied between 1.82 – 20.4% at drying air temperature of 50^{o}C, slice thickness of 20mm, mass flow rate of 3.43 kgs^{-1} and drying air temperature of 70^{o}C, slice thickness of 10mm, mass flow rate of 1.14 kgs^{-1}, respectively. These values are within the range of the reports of Aghbashlo et al. [35]; Akpinar [34]; Corzo et al. [36], which show that the energy utilization of the drying system was efficiently utilized for drying of red pepper slices, especially at higher air temperatures. Generally, reducing the slice thickness and airflow rate at increased drying air temperature yield high energy utilization ratio, therefore seems to be an important thermodynamic parameter for analyzing the net quantity of energy utilized during thin-layer drying process.



Exergy efficiency

The exergy efficiency as a function of drying time is illustrated by the decreasing trend of the curve in Fig. 8. During the first 6.5 hours of drying, the curve changed to a decreasing pattern and sharply increased towards the later period of the day, following a 3rd-order polynomial function. This initial decrease in the exergy efficiency was probably as a result of substantial increase in exergy loss of the drying chamber at increasing air temperature. Similar observation was reported by Boulemtafes-Boukadoum and Benzaoui [37] in the drying of mint.

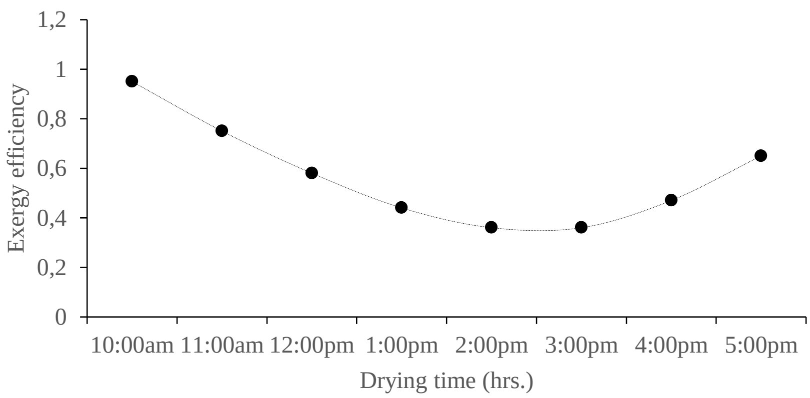


Fig. 8. Mean exergetic efficiency during sunshine periods.

Figure 9., shows the variations of exergy efficiency at varying drying conditions of the hybrid PV/T dryer. Increase in the drying air temperature and airflow rate reduced the exergy efficiency of the dryer, because of substantial exergy loss. Increase in inlet air temperature (with higher exergy) increases the internal moisture diffusion and surface evaporation of the product as well as the exergy utilization, thus increase in exergy loss. However, supply of heat energy by the hybrid heat units caused enormous reduction in the exergetic efficiency of the drying chamber. The exergetic efficiency obtained varied between 26% ≤ η_{ex} ≤ 88%.This is an indication of substantial quantity of supplied thermal exergy of the dryer system being lost to the exhaust drying air.

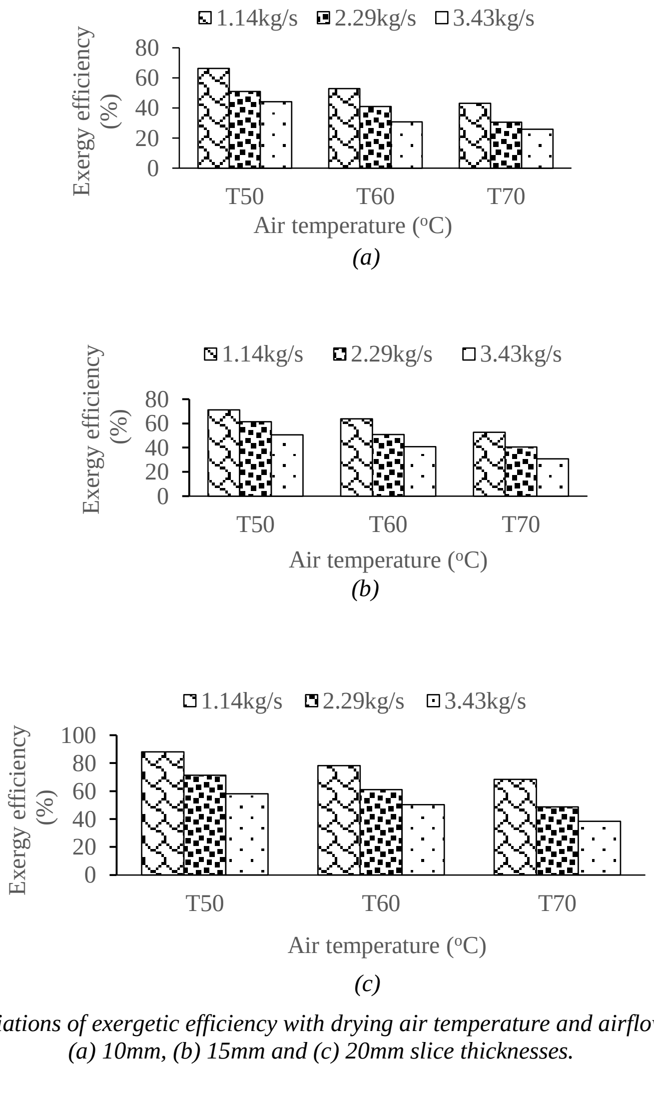


Fig. 9. Variations of exergetic efficiency with drying air temperature and airflow rate at: (a) 10mm, (b) 15mm and (c) 20mm slice thicknesses.

