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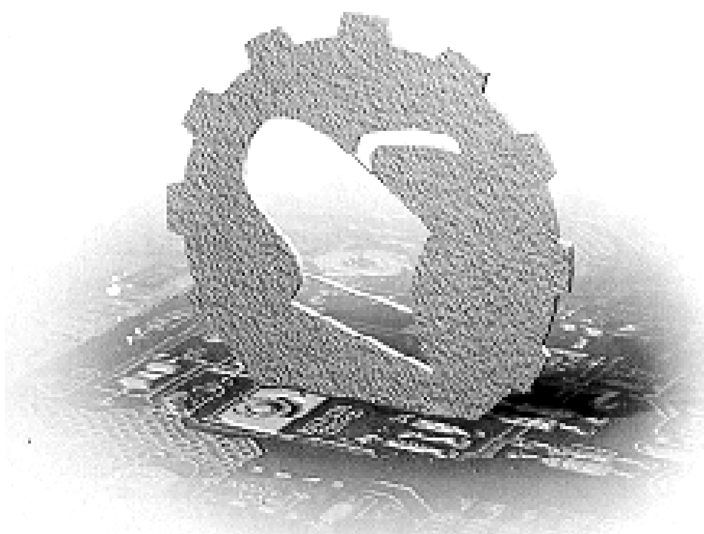

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RAZVOJ HIDRAULIČKO-MEHANIČKOG SISTEMA AUTOMATSKE NIVELACIJE BERAČA MALINE I KUPINE

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Sžetak: U radu su analizirani problemi vezani za stabilnost samohodnog berača pri mehanizovanoj berbi jagodastog voća na nagnutim terenima. Prikazano je rešenje automatske nivelacije berača plodova maline i kupine. Zahvaljujući niskoj ceni, jednostavnosti konstrukcije, visokoj pouzdanosti, uprošćenom i minimalizovanom održavanju, rešenje je posebno pogodno za manje zasade udaljene od servisnih centara. Opisane su komponente sistema, njihova namena i međusobna funkcionalna povezanost. Od posebnog značaja su činjenice da je sistem nivelacije, kao i njegove komponente, projektovan i proizvedene u našoj zemlji.

Ključne reči: *samohodni berač, stabilnost, nagib, mehanička berba, malina, kupina*

UVOD

U savremenoj proizvodnji voća, uključujući i jagodasto, konkurencija stalno jača, globalizacija je izraženija, a ekološki, ekonomski i marketinški zahtevi su sve izraženiji i oštriji. U tim uslovima, poslovanje je moguće samo uz stalno poboljšanje kvaliteta proizvoda i povećanje obima proizvodnje. Neophodno je podizanje efikasnosti i ekonomičnosti svih, ili bar najvažnijih, tehničko-tehnoloških segmenta proizvodnog

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Rezultati istraživanja su proizašli iz aktivnosti projekta *Unapređenje biotehnoloških postupaka u funkciji racionalnog korišćenja energije, povećanja produktivnosti i kvaliteta poljoprivrednih proizvoda*, broj TR 31051, pod pokroviteljstvom Ministarstva prosvete, nauke i tehnološkog razvoja Republike Srbije.

ciklusa. Posebno je značajna tendencija povećanja proizvodnje maline i kupine u nekim članicama Evropske Unije (Poljska i Mađarska), koja izrazito pooštrava konkurenciju i na domaćem tržištu. Proizvodnja u Srbiji se do sada uglavnom sprovodila na manjim posedima i zasnivala na ručnoj berbi. Usled ubrzanog razvoja proizvodnje jagodastog voća u okruženju, okarakterisane velikim zasadima i primenom mehanizacije za obavljanje svih radnih operacija kao i procesa berbe, smanjeni su proizvodni troškovi (uzgoja i eksploatacije zasada). Sve to je rezultiralo padom cena maline na svetskom tržištu, zbog čega je domaća proizvodnja u Srbiji izložena dodatnom pritisku [7].

Malina, ribizla, kupina i aronija imaju dosta zajedničkih osobina, ali i značajnih razlika u pogledu gajenja i berbe. Jednu od najkritičnijih faza u procesu proizvodnje svih ovih vrsta voća, predstavlja berba [12]. Ona predstavlja prvi i najvažniji postupak u procesu realizacije njihove proizvodnje, koji značajno utiče na konačan rezultat iskorišćavanja ovog voća [6]. Za to postoji više razloga. Berba je suštinski uslovljena ne samo nizom bioloških ograničenja, vezanih za fiziološke i morfolške karakteristike gajenih biljaka, nego i geografskim, klimatološkim, pedološkim i drugim uslovima terena na kome se proizvodnja odvija. Kao posledica navedenih faktora, berba je sezonska, vremenski strogo ograničena aktivnost [5]. Često je veoma teško pronaći slobodnu radnu snagu za taj povremeni posao u odgovarajućem vremenskom periodu.

Zbog razgranatosti žbunova (razgrtanje pri branju), sitnih plodova, potrebe da se berba obavi u nekoliko navrata (plodovi ne sazrevaju istovremeno), ručno ubiranje jagodastog voća zahteva veliki udeo radne snage u ukupnim proizvodnim troškovima [13]. Ručna berba maline i kupine dostiže čak i 70 % ukupnih proizvodnih troškova. Mašinska berba voća predstavlja moguće rešenje problema, uz nezaobilazni uslov da se pri tome strogo vodi računa o specifičnim zahtevima berbe za svaku biljnu vrstu i sortu [9], [10], [11]. Stoga se u poslednje vreme posebna pažnja posvećuje evaluaciji rezultata mehanizovane berbe jagodastog voća (videti [8], [13]).

Tipični primeri navedenih problema sreću se u proizvodnji maline. Proizvodni proces ove vrste jagodastog voća karakteriše sezona berbe koja traje od 30 do 90 dana, u zavisnosti od sorte. Ubiranje plodova se vrši svaki drugi ili treći dan. Plodovi ove biljke su nežni i ne dozvoljavaju pranje u procesu prerade. Stoga, razlozi ekonomičnosti i higijene branja mogu poslužiti kao dodatni motiv uvođenja mašinske berbe za ovo voće. Plodovi kupine takođe ne sazrevaju istovremeno, te je i u ovom slučaju potrebno više ciklusa ubiranja da bi se osigurao maksimalni kvalitet. Berba se obavlja svaki drugi dan ili češće, ukoliko su temperature visoke. Najviši kvalitet se ostvaruje ako se berba obavlja ujutro, nakon povlačenja rose, a pre nastupa visokih temperatura. Stoga je i kod ove kulture veoma strogo određen vremenski interval za ubiranje, što ponovo navodi na mašinsku berbu. Zasadi maline i kupine, kao i ostalog jagodastog voća, često se nalaze na terenima pod nagibom. To može predstavljati ozbiljan problem za normalno funkcionisanje i bezbedan rad kombajna u toku transporta i berbe. Problem se može rešiti uvođenjem mehanizma za automatsku nivelaciju berača, što čini fokus ovoga rada.

Savremeni berači jagodastog voća. Tehnička rešenja kombajna za berbu malina i kupina, koji se koriste u razvijenim zemljama, izvedena su u formi vučenih ili samohodnih mašina. Prvoj grupi pripadaju berači čije kretanje u transportu i radu obezbeđuje traktor. Sa konstruktivne tačke gledišta, ovo su po pravilu jednostavniji, a time obično i jeftiniji berači od samohodnih. Tipični predstavnici ove grupe mašina za branje jagodastog voća su američki vučeni berač "Oxbo 930" [1], kao i vučeni berač jagodastog voća SP-07, domaće firme „ELEKTRONIK“ iz Sopota (Beograd) [3] (Sl. 1 i 2).

Slika 1. Vučeni berač jagodastog voća "Oxbo 930" [1]
Figure 1. Trailed Berry Fruit Harvester "Oxbo 930" [1]

Slika 2. Vučeni berač jagodastog voća „ELEKTRONIK“ SP-07. Izvor: [4]
Figure 2. Trailed Berry Fruit Harvester„ELEKTRONIK“ SP-07. Sources:[4]

Korvan 9000 za berbu maline
Korvan 9000, specified for raspberry

Korvan 7240 za berbu kupine
Korvan 7240 for blackberry harvesting

Slika 3. Mehanički berači jagodastog voća firme "OXBO" iz SAD [2][3]
Figure 3.Mechanical berry fruit harvestersmade by "OXBO" USA [2][3]

Samohodni berači pripadaju drugoj grupi kombajna. Opremljeni su pogonskim motorom koji u sadejstvu sa prenosnim i oslono-kretnim sistemom omogućava samostalno kretanje i pogon mehanizama za branje i transport plodova do kolektora. Realno je očekivati da su berači ove grupe energetski efikasniji, jer koriste jedan pogonski motor za svoje funkcionisanje, optimizovan za stvarne potrebe berača. Poznati, predstavnici ove grupe su kombajni "KORVAN" 9000 i 7240, namenjeni berbi maline i kupine, respektivno (Sl. 3), kompanije "OXBO" iz SAD-a.

Na nacionalnom nivou, firma "ELEKTRONIK" iz Sopota projektovala je i proizvela samohodni kombajn za berbu jagodastog voća. U poređenju sa odgovarajućim modelima inostranih proizvođača iste namene i sličnih radnih karakteristika, uključujući ekonomičnost i efikasnost, ovaj domaći berač odlikuju znatno niža nabavna cena, pojednostavljena konstrukcija, kao i lakše i jeftinije održavanje (Sl. 4).

Slika 4. Samohodni mehanički berač maline i kupine firme "ELEKTRONIK" [4]
Figure 4. Self-propelled Mechanical Berry Harvester made by "ELEKTRONIK" [4]

MATERIJAL I METODE RADA

Predmet ovoga rada je prototip samohodnog berača za malinu i kupinu firme "Elektronik" i njegov sistem automatske hidrauličko-mehaničke nivelacije. Ovaj berač ubiranje plodova obavlja mehaničkim izazivanjem oscilacija rodnih lastara maline i kupine preko direktnog kontakta rodnih delova biljaka sa oscilujućim radnim organima mašine, izvedenih u formi rotora sa elastičnim prstima. Vrednosti amplituda i frekvencija radnih organa se podešavaju tako da izazovu opadanje samo zrelih plodova. U cilju minimiziranja gubitaka, berač je konstruisan za istovremenu berbu maline i kupine obe strane špalira (slika 4). Obrani zreli plodovi se sistemom tzv. „krljušti" nežno usmeravaju na transportne trake, koje ih dalje prenose preko sekcije za prečišćavanje. Ta sekcija je opremljena bočnim ventilatorom, koji indukuje struju vazduha usmeravajući je preko plodova nošenih transportnom trakom. Zahvaljujući ovakvoj konstrukciji berača, ubiru se zreli, čisti, mikro-biološki ispravni i neoštećeni plodovi, koji nisu došli u neposredni dodir sa rukama poslužioca kombajna.

Za razliku od većine naprednih inostranih berača jagodastog voća, ova mašina se u transportu i radu direktno oslanja na mehaničke i hidrauličke upravljačke sisteme, ne koristeći elektronske komponente za ove namene. Na ovaj način je podignuta i pogonska pouzdanost mašine, uz istovremeno smanjenje nabavnih i troškova održavanja. Primenom standardnih hidrauličkih komponenata domaće proizvodnje, takođe je smanjena i zavisnost korisnika od proizvođača u pogledu nabavke rezervnih delova. Osnovni tehnički podaci kombajna obuhvataju sledeće parametre [4]: dužina 4,6 m; širina 2,7 m; visina 2,9 m; težina 3 t; radna brzina kretanja 1,8 kmh^{-1} (0,5 ms^{-1}); transportna brzina kretanja: 10 kmh^{-1} (2,78 ms^{-1}); pogonski dizel motor 26 kW (35 KS). Primena ovog kombajna zahteva minimalno međuredno rastojanje između vrsta od 2 m i dopušta maksimalnu visina stubova u vrsti do 2 m.