Sustainability indicators

The need to raise the drying air temperature above the ambient results in loss of exergy to the exiting air. In comparison of this lost exergy with the exergy inflow into the drying chamber is referred to as waste exergy ratio (WER), which was calculated with Eq. (11). The effect of varying air temperatures and airflow rates (at constant slice thickness) on WER is shown in Fig. 10. At increased air temperature and airflow, more exergy is lost to the exiting air, hence increased WER. The values of WER obtained range between 0.0827 ≤ WER ≤ 0.1579, which are close to the result obtained by Ndukwu et al [8].

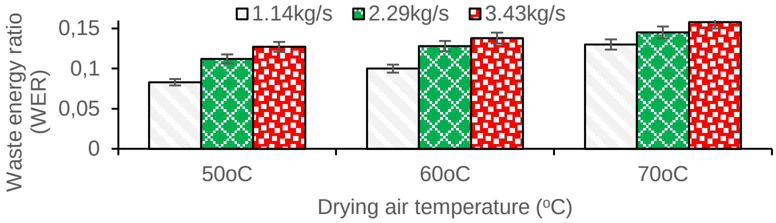


Fig. 10: Waste exergy ratio of red pepper slices in a hybrid solar-electric dryer.

Variation of the exergy sustainability index (SI) with varying air temperatures and airflow rates was calculated with Eq. (12) and presented in Figure 11. Air temperature decrease increases SI at increasing airflow rate. This results in increase in the exergy efficiency, which reduces environmental impact [38]. The values of SI obtained varied between: 1.137 ≤ SI ≤ 6.119. These values compared closely with the results of [8, 36] for solar dryers, which are in the range of 3.01 – 8.15 and 1.9 – 5.1, respectively. Therefore, improving the exergetic efficiency of the dryer is paramount in maintaining low environmental impact.

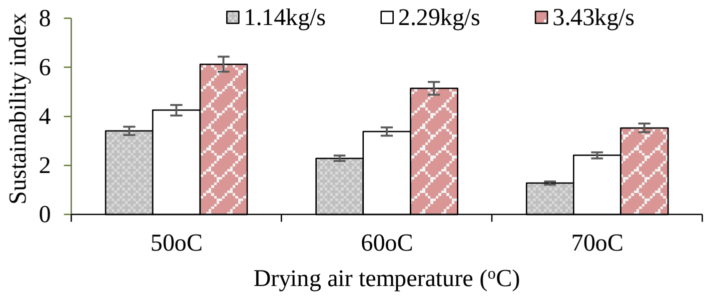


Fig. 11: Exergetic sustainability index at varying drying air temperature and air mass flow rate.

Fig. 12 illustratively presents the improvement potential (Eq. 13) of the drying system together with the exergy of the solar irradiance and exergy of the system.

The exergy of the solar irradiance varies between 0.311 – 0.77kW at 5pm and 1pm, respectively; whereas the improvement potential ranges from 0.198 – 0.583kW at 5pm and 1pm, respectively. The exergy of the hybrid PV/T system obtained varies from 0.0592 – 0.111kW at 9am and 1pm, respectively. The improvement potential of the hybrid dryer is a function of the difference between the inlet and outlet exergy of the drying chamber as well as the exergy efficiency [21]. A substantial quantity of exergy entering the drying chamber is wasted and goes into exergy destruction as depicted by the large difference. Therefore, the exergy efficiency would be reduced and the improvement potential (IP) would grossly increase. It can be deduced from Fig. 12 that large scope for system improvement exists as only 12.1 – 18.4% of the exergy from the solar radiation was utilized [21].

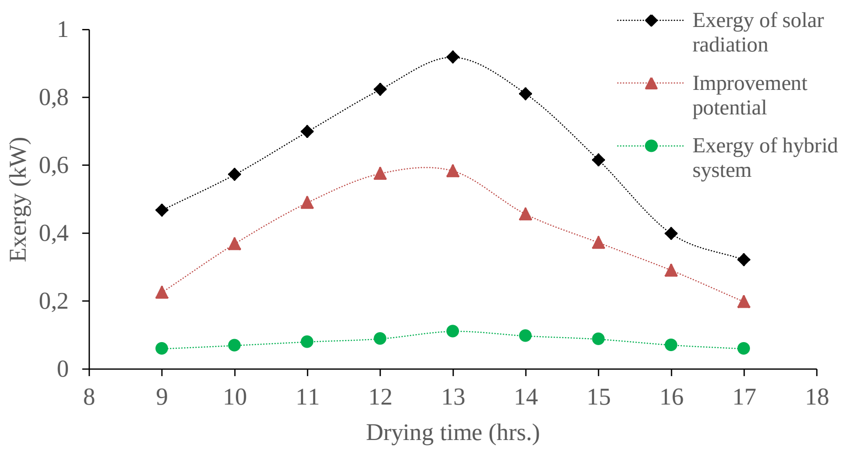


Fig. 12: Hourly variation of exergies of the drying chamber, solar radiation and improvement potential of the hybrid PV/T system.

The effect of drying chamber temperature on improvement potential (IP) is shown in Fig. 13. A linear relationship with high coefficient of correlation exists between the drying air temperature and IP. Improvement potential depends on exergy efficiency, which decreases with increasing air temperature and exergy loss, thus high improvement potential of the system [6, 7, 36]. The effect airflow rate was not noticeable on IP yield (Castro et al., 2018). The values of IP obtained varied between 0.099 ≤ IP≤-0.289 kW.

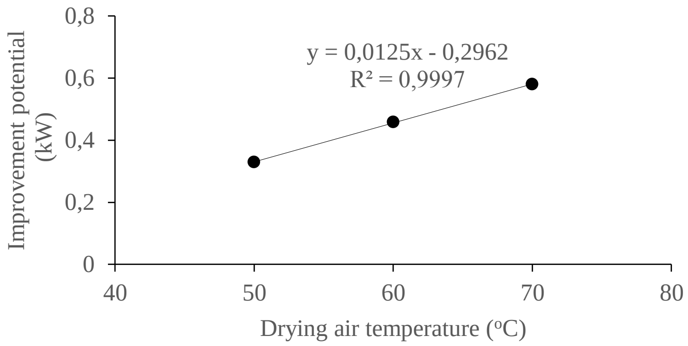


Figure 13: Effect of drying air temperature on the exergetic improvement potential.

CONCLUSIONS

A comprehensive performance analysis of a hybrid PV/T dryer in hot humid Nigerian environment applied to drying of red pepper slices is discussed. Based on the experimental findings of this study, the following conclusions can be drawn:

- The system performed satisfactorily during sunshine period of the drying process. The maximum electrical, thermal and overall efficiencies obtained were 23.86, 69.16 and 93.03%, respectively. Maximum solar irradiance (959.26Wm^{-2}) was obtained at 1:00pm with corresponding low electrical and thermal efficiencies of 14.3% and 59.43%, respectively.
- Energy efficiency reduces as air temperature, airflow rate and slice thickness increase. It varied between 15.67 to 38.17%.
- The mean drying efficiency of the hybrid system varied between 7.12 – 40.27%.
- The total and specific energy consumption for drying 500g batch of red pepper sliced samples in a hybrid PV/T dryer varied between 2.08 – 34.91kJ and 7.04 – 62.76 kJkg^{-1}, respectively. Increasing the drying air temperature and airflow rate at constant slice thickness reduced the total and specific energy consumption, whereas increase in slice thickness increased the total and specific energy consumption.
- The energy utilization during the drying process ranged from 195.75 – 3013.21 Js^{-1}, whereas the energy utilization ratio varied between 1.82 – 20.4%.
- The exergy efficiency decreased with drying time as temperature and airflow rate increased. It varied from 26% to 88%.

- The sustainability indicators show that waste energy ratio varied between $0.0827 \leq WER \leq 0.1579$; whereas sustainability index and improvement potential varied from: $1.137 \leq SI \leq 6.119$ and $0.198 \leq IP \leq 0.583$kW, respectively.
- It is therefore, suggested that exergy performance analysis and assessment of PV/T be conducted in order to model, evaluate, plan and apply PV/T systems to crop dryers. There is wide scope of system improvement for better performance. Air circulation device may be incorporated to remove generated heat from the PV modules in order to enhance the system's energy and exergy efficiencies, as well as to improve the energy conversion rate.

REFERENCES

[1] Augustine, C. and Nnabuchi, M.N. 2010. Analysis of some meteorological data for some selected cities in the Eastern and Southern zone of Nigeria. *African Journal of Environmental Science and Technology*, 4(2), 92 – 99.

[2] Okoroigwe, E.C., Eke, M.N. and Ugwu, H.U. 2013. Design and evaluation of combined solar and biomass dryer for small and medium enterprises for developing countries: *International Journal of Physical Sciences,* 8(25), 1341- 1349.

[3] Nazghelichi, T. Kianmehr, M.H. and Aghbashlo, M. 2010. Thermodynamic analysis of fluidized bed drying of carrot cubes. *Energy*, 35(2010), 4679 – 4684.

[4] Nwakuba, N.R., Asoegwu, S.N. and Nwaigwe, K.N. 2016. Energy requirements for drying of sliced agricultural products: a review. *Ag. Eng. International. CIGR E-Journal,* 18(2), 144-155.

[5] Motevali, A., Minaei, S., Banakar, A., Ghobadian, B. and Khoshtaghaza, M. H. 2014. Comparison of energy parameters in various dryers. *Energy Con. and Management*, 87, 711-725.

[6] Aviara, N.A., Onuoha, L.N., Falola, O.E. and Igbeka, J.C. 2014. Energy and exergy analyses of native cassava starch drying in a tray Dryer. Energy. 73 (2014), 809 – 817.

[7] Erbay, Z. and Icier, F. (2009). Optimization of hot air drying of olive leaves using response surface methodology. *Journal of Food Engineering,* 91(2009), 533 - 541.

[8] Ndukwu, M.C., Bennamoun, L., Abam, F.I., Eke, A.B. and Ukoha, D. 2017. Energy and exergy analysis of a solar dryer integrated with sodium sulfate decahydrate and sodium chloride as thermal storage medium. *Renewable Energy*. 113 (2017) 1182 – 1192.

[9] Koyuncu, T., Tosun, I. and Pinar, Y. 2007a. Drying characteristics and heat energy requirement of cornelian cherry fruits (Cornus *mas* L.). *J. of Food Eng.,* 78 (2007), 735 – 739.