Mehaničko-hidraulički sistem automatske nivelacije omogućava upotrebu berača i na nagnutim terenima.

REZULTATI ISTRAŽIVANJA I DISKUSIJA

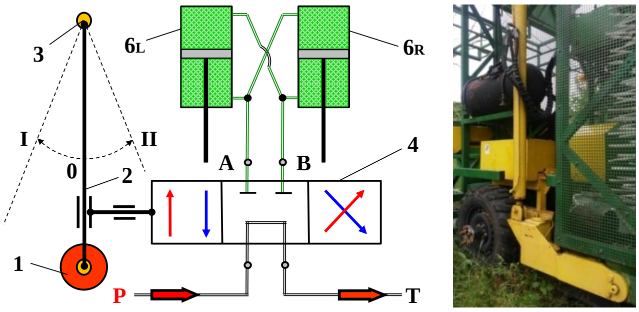
Kretni sistem berača za maline i kupine, firme "Elektronik", poseduje tri točka. Prednji je upravljačko-pogonski, a dva zadnja su pogonska (Sl. 5). Time je konstruktivno olakšana njegova nivelacija, jer je položaj ravni oslanjanja jednoznačno određen sa tri pripadajuće tačke – teorijski to su kontaktne „tačke" točkova i terena.

Opšti prikaz *General view* | Klatno *Pendulum* | Upravljanje *Control unit*

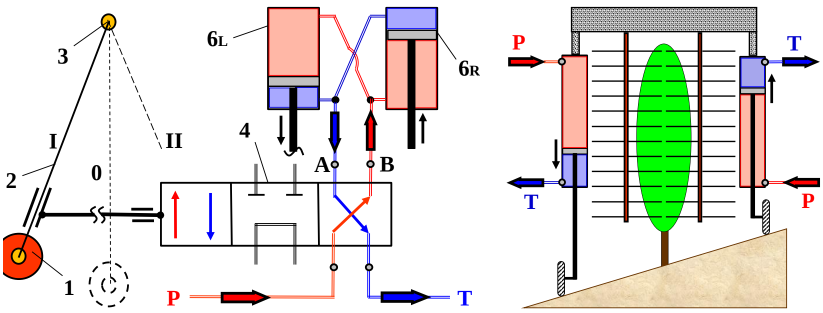
Slika 5. Hidrauličko-mehanički sistem za automatsku bočnu nivelaciju berača
1-teg, 2-nosač klatna, 3-zglobni oslonac klatna, 4-razvodnik ulja, 5-ramena rama (šasije), 6-radni cilindar, 7-prednji upravljački točak, 8-zadnji pogonski točak
Figure 5. Mechanically controlled hydraulic system for automatic lateral leveling of the harvester: 1-weight, 2-pendulum cross arm, 3-pendulum bearing, 4-slide valve, 5-chassis sholders, 6-hydraulic cyilinder, 7-front wheel (steering), 8-rear propulsive wheel

Visina šasije kombajna u odnosu na sva tri točka može se manuelno podešavati za svaki točak nezavisno od druga dva. Time se položaj radne sekcije kombajna može prilagoditi uzgojnom obliku biljaka u svakom konkretnom zasadu. Približno jednako opterećenje svih točkova berača ostvareno je zahvaljujući pogodnom rasporedu konstruktivnih elemenata berača na nosećem ramu (šasiji). Međutim, praksa je pokazala da u zasadima na neravnim i terenima promenljivog nagiba manuelna nivelacija nije dovoljno efikasna. Stoga je za potrebe ovog berača razvijen i dodatni mehaničko-hidraulički sistem za automatsku bočnu nivelaciju. Horizontalno poravnavanje berača omogućeno je automatskim vertikalnim podešavanjem položaja dva zadnja točka. Karakteristične komponente ovog sistema prikazane su na Sl. 5.

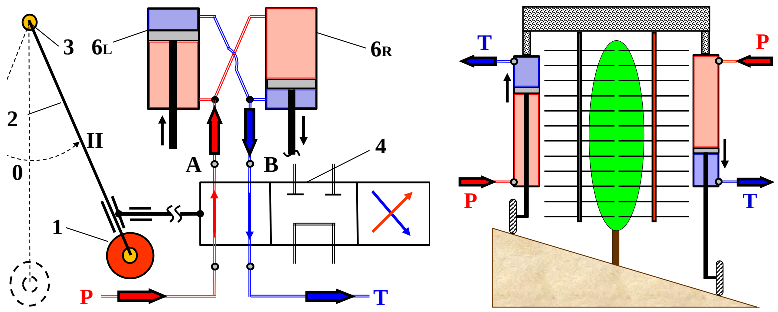
Osnovni elementi i hidraulička funkcionalna šema nivelacionog sistema principijelno su skicirani na Sl. 6. Automatsko horizontalno poravnavanje mašine se postiže istovremenim suprotnosmernim aktiviranjem hidrauličnih radnih cilindara za pozicioniranje zadnjih točkova. Time se ostvaruje usklađeno podizanje jednog zadnjeg točka i spuštanje drugog istim intenzitetima brzine. Suprotnosmerni vertikalni pomeraji točkova u odnosu na ram (šasiju) su identične amplitude, čime se omogućava održavanje njegovog horizontalnog položaja na neravnom i nagnutom terenu u radu. Klatno (1), povezano sa hidrauličkim razvodnikom (2) sa mehaničkim upravljanjem preko poluge sa osloncem u "tački" 3 nosećeg rama, uvek nastoji da zauzme vertikalan položaj koji odgovara njegovoj stabilnoj ravnoteži. Time se hidraulički razvodnik automatski postavlja u optimalni položaj preko poteznice.



(a)



(b)



(c)

Slika 6. Fukcionalna šema sistema nivelacije: (a) neutralno stanje na vodoravnom terenu, (b) podizanje desnog i spuštanje levog točka pri radu na nagibu i (c) obrnuto.
Figure6. Functional sketch of the leveling system: (a) neutral position at horisontal terrain, (b) right wheel lifting and left wheel lowering while working at sloped terrain and (c) vice versa.

Uočavaju se tri tipična slučaja, koji odgovaraju trima mogućim radnim položajima hidrauličkog razvodnika i obezbeđuju automatsku bočnu nivelaciju berača.

1. Kada je noseći ram mašine u horizontalnom položaju, klatno prirodno ostaje u vertikalnom položaju (**0**) - upravno na osnovu šasije i održava razvodnik u neutralnom (srednjem) položaju (slika 6a). Tada su svi priključci oba hidraulička cilindra zatvoreni, a ulje visokog pritiska dovedeno iz pumpe P se kratko-spojnom obilaznom vezom (engl. *bypass*) odvodi u rezervoar T i noseći ram zadržava horizontalni položaj.

2. Kada dođe do bočnog naginjanja nosećeg rama mašine u levu stranu, klatno rotira ulevo, tj. u negativnom matematičkom smeru (smeru kazaljke časovnika, na slici 6b taj položaj klatna je označen sa **I**) dovodeći razvodnik u položaj prikazan na slici 6b. Time se ulje visokog pritiska iz pumpe P dovodi u gornji deo hidrauličkog cilindra levog točka i on se spušta podižući levu stranu mašine. Istovremeno, ulje visokog pritiska se dovodi i u donji deo desnog hidrauličkog cilindra, te se desni točak podiže spuštajući desnu stranu šasije berača. Ovi procesi se aktiviraju automatski i traju dok se ne poništi bočni nagib nosećeg rama mašine, odnosno dok se isti ne vrati u horizontalni položaj. Istovremeno sa vraćanjem u horizontalni položaj nosećeg rama, vraća se i klatno u vertikalni položaj, te vraća i zadržava razvodnik u neutralnom položaju 0.

3. Pri bočnom naginjanju mašine na desnu stranu (slika 6c) proces je obrnut.

Dakle, uključenje razvodnika je mehaničko i automatski dovodi do nivelacije mašine u horizontalni položaj, kada se razvodnik automatski isključuje.

Osnovni konstruktivni i radni parametri sistema nivelacije

Elementi hidrauličkog sistema za automatsku bočnu nivelaciju berača moraju biti dimenzionisani i međusobno usklađeni tako da svaki od dva radna hidraulička cilindra 6L i 6R (označeni prema slici 6) može ostvariti dovoljnu silu za podizanje pripadajuće strane (leve ili desne) mašine. Osnovni proračun obuhvata nekoliko koraka, fokusiranih na hidrauličku pumpu i hidrauličke radne cilindre.

1. Maksimalna težina Q_{MAX}, koja može delovati na svakom od dva zadnja točka kombajna, određena je pod sledećim pretpostavkama:

- rezervoar dizel goriva je pun;
- mašinu opslužuju rukovaoc i dva poslužioca, svaki težine po 100 [*daN*] ;
- kombajn je opterećen i maksimalnom težinom ubranih plodova sa gajbama, koja iznosi 200 [*daN*] .

Merenjem pomoću vage merne rezolucije 10 [*daN*] , određena je max. sila po jednom zadnjem točku intenziteta: Q_{MAX} = 1000 [*daN*] .

2. Za faktor sigurnosti je usvojena vrednost: v_Q = 2,5 [-] .

3. Sledi da je merodavna računska vrednost težine Q_T po zadnjem točku, jednaka proizvodu maksimalne težine Q_{MAX} i usvojenog stepena sigurnosti v_Q , iznosi:

$$Q_T = Q_{MAX} \cdot v_Q = 1000\ [daN] \cdot 2{,}5\ [-] = 2500\ [daN] \quad (1)$$

4. Sila *F* [*N*] koju razvija hidraulički cilindar jednaka je proizvodu radnog pritiska, koji iznosi p= 150 [*bar*] = 15000000 [*Pa*], i površine čela klipa *S* [m^2] :

$$F = p \cdot S \quad (2)$$

Ona mora biti dovoljnog intenziteta da podigne jednu stranu kombajna:

$$F_{MIN} = Q_T \tag{3}$$

Na osnovu prethodnih izraza moguće je za poznati intenzitet potrebne radne sile cilindra i poznat radni pritisak hidrauličkog cilindra izračunati potrebnu površinu poprečnog preseka radnog cilindra:

$$Q_T = p \bullet S \Rightarrow \; S = \frac{Q_T}{p} = \frac{25000\,[N]}{15000000\,[Pa]} = 0{,}00167\,[m^2] \tag{4}$$

Cilindar i klip su kružnog poprečnog preseka, radijusa *r*, koji treba odrediti.

$$S = r^2 \cdot \pi \Rightarrow r = \sqrt{\frac{S}{\pi}} = \sqrt{\frac{0{,}00167}{\pi}} = \sqrt{0.0005305} = 0{,}02303\;[m] \approx 23\;[mm] \tag{5}$$

Usvaja se unutrašnji poluprečnik radnog cilindra $r = 25\,[mm]$, kome odgovara površina svetlog preseka cilindra od

$$S = \pi \cdot r^2 = \pi \cdot \{2{,}5\ [cm]\}^2 = 19{,}63\ [cm^2]. \tag{6}$$

5. Brzina bočnog dizanja kombajna, pri automatskoj nivelaciji, zavisi od površine poprečnog preseka radnog hidrauličkog cilindra *S* i zapreminskog protoka (dotoka) hidrauličkog ulja $\dot{Q}$. Radna zapremina hidrauličke pumpe u cirkulacionom krugu hidrauličkog sistema za automatsku nivelaciju berača maline i kupine iznosi: V = 3,15 [cm^3], a radni broj obrtaja n = 1500 [o/min].

Zapreminski protok $\dot{Q}$ ulja pri predviđenom radnom broju obrtaja jednak je proizvodu radne zapremine *V* i broja obrtaja *n* pumpe:

$$\dot{Q} = 3{,}15\,[cm^3] \cdot 1500\,[\min^{-1}] = 4725\,[cm^3 \min^{-1}] = 78{,}75\,[cm^3 s^{-1}] \tag{7}$$

Na osnovu jednačine kontinuiteta za nestišljivu hidrauličku tečnost sledi da je zapreminski protok $\dot{Q}$ jednak proizvodu brzine *v* pomeranja klipa radnog cilindra i njegovog poprečnog preseka *S* :

$$\dot{Q} = v \cdot S \,. \Rightarrow v = \frac{\dot{Q}}{S} \tag{8}$$

$$v = \frac{\dot{Q}}{S} = \frac{78{,}75\,[cm^3 s^{-1}]}{19{,}63\ [cm^2]} = 4\ [cms^{-1}] \tag{9}$$

Ispitivanja mašine su pokazala da je ovaj intenzitet brzine u granicama prihvatljivosti odziva sistema u normalnim uslovima rada i terena.

ZAKLJUČAK

Kod ove mašine, nivelacija je urađena bez elektronike i žiroskopa, čime je smanjen rizik od kvarova u radu. Smanjeni su troškovi održavanja, a kvarovi se mogu otkloniti bez većih problema. Na ovaj način je podignuta i pogonska pouzdanost mašine, uz istovremeno smanjenje nabavnih i troškova održavanja. Primenom standardnih hidrauličkih komponenata takođe je smanjena i zavisnost korisnika od proizvođača u pogledu nabavke rezervnih delova.

Većina sorti maline (Vilamet, Miker...) se formiraju na špaliru, pa oscilacije rotora sa elastičnim prstima na jednoj strani špalira izazivaju delimično opadanje plodova i sa druge strane. Stoga se, kao efikasno tehničko rešenje ove vrste berača, nameće konstrukcija za istovremenu berbu maline i kupine sa obe strane špalira. Dakle, mašina (slika 1) treba da istovremeno ubira plodove sa obe strane špalira. Obrani plodovi se usmeravaju na transportne trake, koje plodove dalje nose preko sekcije opremljene bočnim ventilatorom. Na njoj struja vazduha indukovana ventilatorom izbacuje nečistoće (lišće, grančice itd.), a čisti plodovi završavaju u ambalaži.

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DEVELOPING THE HYDRAULIC AUTOMATIC LEVELING SYSTEM OF BERRY FRUIT HARVESTER

Abstract: Problems related to self-propelled harvester stability during mechanized berry fruits harvesting at sloped terrains are analysed in this manuscript. The paper also presents an automatic leveling system of the raspberry and blackberry harvester. Low cost, simple design, reliability and minimized maintenance make it very suitable for berryfruits harvesters applied on terrains distant from service centres. The whole system, as well as its components, is designed and manufactured in Serbia.

Key words: *self-propelled harvester, stability, slope, mechanical harvest, raspberry, blackberry*

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EFFECT OF LAG TIME BETWEEN HARVEST AND PRE-COOLING ON RESPIRATION RATE OF GRAPES (*Thompson Seedless*) DURING STORAGE

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Abstract: During the respiration, the oxygen concentration decreased and the carbon dioxide concentration increased which results in decreased respiration rate. After precooling, the grapes were stored under cold storage. The storage studies was carried out for 40 days during which the changes in respiration rate were analyzed. During 2nd day of storage, grapes stored in ambient condition showed higher respiration rate of 100.36 and grapes precooled immediately after harvest showed minimum respiration rate of 28.73 mg CO_2 kg^{-1} h^{-1}. During 40th day of storage, the respiration rate of grapes precooled immediately after harvest showed 17.57 whereas the respiration rate of grapes precooled with time lag of 6 h was found to be 18.76 and it was 17.05 mg CO_2 kg^{-1} h^{-1} in grapes precooled after time lag of 12 h from harvest, respectively. The grapes stored in ambient condition showed the lowest respiration rate of 6.73 mg CO_2 kg^{-1} h^{-1} during 32nd day of storage.

Key words: *Precooling, Respiration rate, Thompson seedless grapes*

INTRODUCTION

Grapes (*Vitis vinifera*) are the third most widely cultivated fruit after citrus and banana in India. Globally grapes production contributes to about 16% among the total fruit production. India produced 1878 thousand tonnes during 2008 which was about 2.77% of the total world production [5]. Thomson seedless is the major exporting variety from India and approximately, 2.5% (53190 tonnes valued at 48505 thousand US dollars) of fresh

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grapes are exported to the Middle East and European countries. India's share out of total world's export was only 1.46%. Even though the grape production in India is high its contribution to the export market was less due to lack of cold chain management and improper precooling facilities.

Tropical fruits and vegetables are harvested at temperatures in the range of 25 to 30°C. Therefore, the respiration rate of the produce is high and the storage life is short. The time lag before precooling of fruits and vegetables will also affect the respiration rate during storage. Even though the fruits and vegetables are placed in cold storage 2 or 3 days after harvest, the quality of produce cannot be maintained due to increased metabolic activity such as respiration rate and ethylene production immediately after harvest [4].

Respiration rate. Respiration occurs continuously in all active cells of a fruit or a vegetable after harvest. It is an oxidation-reduction process in which photosynthetic compounds were oxidized to carbon dioxide (CO_2) and oxygen (O_2) is reduced to form water. The chemical reaction under aerobic conditions is represented as the following [6]:

$$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O + 2872 \text{ kJ/mol} \qquad (1)$$

The reaction shown above is based on one mole of glucose ($C_6H_{12}O_6$). The above reaction is simplified for easy understanding. The entire reaction is actually made up of more than 50 component reactions, with each reaction occurring due to a different enzyme. The process of respiration can use many substrates other than $C_6H_{12}O_6$, such as starches, sucrose, fats, organic acids, and proteins [8].

When the process of respiration completely oxidizes the carbohydrates, such as glucose, sucrose, or starch, the amount of CO_2 evolved will equal the amount of O_2 absorbed. If other substrates are used, or if there is incomplete oxidation, then the amount of O_2 used and the amount of CO_2 evolved will not always be equal. The ratio of CO_2 to O_2 is referred to as the respiratory quotient (RQ) and may be expressed as follows.

$$RQ = \frac{CO_2 \text{evolved } (\text{ml } CO_2 . \text{kg}^{-1} . \text{h}^{-1})}{O_2 \text{ absorbed } (\text{ml } O_2 . \text{kg}^{-1} . \text{h}^{-1})} \qquad (2)$$

The value of RQ can be useful in determining what type of substrates the cells are using. The difficulty in this is that many substrates can be oxidized at the same time and the RQ value gives an average of the CO_2 and O_2 relations.

The respiration rate depends on enzymatic activity, which is a function of temperature. Thus, temperature plays a significant role on the overall respiration rate since respiration requires the action of over 50 enzymes and the level of enzyme activity is affected by temperature. The effect of temperature on the respiration rate is often quantified by determining the Temperature Coefficient (Q_{10}) [6].

$$Q10 = \frac{[\text{Respiration rate at } (\text{T°C} + 10\text{°C})]}{\text{Respiration rate at T°C}} \qquad (3)$$

The Q_{10} may be calculated based on the number of ml-kg^{-1}-h^{-1} of CO_2 evolved or O_2 absorbed. Generally, the respiration rate (Q_{10}) is increased by a factor of 2 to 4 for each temperature increase of 10°C [11].

Modification of the gas composition surrounding the produce after harvest may be used to control the respiration rate. It has been observed that increasing the CO_2 level and decreasing the O_2 level tend to decrease the rate of respiration of some produce [12].

MATERIAL AND METHODS

Experimental procedure for on-farm precooling of grapes. The precooling unit was installed in farmer's field (Madampatti village) in Coimbatore district and the experiments were carried out during the month of September and November, 2014. The matured Thompson seedless grape bunches were harvested from the field and immediately precooled with different time lag. [1] reported that weight loss due to transfer of moisture was more while precooling grapes with 3 m/s air velocity and with the air velocity 1.5 m/s the cooling rate was optimum with less moisture loss. Four crates of grapes were placed inside the chamber and the precooling operation was carried out with the air velocity of 1.5 m/s with the air temperature of 2°C. To evaluate the effect of cooling time delay on physiochemical quality during storage period the grapes are precooled with different time lag from harvest such as precooled immediately after harvest (T1), harvested grapes are kept in field under atmospheric condition and then precooled with time lag of 6 h (T2), precooled after time lag of 12 h from harvest (T3), directly stored in cold storage without precooling treatment after lag of 24 h from harvest (T4), stored in ambient condition (T5).

After different precooling treatments, the grapes were placed in crates and stored inside the cold storage maintained at 4ºC and 85% RH and the control sample was placed in ambient condition continuously throughout the storage period. The samples were taken once in five days for various bio-chemical analysis throughout the storage period.

Studies on respiration rate of Grapes. The changes in respiration rate that occurred in the grapes during storage were the important criteria for assessing the quality. After precooling, the grapes were stored under cold storage for storage studies except (T5), which was stored under ambient condition as control sample. The storage studies was carried out for 40 days during which the changes in respiration rate were analyzed with 2 days interval. The precooling and storage studies were carried out with three replications and average values were calculated and used for discussion.

Respiration rate of grapes. Respiration is a metabolic process, which consists of oxidative breakdown of organic matter present in the cells such as starch, sugars, acids, fats, proteins into simpler molecules such as carbon dioxide and water along with concurrent production of energy and other molecules which will be used by the cell for synthetic reactions [10]. Though it is necessary to maintain the metabolic process, it hastens senescence which is undesirable for shelf life extension. Respiration results in the loss of moisture from the fresh produce which results in the shrinkage and physiological loss in weight. The extent of respiration can be measured by determining the amount of substrate loss, oxygen consumed, carbon dioxide liberated and heat produced and energy evolved [8].

To measurement the respiration rate of grape stored under cold storage according to different precooling treatments. One kg of grape were taken from storage kept inside the containers for the measurement of respiration rate. The containers were closed with the lids. The lid was made air tight by wrapping the lid with packaging tape. The containers were stored in clean and dry place at ambient condition and cold storage conditions according to the storage treatment [7]. Every one hour, the gas samples were drawn from the container through silicon rubber septum using needle and gas concentration was found out using MAP analyzer and using the recorded gas composition, the respiration rate of oxygen and carbon dioxide were calculated. The respiration rate can be calculated by the change in O_2 or CO_2 concentration with time when the commodity was stored in a closed container as given below [3].

$$Ro_2 = \frac{(y^{ti}o_2 - y^{tf}o_2) \times V}{100 \times M \times (t_f - t_i)} \qquad (4)$$

$$Rco_2 = \frac{(y^{tf}co_2 - y^{ti}co_2) \times V}{100 \times M \times (t_f - t_i)} \qquad (5)$$

Where, Ro_2 and Rco_2 = Respiration rate, in terms of O_2 consumed and CO_2 evolved respectively (m^3/kg/h), V = Free volume inside the container, $y^{ti}o_2$ and $y^{tf}o_2$ = Volumetric concentration of O_2 (%) at initial and final time respectively, $y^{ti}co_2$ and $y^{tf}co_2$ = Volumetric concentration of CO_2 (%) at initial and final time respectively, M = Mass of the stored product (kg), t_i and t_f = Initial and final time respectively (h).