[10] Beigi, M. 2016. Energy efficiency and moisture diffusivity of apple slices during convective drying. *Food Science and Technology,* 36 (1), 145 - 150.

[11] Kudra, T. 2012. Energy performance of convective dryers. *Drying Techn.,* 30, 1190-1198.

[12] Raghvan, G.S.V., Rennie, T.J., Sunjka, P.S., Orsat, V., Phaphuangwittayakul, W. and Terdtoon, P. 2005. Overview of new techniques for drying biological materials with emphasis on energy aspects. *Brazilian Journal of Chemical Engineering,* (22), 195-201.

[13] Akpinar, E.K., Midilli, A. and Bicer, Y. 2005. Energy and exergy of potato drying process via cyclone type dryer. *Energy Conversion Management,* 46, 2530–2552.

[14] Bennamoun, L. 2012. An overview on application of exergy and energy for determination of solar drying efficiency. *International Journal of Energy Engineering,* 2(5), 184 – 194.

[15] Erbay, Z. and Icier, F. 2009. Optimization of hot air drying of olive leaves using response surface methodology. *Journal of Food Engineering*, 91(2009), 533 - 541.

[16] Koyuncu, T., Tosun, I. and Pinar, Y. 2007b. Drying characteristics and heat energy requirement of cornelian cherry fruits (*Cornus mas* L.). *J. of Food Eng.,* 78 (2007), 735 – 739.

[17] Darvishi, H., Asi, R.A., Asghari, A., Najafi, G. and Gazori, H.A. 2013. Mathematical modeling, moisture diffusion, energy consumption and efficiency of thin-layer drying of potato slices. *Journal of Food Process Tech*nology, 4(2013), 215 - 219.
[18] Hegazy, A. A. 2000. Comparative study of the performances of four photovoltaic/thermal solar air collectors. *Energy Conversion and Management*, 41, 861 – 881.
[19] Kalogirou, S.A. and Tripanagnostopoulos, Y. 2006. Hybrid PV/T solar systems for domestic hot water and electricity production. *J. of En. Con. and Management*, 47, 3368 – 3382.
[20] Alzaabia, A.A., Badawiyeha, N. K., Hantousha, H. O. and Hamid, A. K. 2014. Electrical/thermal performance of hybrid PV/T system in Sharjah, UAE. *International Journal of Smart Grid and Clean Energy*, 3(4), 385-389.
[21] Joshi, A. S., Dincer, I. and Reddy, B.V. 2011. Analysis of energy and exergy efficiencies for hybrid PV/T systems. *Low-Carbon Technologies*, 6(1), 64 – 69.
[22] Oyewola, M.O. and Adeleke, A.I. 2014. Design and construction of a hybrid dryer with temperature control, utilizing solar and electric energies. International Conference of Mechanical Engineering, Energy Technology and Management. 639 – 646, 10 – 14th May, 2014, Johannesburg, South Africa.
[23] Nwakuba, N.R., Chukwuezie, O.C., Asonye, U.G. and Asoegwu, S.N. 2019. Influence of process parameters on the energy requirements and dried sliced tomato quality. *Applied Engineering in Agriculture* (in press). https://doi.org/10.13031.
[24] Ibrahim, A., Othman, M.Y., Ruslan, M.H., Alghoul, M.A., Yahya, M., Zaharim, A. and Sopian, K. 2009. Performance of photovoltaic thermal collector (PVT) with different absorbers design. *Journal of WSEAS Transactions on Environment and Development*, 5(3), 322-330.
[25] Boughali, S., Benmoussa, H., Bouchekima, B., Mennouche, D., Bouguettaia, H. and Bechki, D. 2009. Crop drying by indirect active hybrid solar– electrical dryer in the eastern *Algerian Septentrional Sahara: Solar Energy,* 83(2009) 2223–2232.
[26] Fudholi, A., Yendra, R., Basri, D.F., Ruslan, M.H. and Sopian, K. (2016). Energy and exergy analysis of hybrid solar drying system. *Cont*. Eng*ineering Science*, 9(2016) 215 – 223.
[27] Midilli, A. and Kucuk, H. (2014). Exergy-based sustainability indicators for a single layer solar drying process. *Progress in Exergy, Energy and Environment*, 3(4), 705 – 712.
[28] Fu, M., Roman, C., Echegaray, M., Mazza, G. and Rodriguez, R. (2018). Exergy analyses of onion drying by convection: influence of dryer param. on performance. *Entropy*, 20 (2018), 2 – 9.
[29] Reyes A., Mahn, A., Huenulaf, P. and Gonzalez, T. 2014. Tomato dehydration in a hybrid solar dryer. *Chemical Engineering Processing Technology*, 5(2014), 1-8.
[30] Lopez-Vidana, E.C., Mendez-Lagunas, L.L. and Rodriguez-Ramirez, J. 2013. Efficiency of a hybrid solar-gas dryer. *Solar Energy*, 93 (2013), 23 – 31.
[31] Doymaz, I. 2004. Drying characteristics and kinetics of okra. *Journal of Food Engineering,* 69(2004), 275-279.
[32] Azadbakht, M., Torshizi, V.M., Ziaratban, A. and Aghili, H. 2017. Energy and exergy analysis during eggplant drying in a fluidized bed dryer. *Agricultural Engineering International: CIGR E-Journal,* 19(3), 177- 182.
[33] Nwakuba, N.R, Chukwuezie, O.C., Asonye, U.G. and Asoegwu, S.N. 2018. Energy efficiency and optimization of convective hot air drying conditions of okra slices. 12th International CIGR Technical Symposium, IITA, Ibadan, Nigeria, Pp. 464 – 488.
[34] Akpinar, E.K. 2004. Energy and exergy analyses of drying of red pepper slices in a convective type dryer. *Int.Communication in Heat and Mass Transfer*, 31(2004), 1165 - 1176.
[35] Aghbashlo, M., Kianmehr, M.H. and Samimi-Akhijahani, H. 2008. Influence of drying conditions on the effective moisture diffusivity, energy of activation and energy consumption during the thin-layer drying of beriberi fruit (Berberidaceae). *Energy Conversion and Management*, 49: 2865–2871.
[36] Corzo, O., Bracho, N., Vasquez, A. and Pereira, A. 2008. Optimization of a thin layer drying process for coroba slices. *Journal of Food Engineering,* 85(2008), 372 – 380.