Statistical analysis was carried out to study the effect of time lag prior to precooling on respiration rate of grapes. Based on the effect of lag time before precooling on the respiration rate have been estimated with the help of statistical analysis using AGRES. Analysis of variance (ANOVA) was conducted to determine whether significant effect exists due to lag time before precooling.

RESULTS AND DISCUSSION

Respiration rate of grapes during storage. The respiration rate of grapes was calculated using the changes in CO_2 and O_2 levels inside a closed container and the change in respiration rate is expressed in mg CO_2 kg^{-1} h^{-1}. The respiration rate of grapes was measured once in two days throughout the storage studies and the respiration rate of grapes was found to be increasing in all the treatments. The respiration rate affected by different precooling treatments (T) and storage period (S) of grapes was presented in Fig.1.

Analysis of variance was performed to find out the effect of different precooling treatments on respiration rate of grapes during storage period and the results were reported in Table.1. The effect of different precooling treatments and the storage days were found to be highly significant at 1% level and the interactions were also found to be significant at 1% level. During 2nd day of storage, T5 showed higher respiration rate of 100.36 and T1 showed minimum respiration rate of 28.73 mg CO_2 kg^{-1} h^{-1}.

The respiration rate of T2 during 2nd day of storage was found to be 25.33 mg CO_2 kg^{-1} h^{-1}, in T3, it was found to be 36.16 and 69.20 in T4 treatments, respectively. During 20th day of storage T5 showed the higher respiration rate of 55.45 whereas it was 22.76 mg CO_2 kg^{-1} h^{-1} in T1. The other three treatments T2, T3 and T4 showed more or less similar respiration rate of 27.86, 29.36 and 32.63 mg CO_2 kg^{-1} h^{-1}, respectively.

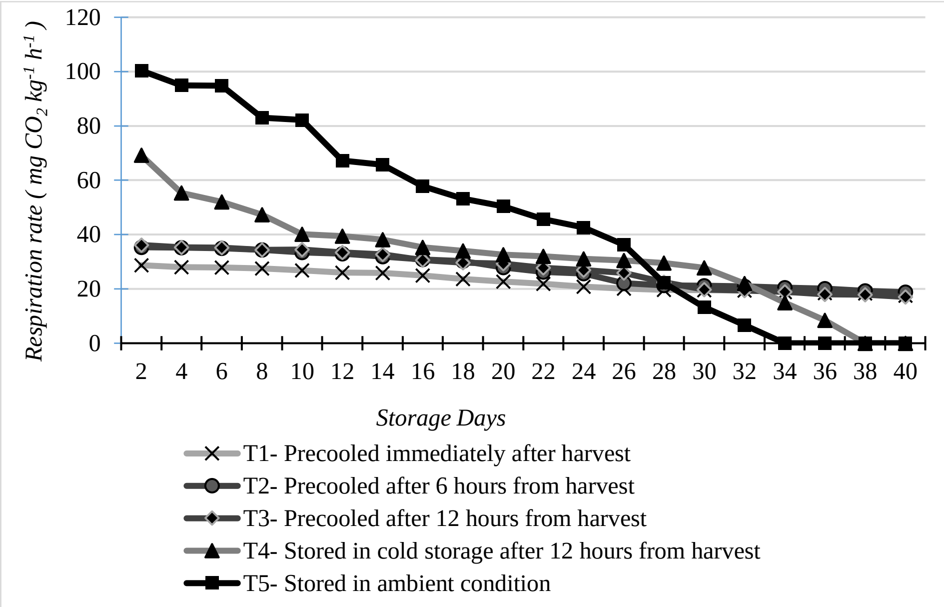

Figure 1. Respiration rate of grapes for different precooling treatments during storage

During the respiration, the oxygen concentration decreased and the carbon dioxide concentration increased which results in decreased respiration rate. The results are in agreement with [2]. Under refrigerated condition the temperature is about 10ºC and the biochemical reactions were found to be lower when compared to ambient condition. The respiration rate decreased with the decrease in temperature due to less reaction rate at lower temperatures [9].

During 40th day of storage, the grapes in T5 and T4 treatments spoiled completely. The respiration rate of grapes in T1 treatment showed 17.57 whereas the respiration rate of grapes in T2 was found to be 18.76 and it was 17.05 mg CO_2 kg^{-1} h^{-1} in T3 treatment, respectively. The grapes stored in ambient condition showed the lowest respiration rate of 6.73 mg CO_2 kg^{-1} h^{-1} during 32nd day of storage. After that the grapes completely spoiled.

Table.1. ANOVA for main effects and its interaction on change in respiration rate of grapes

Source	*df*	*SS*	*MS*	*F*	*PROB*
TOT	*299*	*13711.67*	*45.85*	*301.37*	
Trt	*99*	*13681.24*	*138.19*	*908.18*	*0.062 NS*
Err	*200*	*30.43*	*0.15*	*1.00*	
T	*4*	*2852.06*	*713.0*	*4685.82*	*0.00 *****
S	*19*	*5311.77*	*279.56*	*1837.26*	*0.00 *****
TS	*76*	*5517.40*	*72.59*	*477.09*	*0.00 *****
Err	*200*	*30.43*	*0.15*	*1.00*	
CV	*2.66%*				
	SED		*CD(0.05)*		*CD(0.01)*
T	*0.07*		*0.14*		*0.18*
S	*0.14*		*0.28*		*0.37*
TS	*0.31*		*0.62*		*0.82*

NS- Non Significant,
*** Significant at 1% level,*
** Significant at 5% level.*

CONCLUSIONS

Quality loss after harvest occurs as a result of physiological and biological processes, the rates of which are influenced primarily by product temperature and respiration rate. After harvest, many horticultural products are susceptible to deterioration. Table grapes, for example, should be cooled promptly and thoroughly after harvest in order to maintain their quality. Temperature has a pronounced effect on the respiratory rate of harvested products. As product temperature increases, biological reaction (respiration) rates increase logarithmically. For every 10°C rise in temperature, the rate of respiration is roughly doubled or tripled.

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UTICAJ VREMENA IZMEĐU BERBE I PREDHLAĐENJA NA RESPIRACIJU GROŽĐA (*Thompson Seedless*) TOKOM SKLADIŠTENJA

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Sažetak: Tokom respiracije, koncentracija kiseonika opada i povećava se koncentracija ugljen-dioksida, što dovodi do smanjenja respiracije. Posle predhlađenja, grožđe je skladišteno u hladnom skladištu. Istraživanje je sprovedeno tokom 40 dana i analizirane su promene respiracije. Tokom drugog dana skladištenja, grožđe u normalnim uslovima je pokazalo višu respiraciju od 100.36, dok je grožđe ohlađeno odmah posle berbe pokazalo minimalnu respiraciju od 28.73 mg CO_2 kg^{-1} h^{-1}. Tokom 40-tog dana skladištenja, respiracija grožđa koje je ohlađeno odmah posle berbe iznosila je 17.57, dok je transpiracija grožđa ohlađenog 6 h posle berbe oznosila 18.76, a 17.05 mg CO_2 kg^{-1} h^{-1} kod grožđa sa kašnjenjem hlađenja od 12 h. Grožđe u skladišteno u normalnim uslovima pokazalo je najnižu respiraciju od 6.73 mg CO_2 kg^{-1} h^{-1} tokom 32. dana skladištenja.

Ključne reči: *predhlađenje, respiracija, Thompson loza*

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HARVEST OF CEREALS AND OILSEEDS RAPE BY COMBINE HARVESTERS NEW HOLLAND CX 8090 AND NEW HOLLAND CR 9080

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Abstract: The article is focused on evaluation of the throughput, the fuel consumption and the performance of combine harvesters New Holland CX 8090 and New Holland CR 9080 during harvest of cereals and oilseeds rape. During harvest of winter wheat the throughput of New Holland CR 9080 combine harvester was 15,73 $kg \cdot s^{-1}$. The throughput of New Holland CX 8090 was 13,27 $kg \cdot s^{-1}$. The throughput of the combine harvester New Holland CR 9080, during harvest of winter wheat, was 12,60 $kg \cdot s^{-1}$ for the New Holland CX 8090 it was 8,68 $kg \cdot s^{-1}$. The fuel consumption of New Holland CR 9080 was 17,3$l \cdot ha^{-1}$ during harvest of winter wheat and 16,4 $l \cdot ha^{-1}$ while harvesting winter oilseed rape. New Holland CX 8090 had consumption 16,5 $l \cdot ha^{-1}$ for winter wheat and 15,9 $l \cdot ha^{-1}$ for winter oilseed rape. General operational performance pW_{07} during harvest of winter wheat was, for the New Holland CR 9080, 4,26 $l \cdot ha^{-1}$, weight operational performance mW_{07} was equal to 21,91 $t.h^{-1}$. For harvesting wheat with New Holland CX 8090 the general operational performance pW_{07} was 3,70 $ha.h^{-1}$ and the weight operational performance mW_{07} was 19,03 $t.h^{-1}$. While harvesting oilseed rape the surface operational performance pW_{07} for CR 9080 was 3,13 $ha.h^{-1}$, for CX 8090 it was 2,79 $ha.h^{-1}$. The weight operational performance, of the combine harvester New Holland CR, mW_{07} was 10,00 $t.h^{-1}$, the combine harvester CX 8090 had mW_{07} equal 8,90 $t.h^{-1}$.

Key words: *Combine harvester, throughput, fuel consumption, efficiency*

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INTRODUCTION

Combine harvesters are used for harvesting seed crops by mowing or collecting. Subsequently a combine harvester threshes the weight, cleans and separates the wheat from other parts of the plant, collects it in the tank and prepares it to be transported. Straw and chaff are prepared to be harvested and incorporated into the soil. Comparison of the performance of machinery, which is used for these field operations, is the theme of many scientific papers [1-6].

Effective general performance of a combine harvester in $ha{\cdot}h^{-1}$ is determined by the width of the working width and working speed of the machine. The most efficient types of leading manufacturers achieve operational performance of about 5 $ha{\cdot}h^{-1}$ with an average yield of 4÷6 t of grain per one ha with qualitative grain loss below 2%. Deployment on land with extremely low cereal yields 2÷3 $t{\cdot}h^{-1}$ no longer allows to secure operational conditions for optimal throughput and therefore the maximum utilization of a combine harvester because of ergonomic and technical reasons.

MATERIAL AND METHODS

Researching operational parameters of combine harvesters. During the measurement of the (CH) throughput, the amount of weight that goes through the combine harvester (expressed in $kg{\cdot}s^{-1}$) is measured. For objective measurement it is the best to move with the machine at least 30 meters from the edge of the land. The measuring is done when the thresher of a CH is totally filled. Throughput is determined by equation (1)

$$Q = B_p \, . \, v_{pr} \, . \, m, \tag{1}$$

where:

Q $[kg{\cdot}s^{-1}]$ - throughput of a CH,
B_p [m] - the average width of the cutting table,
v_{pr} $[m{\cdot}s^{-1}]$ - the average operational speed,
m $[kg{\cdot}m^{-2}]$ - yield of the mass.

Combine Harvester fuel consumption. The fuel consumption is measured by refuelling the tank to the neck of the tank, by the end of a shift. The fuel consumption is then determined by equation (2)

$$m_{phm} = O_l \, . \, P^{-1}, \tag{2}$$

where:

m_{phm} $[l{\cdot}ha^{-1}]$ - fuel consumption PHM,
O_l [l] - the amount of refuelled fuel,
P [ha] - harvested area.

The method of researching the performance. The performance is determined according to the methodology designed by [7]. General performance is calculated from the harvested area P per particular time T. There were researched general performance, pW_1 (effective), pW_{02} (operative), pW_{04} (productive) and pW_{07}

(operational). The weight performance is calculated from the observed weight of the sample *m* per time *T*. We search for the weight performance, mW_1 (effective), mW_{02} (operative), mW_{04} (productive) and mW_{07} (operational). The working time of a combine harvester is determined on the basis of recorded time frame, its evaluation and determination of the main time T_1 for the effective performance W_1, time T_{02} for operative performance W_{02}, time T_{04} for the productive performance W_{04} and time T_{07} for the operational performance W_{07}.

RESULTS AND DISCUSSION

The combine harvesters always worked on the same lands, of an agricultural company that belongs to AGROFERT concern, as seen in the Table 1.

Table 1. The characteristics of harvested lands

Land	Crop	Species	Harvested area P[ha]	Yield of grain m_z [t.ha^{-1}]	Humidity of grain v_z [%]
1.	Winter wheat	Midas	55,300	5,700	14,200
2.	Winter wheat	Midas	28,900	5,280	16,700
3.	Winter oilseed rape	Pulzar	34,800	3,130	8,800

Throughput of a combine harvester. The different throughputs of harvesters are presented in Table 2 for winter wheat and for winter oilseed rape in Table 3.

Table 2. The throughput of combine harvesters during harvest of winter wheat

	New Holland CX 8090	New Holland CR 9080
The yield of mass m [kg·m^{-2}]	1,197	1,197
The average operational speed v_p [m·s^{-1}]	1,540	1,460
The average width of the cutting table B_p [m]	7,200	9,000
Throughput of a CH Q [kg·s^{-1}]	13,270	15,730

Table 3. The throughput of combine harvesters during harvest of winter oilseed rape

	New Holland CX 8090	New Holland CR 9080
The yield of mass m [kg·m^{-2}]	0,886	0,886
The average operational speed v_p [m·s^{-1}]	1,380	1,580
The average width of the cutting table B_p [m]	7,200	9,000
Throughput of a CH Q [kg·s^{-1}]	8,680	12,600

The fuel consumption. The fuel consumption of both combine harvesters is presented in Table 4. The fuel consumption, during harvest of winter wheat was measured in the lands 1 and 2, whereas the fuel consumption of a CH, during harvest of winter oilseed rape, was measured in the land 3.

Table 4. Fuel consumption of different combine harvesters during harvest of winter wheat and winter oilseed rape

Combine harvester	*Fuel consumption m_{phm}*	
	Winter wheat [l.ha^{-1}]	*Winter oilseed rape [l.ha^{-1}]*
New Holland CX 8090	*16,500*	*15,900*
New Holland CR 9080	*17,300*	*16,400*

The performance of combine harvesters. The general performance is presented in the Tables 5 and 6, the weight performance is presented in the Tables 7 and 8. The time frames were recorded in lands 1 and 2 while harvesting the winter wheat and in the land 3 during harvest of the winter oilseed rape.

Table 5. The general performance during harvest of winter wheat in lands 1 and 2

The general performance pW	*New Holland CX 8090 [ha·h^{-1}]*	*New Holland CR 9080 [ha·h^{-1}]*
effective pW_1	*5,920*	*6,750*
operative pW_{02}	*5,100*	*5,730*
Productive pW_{04}	*4,200*	*4,910*
operational pW_{07}	*3,700*	*4,260*

Table 6. The general performance during harvest of winter oilseed rape in the land 3

The general performance pW	*New Holland CX 8090 [ha·h^{-1}]*	*New Holland CR 9080 [ha·h^{-1}]*
effective pW_1	*4,800*	*5,190*
operative pW_{02}	*4,090*	*4,300*
productive pW_{04}	*3,660*	*3,610*
operational pW_{07}	*2,790*	*3,130*

Table 7. The weight performance of combine harvesters during harvest of winter wheat

The weight performance mW	*New Holland CX 8090 [t·h^{-1}]*	*New Holland CR 9080 [t·h^{-1}]*
effective mW_1	*30,44*	*34,71*
operative mW_{02}	*26,24*	*29,46*
productive mW_{04}	*21,59*	*25,22*
operational mW_{07}	*19,03*	*21,91*

Table 8. The weight performance of combine harvesters during harvest of winter oilseed rape

The weight performance mW	*New Holland CX 8090 [t·h^{-1}]*	*New Holland CR 9080 [t·h^{-1}]*
effective mW_1	*15,31*	*16,60*
operative mW_{02}	*13,06*	*13,75*
productive mW_{04}	*11,67*	*11,56*
operational mW_{07}	*8,90*	*10,00*

The throughput evaluation. The bigger throughput was reached with the combine harvester New Holland CR 9080, during harvest of winter wheat it was 15,73 kg·s^{-1}, New Holland CX 8090 reached the throughput of 13,27 kg·s^{-1}. During harvest of winter oilseed rape went through the combine harvester New Holland CR 9080 12,60 $kg·s^{-1}$ of mass, through the combine harvester New Holland CX 8090 it was 8,68 $kg·s^{-1}$. Measurements have confirmed bigger throughput of axial combine harvesters in comparison with tangential ones. The results confirms the measurement [8] when the combine harvester JD 9880 STS reached the throughput of 13,59 $kg·s^{-1}$during harvest of wheat and the combine harvester New Holland CR 9080 reached the throughput of 15,25 $kg·s^{-1}$. The throughput of JD 9880 STS during harvest of oilseed rape was 7,83 $kg·s^{-1}$ and New Holland CR 9080 reached the throughput of 8,43 $kg·s^{-1}$.

The fuel consumption evaluation. Lower fuel consumption was reached with both combine harvesters during harvest of winter oilseed rape when the recorded consumption of New Holland CX 8090 was 15,9 $l·ha^{-1}$ and the consumption of New Holland CR 9080 was 16,4 $l·ha^{-1}$. Bigger consumption is probably caused by bigger throughput which means bigger engine load. The fuel consumption of New Holland CX 8090, during harvest of winter wheat, was 16,5 $l·ha^{-1}$ and the fuel consumption of New Holland CR 9080 was 17,3 $l·ha^{-1}$.

The performance evaluation. During harvest of winter wheat the New Holland CR 9080 combine harvester reached general operational performance of 4,26 $ha·h^{-1}$, New Holland harvester CX 8090 reached the value of 3,70 $ha·h^{-1}$. During harvest of winter oilseed rape New Holland CR 9080 reached the general operational performance of 3,13 $ha·h^{-1}$, New Holland CX 8090 reached the general operational performance of 2,79 $ha·h^{-1}$.

During harvest of winter wheat, the reached weight operational performance of New Holland CR 9080 was 21,91 $t.h^{-1}$, for winter oilseed rape, was 10,00 $t.h^{-1}$. New Holland CX 8090 reached, during harvest of winter wheat, weight operational performance of 19,03 $t.h^{-1}$ and during harvest of winter oilseed rape it was 8,90 $t.h^{-1}$.

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ŽETVA STRNIH ŽITA I ULJANE REPICE KOMBAJNIMA NEW HOLLAND CX 8090 I NEW HOLLAND CR 9080

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Sažetak: Rad se bavi ocenjivanjem protoka, potrošnje goriva i performansi kombajna New Holland CX 8090 i New Holland CR 9080 u žetvi strnih žita i uljane repice. U žetvi ozime pšenice protok kod New Holland CR 9080 bio je 15,73 $kg{\cdot}s^{-1}$. Protok kod New Holland CX 8090 bio je 13,27 $kg{\cdot}s^{-1}$. Protok kod New Holland CR 9080 u žetvi ozime pšenice bio je 12,60 $kg{\cdot}s^{-1}$, a kod New Holland CX 8090 8,68 $kg{\cdot}s^{-1}$. Potrošnja goriva kod New Holland CR 9080 bila je 17,3$l{\cdot}ha^{-1}$ u žetvi ozime pšenice i 16,4 $l{\cdot}ha^{-1}$ u žetvi ozime uljane repice. New Holland CX 8090 imao je potrošnju od 16,5 $l{\cdot}ha^{-1}$ kod žetve ozime pšenice i 15,9 $l{\cdot}ha^{-1}$ pri žetvi uljane repice. Opšte radne performanse pW_{07} pri žetvi ozime pšenice bile su, kod New Holland CR 9080, 4,26 $l{\cdot}ha^{-}$. Pri žetvi žita sa New Holland CX 8090 opšte performance bile su pW_{07} 3,70 $ha.h^{-1}$.

Ključne reči: *kombajn, protok, potrošnja goriva, efikasnost*

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PERFORMANCE EVALUATION OF A MODIFIED OFFSET ROTAVATOR IN MANGO ORCHARD

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Abstract: Rotary tillage implements are now projected as important tillage machinery for better seedbed preparation; however the ordinary rotavator being in line with the tractor center line at the rear cannot be used in orchards due to the hindrance posed by narrow space between the plants. Therefore, the concept of a modified offset rotavator was proposed, which could perform intercultural operation between the plants. The study was conducted to evaluate the performance of the modified offset rotavator in mango orchard of Horticulture Research Center, Pantnagar. It was found that the draft (negative) for the L-shaped blades increased (1086.8 to 1651.3 N) as the forward speed increased (2.0 to 3.0 km/h) with Increase in depth of cut (80 to 120 mm) for the shield kept in the lowered (down) position and fuel consumption was higher 9.40 l/h at given forward speed 3.0 km/h with 120 mm depth of cut. Soil break up (mean mass diameter) resulting from the Impact action of L-shaped blades on soil was found increased (1.21 to 2.20) as the forward speed increased (2.0 to 3.0 km/h). The extent of residue incorporation was the maximum 96.68% at forward speed 2.0 km/h with 120 mm depth of cut, whereas at higher forward speed 3.0 km/h, field performance index was observed 89.54%. The minimum area uncovered near the girth was reported at higher girth while plant injury resulted from impact of sensing assembly with 83.3% in form of scratches on the plant girth.

Key words*: tillage, modified offset rotavator, field performance, mango orchard*

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INTRODUCTION

The rotavator (derived from rotary cultivator) is a tractor mounted active tillage implement comprising of blades mounted on flanges with affixed to a shaft that is driven by the tractor (PTO). Rotavator performs (one plowing and two harrowing) operation in single pass therefore, rotavator is accepted by the majority of farmers in Indian, as a time-saving equipment under low land and high land conditions. It gave higher quality of work (25–30%) than the cultivator [1]. The power available at the drawbar of tractor is about 40-56% of net engine power, when transmitting power through the soil-tyre interface, whereas about 80-85% for PTO driven active tillage tools [2]**.** Rotavator obtain their energy in more than one manner reduce the draft requirement and have greater versatility in manipulating the soil to obtain the desire result. Thus, rotavator also reduces the time required to get an optimum seedbed by combining the primary and secondary tillage operation. The degree of soil pulverization attained by the rotavator is more comparable with the use of a mould board plough, and harrow (twice) and spiked tooth harrow [4] and energy required per unit volume of soil for rotavator is about 39.2 to 47.0 MJ/m^3 while, 70.7 to 116.3 MJ/m^3, 62.2 to 103 MJ/m^3 and 53.3 to 110.2 MJ/m^3 for mould board plough, desi plough and cultivator respectively [4]**.** Depending on the soil constitution the fuel consumption increases per centimeter ploughing depth between 0.5 and 1.5 l/ha [5]. In a conventional cropping system the greatest energy consumer is soil tillage [6]. Therefore, farmers are increasingly accepting rotavators for high degree of pulverization [7].