[37] Boulemtafes-Boukadoum, A. and Benzaoui, A. 2011. Energy and exergy analysis of solar drying process of mint. *Energy Procedia*, 6(2001), 583 – 591.
[38] Rosen, M.A., Dincer, I. and Kanoglu, M. 2008. Role of exergy in increasing efficiency and sustainability and reducing environmental impact, *Energy Policy*, 36 (2008), 128 – 137.

PERFORMANSE HIBRIDNOG FOTOVOLTAŽNOG / TOPLOTNOG SUŠENJA U TOPLO-VLAŽNOM REGIONU NIGERIJE

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Sažetak: Ovaj rad predstavlja studiju koja je sprovedena u cilju ispitivanja performansi hibridne fotonaponske/termičke sušare u toplo-vlažnom regionu Umuagvo-Ohaji, jugoistočni region Nigerije, kroz energetske i eks energijske analize: sušenje, električne i toplotne efikasnosti , koeficijent korišćenja energije i iskorišćenja energije, indikatori održivosti kao što su odnos energije otpada (VER), indeks održivosti (SI) i potencijal za poboljšanje (IP). Eksperimenti sušenja su sprovedeni na različitim temperaturama ulaznog vazduha (50, 60 i 70^{o}C), brzinama protoka vazduha (1,14, 2,29 i 3,43 kg^{-1}) i debljinama preseka (10, 15 i 20 mm) na 500g serije šarži crvenog bibera tokom perioda izlaganju sunčevoj svetlosti.
Dobijeni rezultati pokazuju da ukupna i specifična potrošnja energije za sušenje serije rezanih uzoraka crvene paprike varira između 2,08 - 34,91 kJ i 7,04 - 62,76 kJkg^{-1}, respektivno. Koeficijent korišćenja energije i iskorišćenosti energije tokom procesa sušenja kretao se od 195,75 do 3013,21 Js^{-1} i 1,82 do 20,4%, respektivno. Efikasnost energije i eks energije varira od 15,67 do 38,17% i 26% do 88%, respektivno. Srednja efikasnost sušenja sistema kretala se od 7,12 do 40,27%. Dobijene maksimalne električne i toplotne efikasnosti su od 23,86% i 93,03%. Dobijen je odnos energije energije od 0.0827 do 0.1579, dok su SI i IP vrijednosti u rasponu $1.137 \leq SI \leq 6.119$ i $0.198 \leq IP \leq 0.583$ kV, respektivno. Svakako postoji širok spektar poboljšanja u PV / T sistemu kao 12,1 do 18,4% solarnog zračenja koje je potrošeno za sušenje.
Predložene su perspektive za poboljšanje i preporuke za dalje studije.

Ključne reči: *energija, eksenergija, PV-T sistem, indikatori održivosti, termička konverzija*

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UBIRANJE SOJE KOMBAJNOM CLAAS LEXION 430 -EKPLOATACIONI PARAMETRI

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Sažetak: Soja (*Glycine*) je jedna od najvažnijih ratarskih kultura, od koje se dobijaju proizvodi važni u ishrani ljudi i domaćih životinja i za preradu u industriji. Soja je važan izvor belančevina i ulja. Seme soje sadrži više proteina (35- 50%) i masti (17- 24%), a manje ugljenih hidrata od ostalih mahunastih biljaka.

Kombajn Claas Lexion 430 posle eksploatacionih istraživanja imao je u žetvi merkantilne soje gubitke u neodrezanim mahunama u svim merenjima iznad tolerantnih 2%. Ovi gubici su bili u intervalu od 2,46 % do 2,94 %.

Kombajn Claas Lexion 430 na vršalici ima gubitke u slobodnom zrnu koji su varirali od 0,18% do 0,34 % (proseku 0,26%), što je zadovoljavajuće u odnosu na zadatih 0,3 %. Prosečni gubici u neovršenim mahunama su 0,35 %, što je više od projektovanog nivoa, ali se za uslove ubiranja mogu prihvatiti kao zadovoljavajući, iz razloga značajne zakorovljenosti parcele.