MATERIAL AND METHODS

The modified offset rotavator was designed and developed by CSIR-Center of Excellence for Farm Machinery, Central Mechanical Engineering Research Institute, Ludhiana (Punjab) and tested for performance evaluation by one of networking partner, Department of Farm Machinery and Power Engineering, College of Technology, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (Uttarakhand). The modified offset rotavator has rotating tines mounted on a horizontal shaft and can be attached to the three point linkage of 50-65 hp tractors. It is powered by PTO and provided with adjustable mechanical sensing unit which can be adjusted at any position on the frame according to the type of orchard with a side shift of 300 mm. It has seven flanges spaced 220 mm apart and each flange carries in it six blades. It is also provided with an external gear type pump of capacity 15 l/min driven by PTO of the tractor. The different components of modified offset rotavator are presented in Fig. 1.

The experiments were conducted in the Horticulture Research Center, Pantnagar. The performance of modified offset rotavator was evaluated during the field experiment in which, the independent variables were selected as machine parameter like λ- ratio, forward speed and soil parameters like moisture content, bulk density, cone index and the dependent variables were selected as draft requirement, fuel consumption, residue incorporation, actual field capacity, field performance index, area uncovered near the girth and plant injury etc. The field experiment was performed in mango orchard which follows high density pattern with plant spacing of 5×5 m from each other and some of the selected parameters related to plant geometry were taken during field experiments and these data was shown in Tab. 1.

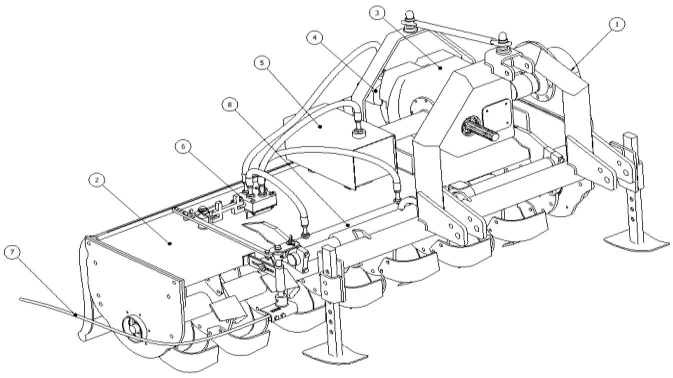

Figure 1. Different components of modified offset rotavator
1. Secondary transmission system, 2. Frame, 3. Primary transmission system, 4. Hydraulic pump, 5. Oil tank, 6. Control valves, 7. Sensing rod, 8. Double acting cylinder

Table 1. Data of different parameters observed in mango orchard

Orchard	*Plant girth [m]*	*Plant canopy [m]*	*Heading height of branches from ground [m]*
Mango	*0.92*	*4.82*	*1.72*
	0.90	*4.52*	*1.45*
	0.93	*4.95*	*1.53*
	0.95	*5.05*	*1.86*
	0.98	*4.74*	*1.97*
Average	*0.94*	*4.82*	*1.71*

An experimental plot was selected for mango orchard having 6000 m^2 area and it was divided into subplots of the size of 15×30 m^2. Soil samples were taken from field plot to determine soil moisture content, bulk density and cone index. The three **λ** -ratios 4, 5 and 7 were determined by changing forward speed of tractor 2.0, 2.5, 3.0 km/h respectively with constant rotor speed 243 rpm and different depths 80, 100 and 120 mm were taken into consideration. All the treatments were repeated thrice. Statistical analysis of data was carried out and the variance at 5% level of significance.

RESULTS AND DISCUSSION

Effect of λ –ratio and depth of cut on the draft requirement. The modified offset rotavator was evaluated for draft requirement at forward speed 2.0, 2.5 and 3.0 km/h (corresponding λ– ratio 7, 5, and 4) for the depth of operation 80, 100 and 120 mm respectively in mango field. Tab. 2 represents the draft required at different λ– ratios and depth of cut. The relation of λ– ratio and depth of cut with draft was shown in Fig 2. The draft at forward speed 2.0 km/h (7 λ– ratio) and depth 80 mm was observed 1086.8 N. With an increase in forward speed to 2.5 km/h (5 λ– ratio) and depth 100 mm, then draft was observed 1321.0 N and further increase in forward speed 3.0 km/h (4 λ– ratio) and depth 120 mm, the draft was observed 1651.3 N. It was observed that, the increase in forward speed with depth of operation draft increased. This was mainly due to increasing the forward speed because the more specific energy per unit volume of soil requires to cut the soil mass in less time and blade has to handle more volume of soil, similarly as increasing the depth of operation the blades cut more volume of soil per unit time thus, soil metal friction increases. It was revealed that orchard field, λ– ratio and depth of cut have significant effect on the draft at 5% level of significance.

Table 2. Effect of λ- ratio and depth of cut on draft (N) requirement of a modified offset rotavator under mango orchard

Experiment no.	*λ- ratio*	*Depth of cut [mm]*	*Average of draft [N]*
1	4	*80*	*1350.4*
2	4	*100*	*1520.9*
3	4	*120*	*1651.3*
4	5	*80*	*1178.9*
5	5	*100*	*1321.0*
6	5	*120*	*1457.2*
7	7	*80*	*1086.8*
8	7	*100*	*1201.5*
9	7	*120*	*1337.7*

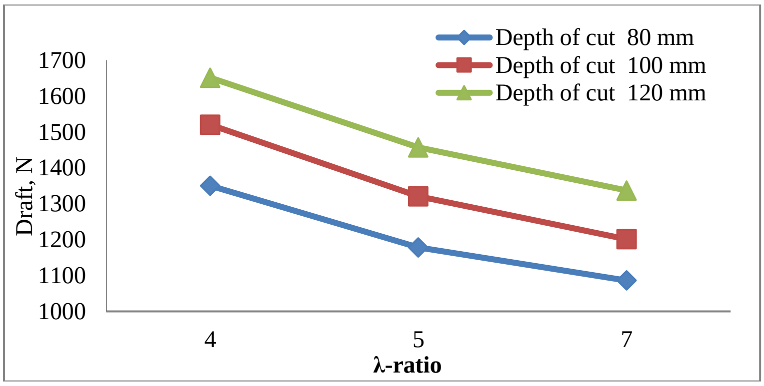

Figure 2. Effect of different λ– ratio and depth of cut on draft requirement for mango orchard

Effect of λ– ratio and depth of cut on fuel consumption. The modified offset rotavator was evaluated for fuel consumption at forward speed 2.0, 2.5, 3.0, (corresponding λ – ratio 7, 5, and 4) for the depth of operation 80, 100 and 120 mm respectively. The fuel consumption during the experiment for different orchards field at different λ– ratio and depth of cut is presented in the Tab. 3. The relation of λ– ratio and depth of cut on the fuel consumption for mango orchards is shown in Fig. 3. The fuel consumption at forward speed 2.0 km/h (7 λ– ratio) and depth of cut 80 mm was observed 3.84 l/h. When increase in forward speed 2.5 km/h (5 λ– ratio) and depth 100 mm, then fuel consumption was observed 7.3 l/h and further increase in forward speed 3.0 km/h (4 λ– ratio) and depth of cut 120 mm, the fuel consumption was observed 9.40 l/h. The results show that, as increase in forward speed with depth of operation, the fuel consumption increased. The main fact that, by increasing forward speed tends to increase in specific energy per unit volume of soil requires to cut the soil mass in less time and similarly by increasing the depth of operation the blades comes contact more volume of soil thus, soil metal friction increases hence, fuel consumption increases. Statistical result indicated, that orchards field, λ– ratio and depth of cut have significant effect on the fuel consumption at 5% of significance.

Table 3. Effect of λ-ratio and depth of cut on fuel consumption for modified offset rotavator under mango orchard

Experiment no.	*λ- ratio*	*Depth of cut [mm]*	*Average of fuel consumption [l/h]*
1	*4*	*80*	*7.20*
2	*4*	*100*	*8.47*
3	*4*	*120*	*9.40*
4	*5*	*80*	*6.14*
5	*5*	*100*	*7.3*
6	*5*	*120*	*8.0*
7	*7*	*80*	*3.84*
8	*7*	*100*	*4.46*
9	*7*	*120*	*5.87*

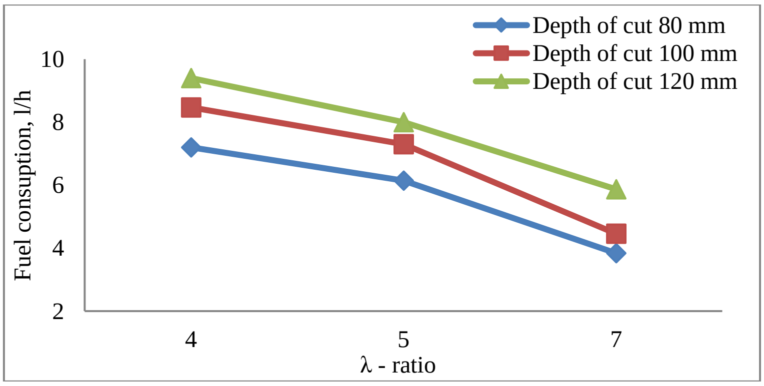

Figure 3. Effect of different λ– ratio and depth of cut on fuel consumption for mango orchard

Effect of different λ– ratio and depth of cut on mean mass diameter. The modified offset rotavator was evaluated for mean mass diameter at forward speed 2.0, 2.5 and 3.0 (corresponding λ – ratio 7, 5, and 4) for the depth of operation 80, 100 and 120 mm for mango orchard. Mean mass diameter during the experiment for mango orchard at different λ– ratio and depth of cut are presented in the Tab. 4. The variation in the mean mass diameter due to the effect of λ– ratio and depth of cut for mango orchards is shown in Fig 4. The mean mass diameter at forward speed 2.0 km/h (7 λ – ratio) and depth 80 mm was observed 1.21 mm. When increase in forward speed 2.5 km/h (5 λ – ratio) and depth 100 mm, then mean mass diameter was observed 1.76 mm and further increase in forward speed 3.0 km/h (4 λ – ratio) and depth of cut 120 mm, the mean mass diameter was observed 2.20 mm. it is found from above result that, as increase in forward speed, then mean mass diameter increases corresponding to all level of forward speed and depth of operation. It may be due to when forward speed increases, the blade impact forces on soil decreases. Therefore mean mass diameter of soil particle increases at all level of forward speed. The statistical analysis (ANOVA) is expressed that, λ– ratio and orchards field have significant effect on the mean mass diameter at 5%.