Ključne reči*: kombajn, soja, gubici, produktivnost*

UVOD

Soja (*Glycine*) spada u najvažnije njivske biljke. Pored ishrane ljudi i stoke, soja je bitna i zbog mogućnosti dobijanja biodizela, [4]. Soja je specifičan usev čije se najniže mahune na stablu biljke, u zavisnosti od sorte, nalaze na visini od 0 do 8 ili 8 do 21 cm iznad podloge.

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Pri ubiranju kombajnima sorata sa niskim mahunama, gubici se mogu kretati i do 20% prinosa. Kod sorata sa visokim mahunama ovi gubici se kreću oko 6%, od čega približno 50 % odlazi na heder, a 50 % na vršalicu.

Kod sorti sa većom količinom biljne mase povećavaju se gubici na vršalici, pa je preporučljivo da se usev prethodno tretira sredstima za brže sušenje. Gubici na hederu uglavnom nastaju radom vitla, kao i u odrezanim i neodrezanim mahunama.[4]

Na osnovu nezvaničnih podataka poslovnog udruženja "Industrijsko bilje", površine pod sojom u Srbiji iznosila je 230.000 ha u 2017. godini, sa prosečnim prinosom od 1,5 t/ha [1].

Žetva soje se obavlja u tehnološkoj ili tehničkoj zrelosti koja nastaje uobičajeno 7 do 14 dana posle fiziološke zrelosti. Sušenje mahuna soje je pasivan proces, jer je biljka već odumrla, i brzina sušenja prvenstveno zavisi od vremenskih uslova, odnosno temperature i padavina. Zbog slabljenja veze između biljke i semena, tokom sušenja dolazi do gubitaka semena u polju, a takođe se oni povećavaju i u momentu žetve, što se posebno potencira pri kašnjenju sa žetvom. Znači da ostvareni prinos u polju može biti znatno umanjen zbog žetvenih gubitaka koji dostižu i do 20 % od biološkog prinosa, pa je žetva veoma važna mera u procesu proizvodnje soje. Sa žetvom treba početi kada je sadržaj vode u semenu 13-14%, mada može i ranije, no tada je neophodno dosušivanje, dok se pri kasnijoj žetvi povećavaju gubici i smanjuje kvalitet semena soje. Žetveni gubici i oštećenje semena su minimalni pri vlažnosti zrna soje od 12 do 15%, [5].

Pravilnim izborom odgovarajuće brzine kretanja kombajna mogu se postići značajne uštede goriva i energije. Povećanjem brzine kretanja u radu do određene granice koja je limitirana snagom kombajna, povećava se časovna potrošnja goriva, ali se postiže veći učinak, pa je ukupna potrošnja goriva i energije po jedinici površine manja, a pri tome se postiže i ušteda u efektivnom radnom vremenu[5].

Uz obezbeđenje određenih preduslova, ulaganje u kupovinu univerzalnog žitnog kombajna može da pokaže visok stepen ekonomske efektivnosti [8].

Uvođenjem savremenih žitnih kombajna gubici u žetvi svode se na manje od 2,0-2,5%, uz zadovoljavajući kvalitet i čistoću ovršene mase. Sadržaj primesa, polomljenog i šturog zrna u masi celog zrna nije poželjan, bilo u semenskom bilo u zrnu za preradu [1].

MATERIJAL I METODE RADA

Ogled je izveden 2017.godine na parcelama Instituta za kukuruz "Zemun Polje" Zemun polje - Beograd. Proizvodne parcele VII i VIII na kojima je urađeno istraživanje nalaze se u blizini ekonomskog dvorišta Instituta. Temperatura vazduha u toku ispitivanja kretala se od 12^{o}C (jutarnji sati) do 16^{o}C u toku dana. Vlažnost vazduha se kretala od 88% (jutarnji sati) do 77% u toku dana.

Ispitivanje kombajna Claas Lexion 430 je izvršeno u merkantilnoj soji, pri čemu su evidentirani pokazatelji koji su od bitnog značaja za proces ubiranja:

- sorta soje-Laura (hibrid – Zemun Polje)
- broj mahuna po biljci - 48 kom
- prosečna visina biljaka - 92 cm
- sklop biljaka u žetvi - 392000 biljaka/ha
- međuredno rastojanje - 50 cm
- rastojanje u redu - prosečno - 5,1 cm
- vlažnost zrna - prosečno 16,15%
- prinos zrna - prosečno – 1.556 kg/ha
- stabljike uspravne

U vreme ogleda kombajn Claas Lexion 430 ima parametre rada:

• brzina kretanja kombajna: 6 kmh^{-1}
• broj obrtaja motora kombajna: 2100 min^{-1}
• broj obrtaja bubnja: 410 min^{-1}
• zazor podbubnja na ulazu: 25 mm
• broj obrtaja ventilatora: 1300 min^{-1}
• sita, gornja otvorenost: 15 mm
•sita, donja otvorenost: 10 mm

U ispitivanjima su korišćeni: hronometar, merna traka, trasirke, merno platno, platneno crevo, koš i vaga. Za svaki ispitivani parametar uzeti su odgovarajući uzorci u tri ili više ponavljanja.

Za ocenu uspešnosti ubiranja soje definisani su svi gubici i određena je maksimalna vrednosti istih u datim uslovima. Prvo su predhodno utvrđeni gubici, koji čine gubitke u slobodnom (otpalom) zrnu i gubitke zrna u otpalim mahunama.

Gubici na hederu utvrđuju se sakupljanjem zrna iz otpalih, odrezanih i neovršenih mahuna sa 1m^2 .