Table 4. Effect of λ-ratio and depth of cut on mean mass diameter, (mm) under mango orchard

Experiment no.	*λ- ratio*	*Depth of cut [mm]*	*Average of mean mass diameter [mm]*
1	*4*	*80*	*1.72*
2	*4*	*100*	*2.08*
3	*4*	*120*	*2.20*
4	*5*	*80*	*1.53*
5	*5*	*100*	*1.76*
6	*5*	*120*	*1.98*
7	*7*	*80*	*1.21*
8	*7*	*100*	*1.54*
9	*7*	*120*	*1.86*

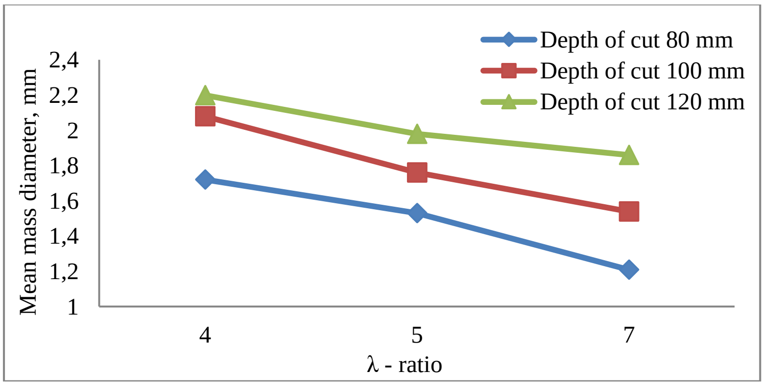

Figure 4. Effect of different λ– ratio and depth of cut on mean mass diameter for mango orchard

Effect of different λ– ratio and depth of cut on residue incorporation. The modified offset rotavator was evaluated for residue incorporation at forward speed 2.0, 2.5 and 3.0 km/h (corresponding λ– ratio 7, 5, and 4) for the depth of operation 80, 100 and 120 mm for mango orchard. The Residue incorporation, during the experiment for mango orchard field at different λ– ratio and depth of cut is presented in the Tab. 5. The variation in the residue incorporation due to the effect of λ– ratio and depth of cut for mango orchards is shown in Fig. 5. The residue incorporation at forward speed 2.0 km/h (7 λ – ratio) and depth 80 mm was observed 93.50 percent. When increase in forward speed 2.5 km/h (5 λ – ratio) and depth 100 mm, then residue incorporation was observed 93.64 percent and further increase in forward speed 3.0 km/h (4 λ– ratio) and depth of cut 120 mm, the residue incorporation was observed 93.35 percent. It was observed that, as increase in forward speed then residue incorporation decreases. This may due when forward speed increase then blade impact forces on the soil also deceases resulted in less impact on soil which causes less amount of residue incorporation. The statistical analysis (ANOVA) exhibited that, depth of cut and orchards field have significant effect on the residues incorporation at 5%.

Table 5. Effect of λ-ratio and depth of cut on residue incorporation, (%) for modified offset rotavator under mango orchard

Experiment no.	*λ- ratio*	*Depth of cut [mm]*	*Average of residue incorporation [%]*
1	*4*	*80*	*90.43*
2	*4*	*100*	*92.56*
3	*4*	*120*	*93.35*
4	*5*	*80*	*92.27*
5	*5*	*100*	*93.64*
6	*5*	*120*	*94.70*
7	*7*	*80*	*93.50*
8	*7*	*100*	*95.78*
9	*7*	*120*	*96.68*

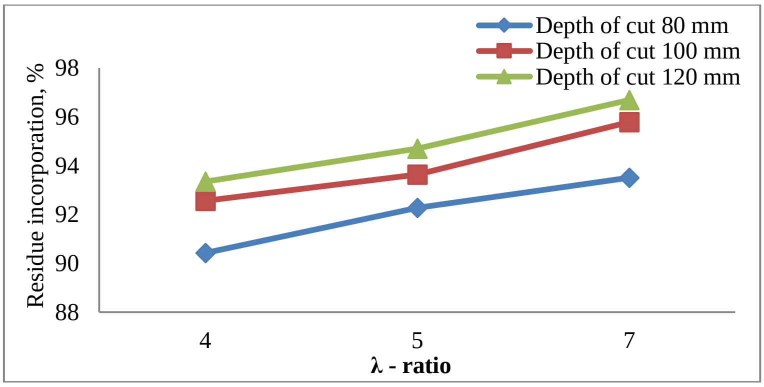

Figure 5. Effect of different λ – ratio and depth of cut on residue incorporation for mango orchard

Effect of λ– ratio on field performance index. Field performance index during experiment for mango orchard at different λ– ratio is presented in the Tab. 6. The variation in the field performance index due to λ– ratio for mango orchard is shown in Fig. 6. The field performance index at forward speed 2.0 km/h (7 λ– ratio) was observed 79.32 percent. When increase in forward speed 2.5 km/h (5 λ– ratio), then field performance index was observed 83.47 percent and further increase in forward speed 3.0 km/h (4 λ– ratio), the field performance index was observed 89.54 percent. The result shows that, when forward speed increases then field performance index increases with increase in actual field capacity. The statistical analysis (ANOVA) showed, that λ– ratio has significant effect on the field performance index at 5% level.

Table 6. Effect of λ –ratio on field performance index (%) under mango orchard

Experiment no.	*λ- ratio*	*Average of field performance index [%]*
1	*4*	*89.54*
2	*5*	*83.47*
3	*7*	*79.32*

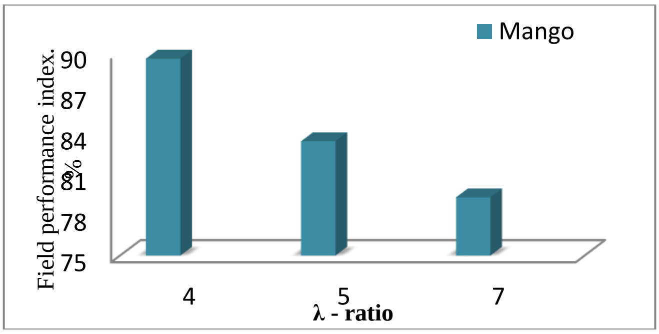

Figure 6. Effect of different λ – ratio on field performance index for mango orchard

Table 7. Effect of girth on area uncovered near the girth (m^2) under mango orchard

Experiment no.	***Orchard girth, m***	***Average uncovered area near the girth (m^2)***
1	*0.92*	*0.076*
2	*0.90*	*0.078*
3	*0.93*	*0.071*

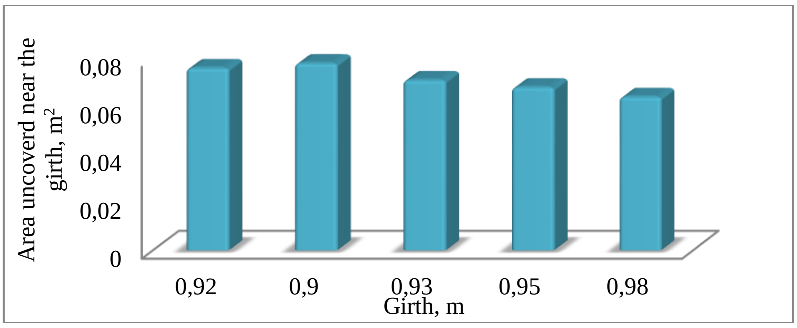

Figure 7. Effect of girth on area uncovered near the girth for mango orchard

Effect of girth on area uncovered near the girth. The Area uncovered near the girth corresponding to girth is presented in Tab. 7. The variation in the area uncovered near the girth for mango orchard shown in Fig. 7. The area uncovered near the girth at 0.90 m girth was observed 0.078 m^2. When increase in girth at 0.92 m, then area uncovered near the girth was observed 0.076 m^2 and further increase in girth at 0.93 m, the area uncovered near the girth was observed 0.071 m^2. The result shows, that as increase in girth of mango orchard, the area uncovered near the girth decreases because of modified offset rotavator has definite side sift of 370 mm which depends on the hydraulic shift actuated by hydraulic piston and independent from forward speed of operation and depth of cut. Therefore, area uncovered near the girth mainly depends on girth of the orchard. Thus, when the girth of the orchard increases then the area uncovered near the girth decreases and vice versa. The statistical analysis (ANOVA) shows that, girth had significant effect on the area uncovered near the girth at 5% level.

CONCLUSIONS

1. The maximum draft requirement in mango orchard was found 1651.3 N at a λ– ratio of 4 and depth of cut 120 mm. For same field, minimum draft in mango field was found 1086.8 N at λ– ratio of 7 and depth of cut 80 mm and fuel consumption was ranges 9.40-3.84 l/h. The maximum mean mass diameter for mango orchard was recorded to be 2.20 mm at a λ– ratio of 4 and depth of cut 120 mm. The excess residue incorporation for mango orchard was found to be 96.68 % at λ– ratio of 7 and depth of cut 120 mm.
2. The maximum field performance index for mango was found to be 89.54 % at λ– ratio while minimum field performance index were found to be 79.32 % at λ– ratio 7.
3. The maximum uncovered area near the girth for mango orchard was found to be 0.78 m^2 at 0.90 m girth and minimum uncovered area near the girth was found to be 0.64 m^2 at 0.98 m girth whereas maximum plant injury was found to be 83.3 percent at λ– ratio of 4 and minimum plant injury was found to be 16.6 %.

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ISPITIVANJE PERFORMANSI MODIFIKOVANOG ROTAVATORA U VOĆNJAKU

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Sažetak: Rotacioni priključci za obradu zemljišta su važne mašine za pripremu setvene posteljice. Uobičajeni zadnji rotavator u liniji sa centralnom osom traktora ne može da se koristi u voćnjacima zbog rastojanje stabala u redu. Zato je ponuđeno rešenje modifikovanog rotavatora za obradu prostora u redu. Istraživanje je izvedeno radi ocene performansi ovog modifikovanog rešenja. Utvrđeno je da se otpor kod L noževa povećao (od 1086.8 na 1651.3 N) sa povećanjem radne brzine (od 2.0 na 3.0 km/h) i povećanjem dubine (od 80 na 120 mm) sa spuštenim štittom i i povećanom potrošnjom goriva od 9.40 l/h pri brzini od 3.0 km/h.

Ključne reči: *obrada, modifikivani rotavator, radne karakteristike, voćnjak*

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DEVELOPMENT OF TRACTOR OPERATED REAL TIME MEASURING SYSTEM FOR MAPPING OF SPATIAL VARIATION IN SOIL pH

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Abstract: Soil pH is an important physio-chemical property representing soil characteristics and plays an important role in plant growth. Soil pH affects crop yields, plant nutrient availability and soil micro-organism activity. For small areas, measuring the spatial variation in soil pH is feasible. However for the large areas, pH determination of the multiple soil samples by using traditional method in laboratory is very tedious and time consuming. Considering the need and scope of precision agriculture in India, a real time data logging pH measuring system was developed to determine the soil pH directly in the field at specific GPS locations by integrating soil pH sensor and a GPS receiver with a portable data logger. Soil mapping was done for observing the spatial variation in soil pH using ArcGIS. The results showed that the field had variation in soil pH and the developed soil pH measuring system was capable to measure the spatial variation in soil pH. The average soil pH measured by developed soil pH measuring system in different tillage treatments varied from 7.98 to 8.18, 7.60 to 7.94 and 8.01 to 8.21, respectively.