Utvrđivanje gubitaka na vršalici i slamotresu vrši se metodom „brzog utvrđivanja gubitaka“ pomoću specijalnih sudova. Posuda se postavlja između prednjih i zadnjih točkova kombajna. U ovu posudu upadaju svi žetveni ostaci koji pređu preko sita i slamotresa. Merenjem dobijene mase utvrđuje se visina gubitaka na 1m^2, a množenjem sa 10.000 količina gubitaka na 1ha.

REZULTATI ISTRAŽIVANJA I DISKUSIJA

Gubici hedera utvrđeni su u 3 ponavljanja, u različitim vremenskim intervalima u toku dana u 11 h, 14 h i 16 h, uzimanjem slobodnog zrna, zrna iz odrezanih mahuna i zrna iz neodrezanih mahuna. Gubici na hederu prikazani su u tabeli 1.

Tabela 1. Gubici na hederu kombajna Claas Lexion 430
Table 1. Header losses of harvester Claas LExion 430

Gubici *Losses*	*I*	*II*	*III*	*% Gubitaka* *% Losses*
Slobodno zrno *Free grain*	*0,18*	*0,22*	*0,16*	*0,19*
Zrno iz odrezanih a palih mahuna *Grain from cuted and droped pods*	*0,24*	*0,26*	*0,22*	*0,24*
Zrno iz neodrezanih mahuna *Grain from uncuted pods*	*2,46*	*2,82*	*2,94*	*2,72*
Ukupno *Total*	*2,88*	*3,30*	*3,32*	*/*

Gubici na vršalici i slamotresu određeni su zbirnom metodom „brzog utvrđivanja“. Uzorci su su uzimani u više navrata u toku radnog dana.

Zbog specifičnosti (oblik i masa zrna soje) ovi gubici su znatno niži od gubitaka u ubiranju strnih kultura, ali ipak postoje.

Tabela 2. Gubici na vršalici i slamotresu kombajna Claas Lexion 430
Table 2. Threshing system and straw walker lossesof harvester Claas Lexion 430

Gubici Losses	*I*	*II*	*III*	*IV*	*V*	*% gubitaka % losses*
Slobodno zrno Free grain	*0,20*	*0,24*	*0,16*	*0,18*	*0,34*	*0,26*
Zrna iz neovršenih mahuna Grains from unthreshed pods	*0,42*	*0,38*	*0,26*	*0,26*	*0,42*	*0,35*
Ukupno Total	*0,62*	*0,62*	*0,42*	*0,44*	*0,76*	*0,57*

Sa aspekta oštećenja i čistoće zrna, analizom većeg broja uzoraka i analizom dobijeni su rezultati za :

- Cela zrna 94 - 98,2 %
- Napukla zrna 0,6 - 1,4 %
- Polomljena zrna 0,8 - 3,2 %
- Biološke nečistoće 1,1 - 3,1 %
- Mehaničke nečistoće 0,1 - 0,4 %

Snimanjem i praćenjem rada na parceli ustanovljeno je:

•Koeficijent iskorišćenja širine radnog zahvata iznosio je 0,78. Uzrok ovoj vrednosti koeficijenta, je neadekvatno određivanje širine zagona, pa se dešavalo da u zadnjem prohodu kombajn ima samo 40% širine zahvata hedera;

•Koeficijent punjenja bunkera iznosio je 0,86%, a razlog je neujednačen prinos soje i zakorovljenost, te se kombajn morao prazniti i sa 80% napunjenim bunkerom;

•Vreme pražnjenja bunkera od 3,8 min. u odnosu na projektovanih 3 min. je nastalo usled nepravilno raspoređenih transportnih sredstava;

•Zbog zakorovljenosti varirala je brzina kretanja kombajna 3,5 kmh^{-1} do 8,6 kmh^{-1};

•24 min. utrošeno je na odgušivanje elevatora i aparata za vršidbu;

•Kombajn ,Claas Lexion 430 utrošio je 15,2 lha^{-1} pogonskog goriva.

Na dan ispitivanja nije ostvaren projektovani dnevni učinak od 17 ha, već učinak od 14,20 ha, što je utvrđeno na kraju radnog vremena merenjem požnjevene površine.

Upoređivanjem ostvarenih rezultata sa projektovanim može se zaključiti da postavljeni zadaci nisu izvršeni u potpunosti u pogledu visine gubitaka, kvaliteta ovršenog zrna i eksploatacionih pokazatelja. Ovome je doprinelo veliko prisustvo korova na parceli.

Gubici hedera izraženi u slobodnom zrnu i zrnu iz otpalih mahuna su bili u okviru zadatih granica, dok su gubici u neodrezanim mahunama u svim merenjima bili iznad tolerantnih 2%, a kretali su se u granicama od 2,46 % do 2,94 %.

Gubici na vršalici u slobodnom zrnu su varirali od 0,18% do 0,34 % u proseku 0,26 %, što je zadovoljavajuće u odnosu na zadatih 0,3 %. Prosečni gubici u neovršenim mahunama su 0,35 %, što je više od projektovanog nivoa, ali se za uslove ubiranja mogu prihvatiti kao zadovoljavajući.

ZAKLJUČAK

Uvođenje visoko produktivnih kombajna u tehnološki postupak žetve, ogleda se sa aspekta gubitaka i kvaliteta ovršenog zrna. Sadržaj primesa, polomljenog i šturog zrna je nepoželjan kako u semenskoj robi tako i u zrnu za preradu.

Upoređivanjem ostvarenih rezultata sa projektovanim zadatkom može se zaključiti da postavljeni zadaci nisu izvršeni u potpunosti u pogledu visine gubitaka, kvaliteta ovršenog zrna i eksploatacionih pokazatelja. Ovome je doprinelo veliko prisustvo korova na parceli.

Kombajn ,Claas Lexion 430 utrošio je 15,2 l ha^{-1} pogonskog goriva, a pri tome je ostvario učinak od 14,20 ha. Konstatovano je dosta praznog hoda mašine, jer je došlo do tehničkih problema zbog zagušenja elevatora i aparata za vršidbu

Gubici hedera izraženi u slobodnom zrnu i zrnu iz otpalih mahuna bili su u okviru zadatih granica.Gubici u neodrezanim mahunama su u svim merenjima bili iznad tolerantnih 2%, gde se za uzročnik problema može potražiti u žitnom hederu kombajna, koji nije imao mogućnost prilagođavanja terenu (fleksibilni hederski sto). Zbog ovog parametra rada kombajna, visina reza biljaka bila nešto veća, a samim tim mahune koje su se nalazile niže na stabljiki biljke, i nisu bile odrezane.

Eksploataciono podešavanje vršidbenih organa je bilo zadovoljavajuće, pa su gubiciu slobodnom zrnu soje varirali od 0,18% do 0,34 %, u proseku 0,26 %.

Gubici u neovršenim mahunama su bili 0,35 %, što je više od projektovanog nivoa, ali usled veće koncentracije korovske vegetacije u usevu soje, mogu se prihvatiti kao zadovoljavajući. Na mestima gde je korov bio prisutniji, kvalitet rada kombajna u svakom pogledu bio je lošiji uz manji eksplatacioni učinak.

LITERATURA

[1] Barać, S., Biberdžić, M., & Đokić, D. 2006. Kvalitet rada separacionih organa pri kombajniranju pšenice kombajnima u agroekološkim uslovima Srema. *Poljoprivredna tehnika*, Poljoprivredni fakultet, Beograd, 31 (3), pp. 29-35.

[2] Đukić, V., Miladinov, Z., Balešević-Tubić, S., Miladinović, J., Đorđević, V., Valan, D., Petrović, K. 2018. Critical moments in soybean production. Proceedings of the 52nd Conference of Agronomists and Farmers of Serbia (SAPS) and 1. Counseling of Agronomists of the Republic of Serbia and the Republic of Srpska, Zlatibor, 21-Publisher Institute of Field and Vegetable Crops, Novi Sad, pp. 34-44.

[3] Filipović, D., Piria, I. 1987. Mogućnosti uštede energije u obradi tla. Zbornik radova sa savetovanja- Aktuelni zadaci mehanizacije poljoprivrede, 2. deo, Zadar, str. 457-461.

[4] Mago, L., Topisirović, G., Oljača, S., Oljača, M. 2010. Solid biomass potential from agriculture in Hungary and Serbia. *Poljoprivredna tehnika*, Poljoprivredni fakultet, Beograd, 35 (4),. pp. 35-45.

[5] Miladinović, J. 2012. Vodič za organsku proizvodnju soje, GIZ-Nemačka organizacija za internacionalnu saradnju GmbH; Novi Sad: Institut za ratarstvo i povrtarstvo.

[6] Milovanović, M., Eksploatacioni parametri kombajna Claas Lexion 430 u uslovima ubiranja soje, Poljoprivredni fakultet Univerziteta u Beogradu, diplomski rad, Zemun - Beograd 2018.

[7] Pajić, M., Miodragović, R., Mileusnić, Z., Gligorević, K., Dražić, M., Balać, N., Pajić, M, Ožegović, M. 2016. Eksploataciona istraživanja rada kombajna New holland CR8070 u žetvi merkantilnog kukuruza. 18. Naučno stručni skup sa međunarodnim učešćem aktuelni problemi mehanizacije poljoprivrede, Poljoprivredni fakultet Beograd, pp. 102-107.

[8] Todorović, S., Ivanović, S., Marković, T. 2012. Ekonomski opravdan iznos ulaganja u kupovinu univerzalnog žitnog kombajna na porodičnim gazdinstvima. *Poljoprivredna tehnika*, Poljoprivredni fakultet, Beograd, 37 (2), pp. 81-90.

RESEARCH OF CLAAS LEXION 430 HARVESTER -EXPLOITATION IN SOYA HARVEST

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Abstract: Soya (*Glycine*) is one of the most important crop plant. It produces products for human and domestic animals and processing industry. It is an important protein and oil plant. The soybean seeds contain more proteins (35-50%) and fats (17-24%) and fewer carbohydrates than others leguminous plants.
Research of the Claas Lexion 430 combine harvester in a mercantile soybeans harvest shown that losses in uncut pods were in all measurements above tolerant 2% and ranged from 2.46% to 2.94%.

Losses on the thresher in the free grain were ranged from 0.18% to 0.34% on average to 0.26%, which is satisfactory in relation to the given 0.3%. The average losses in the unthreshedpods are 0.35%, which is more than the projected level, but for the conditions of harvesting it can be accepted as satisfactory, due to the large percentage of weeds in the field.

Key words: *harvester, soya, losses, productivity*

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