Keywords: *soil pH measurement, pH sensor, data logger, mapping, spatial variation*

INTRODUCTION

The soil pH is an indicator of the acidity or alkalinity of soil. The measure of dissociated hydrogen ion (H^+) in the soil solution directly impacts soil acidity and

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alkalinity, as hydrogen-ion activity increases, the pH value decreases and vice versa. The pH of soil is an important physio-chemical characteristic/property because it influences crop yield, suitability of soil for crop production, availability of plant nutrients in the soil, and soil micro-organism activity which influence key soil processes. Soil pH has profound influence on the relative availability of plant nutrients, lightly acidic conditions generally considered optimal for the overall availability of both macro and micronutrients [1]. Proper soil pH increases microorganism activity which produces improved soil tilth, aeration and drainage which in turn allows better use of nutrients, increased root development and drought tolerance. In Punjab, the soil profile characteristics are influenced to a very limited extent by the topography, vegetation and parent rock and much more pronounced because of the regional climatic differences. The soil pH in 95 % of the net cultivated areas of Punjab ranged between 6.5 and 8.7 with an average pH value of 7.99 and 40 % area of Punjab have soil pH between 6.5 - 7.5 and 55 % area between pH 7.5 - 8.5 [2]. Soils in the pH range of 6.5 - 8.7 are considered as the most suitable for most of the crops [3].

Soil pH may be measured using a number of colorimetric and potentiometric techniques. For rapid determinations of soil pH, colorimetric techniques have been applied in the field. Although these estimates are relatively rapid and suitable for field use, but their precision and accuracy were lower than potentiometric methods. Potentiometric techniques are the preferred laboratory methods for measuring soil pH as they provide precise and accurate results [4]. Sensor development is expected to increase the effectiveness of precision agriculture. In particular, sensors for on-the-go measurement of soil properties have the ability to provide precise measurements at a relatively low cost [5]. The component of precision agriculture includes remote sensing, global positioning system, geographical information system, soil sensing and analysis, soil properties mapping and information. It was observed that many researchers and manufacturers have attempted to develop various on-the-go or real time sensors and techniques to measure mechanical, physical and chemical soil properties as an alternative to tedious manual soil sampling and laboratory testing. As new on-the-go soil sensors are developed, different real-time and map-based variable rate soil treatments may become economically feasible. Sensors based on electric and electromagnetic measurement concept are being used widely these days [6].

For the small agricultural area, monitoring the soil pH changes is feasible. However, for the large scale areas, collecting the soil samples by traditional methods are very tedious and time consuming. Also, the soil pH measurement in laboratories is time consuming and requires sample preparation. Considering the need and scope of precision agriculture in India, this study was aimed to develop a real time soil pH measuring system which measures the geo-referenced soil pH directly in the field at specific locations. The soil pH measuring system with portable data logger was aimed to have the potential to eliminate many of the aforementioned constraints in soil pH determination in field. Data logging is a new technique which is helpful in real time logging of physical parameter i.e. geo referenced soil pH in the field conditions and mapping soil properties.

The present study has been planned with an objective to develop a tractor operated real time soil pH measuring system for mapping the spatial variation in soil pH.

MATERIAL AND METHODS

Selection of instruments/equipments. For the development of real time tractor operated soil pH measuring system a soil pH sensor, GPS receiver, a portable data logger and tractor mounted bund former were required. So, a contact type flat ended pH electrode (2124FE) and a global positioning system (6M GPS Module) were selected for measuring the soil pH directly in the field (Fig. 1). A portable data logger was fabricated which features latest technology support and helps in logging physical parameter with geo-referenced locations and save it into SD card. The portable data logger was synchronized with the soil pH sensor and GPS system and mounted on the tractor operated bund former. A data logger is an attractive alternative to either a recorder or data acquisition system in many applications. The data logger can handle inputs of up to 8 channel (4 analog/digital sensors each) and able to log data from interval of 600 sample/sec to 1 sample/week. A data logger is a self-contained unit that does not require a host to operate. It can be installed in almost any location and left to operate unattended. The data logger itself record, store and analyze the data (Fig. 2).

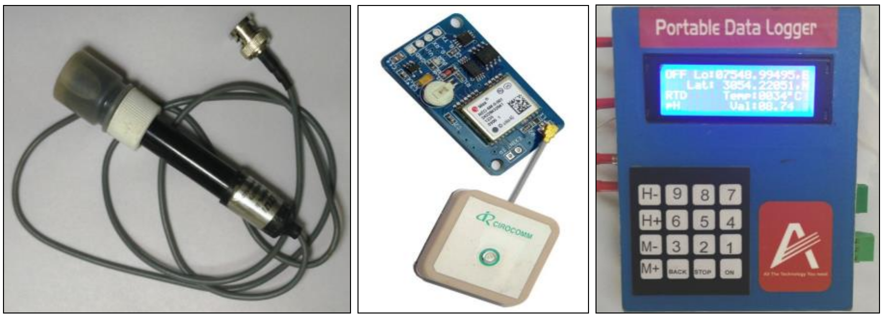


Figure 1. Soil pH sensor, GPS Reciever and Portable data logger

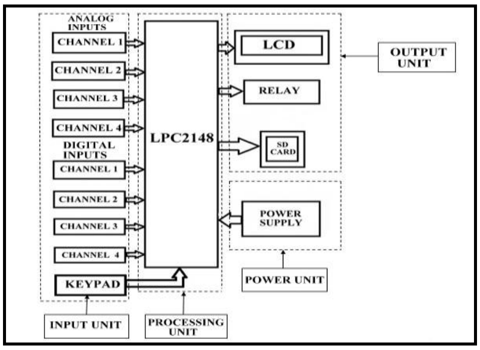


Figure 2. Operation of data logger system

Initially, various soil manipulating implements like cultivator, MB Plough, etc were tried for mounting the developed soil pH measuring system in the field. The proper mounting of the developed system on these implements was difficult and unfavorable for the safety of sensor due to high impact of soil force on pH sensor. Finally, a tractor operated bund former was selected for mounting the developed measuring system.

Development and fabrication of mechanism for integrating the soil pH measuring system on tractor operated bund former. The structural mechanism for mounting the soil pH measuring system on the tractor operated bund former was prepared in three dimensional solid modeling software tool called SoildWorks. The developed system consists of a platform made up of galvanized iron sheet, which was placed on the frame of the bund former. A wooden box made for placing the portable data logger and connecting wires was fixed on the frame of the bund former, keeping in view that there should not be any damage to the developed system (Fig. 3). A clamp for holding the pH electrode was also made by molding a galvanized iron sheet. A slot type arrangement was also made and welded on the one blade of bund former for attaching the clamp of sensor electrode. Initially, sensor probe was fitted vertically to the blade of bund former, but this arrangement was not suitable because when the implement was operated in the field, the soil transmitted a huge impact force to the body of sensor probe. This huge soil force could have easily damaged the delicate electrode of pH sensor. It was observed that mounting of the probe horizontally instead of vertically had received lesser impact. So keeping in view the probe was fitted horizontally on the blade of bund former.

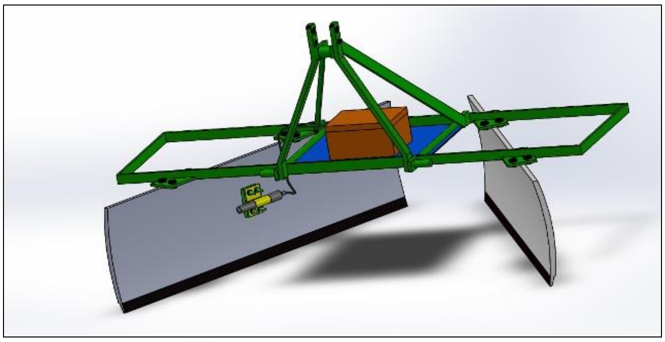


Figure 3. Structural mechanism for integrating the soil pH measuring system on tractor operated bund former

Calibration of soil pH sensor with data logger. The pH sensor should be calibrated before each measurement. So to calibrate for its optimum settings, the pH sensor integrated with data logger was calibrated in Soil Testing Laboratory, Department of Soil Sciences, PAU Ludhiana. The calibration was performed by selecting two standard buffer solutions of pH 7.00 and pH 4.01 or 9.18. The calibration of pH sensor was also done with reference soil samples collected from different locations and cities (Fig. 4) to get variation in the range of soil pH (Fig. 5). The collected soil samples had soil pH ranging from 5.95 to 8.35.

Figure 4. Soil samples collected from different locations and their pH measurement in laboratory

Figure 5. Calibration of pH sensor with data logger using collected soil samples

Experimental field location. The structural mechanism for integrating the soil pH measuring system was developed and fabricated at Research Hall, Department of Farm Machinery and Power Engineering, Ludhiana. The experimental field was located at 30°54'66.100" N latitude and 75°48'68.620" E longitude and the field experiment was conducted in 110 × 30 m (3300 m^2) area from February to May 2016 located at the Research Farm, Department of Farm Machinery & Power Engineering, Ludhiana, Punjab, India. The main plot was divided into 27 subplots of 30 × 4 m each which consists of three different tillage treatments i.e. conventional tillage (T1), no tillage (T2) and residue incorporated soil (T3) at three forward speeds (S1, S2 and S3) with three replications (R1, R2 and R3). The developed soil pH measuring system was operated in the field after every 10 day interval (Fig. 6). The soil sensor was properly calibrated before field experiment and the data was recorded, stored and analyzed.

ArcGIS 9.3 software was used for the mapping the spatial variation in soil pH determined by the developed soil pH measuring system and providing geographical information of soil pH. A GPS receiver and a portable data logger were used to record the geo referenced location of each soil sample or measurements. The recorded data was used to generate maps which showed spatial variation and information of the field. Maps of the soil pH were drawn and compared to access the precision of the developed soil pH measuring system.

Figure 6. Developed soil pH measuring system mounted on a tractor operated bund former

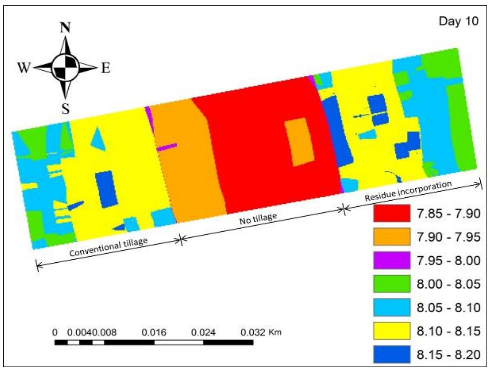
RESULTS AND DISCUSSION

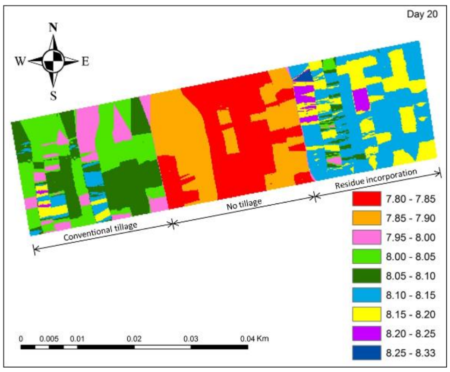
Spatial variation in soil pH measured by developed measuring system in the field from day 10 to 60. The developed measuring system was operated at research farm of Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana. The geo-referenced soil pH measured in field from day 10 to 60 was recorded by developed soil pH measuring system (Table 1). It was observed in conventional tillage (T1) that the soil pH measured with developed measuring system in the field varied from 8.10 to 8.15, 8.08 to 8.13, 7.98 to 8.12, 8.02 to 8.18, 8.03 to 8.14 and 8.01 to 8.13 for day 10, 20, 30, 40, 50 and 60 respectively. In no tillage (T2), the soil pH measured in the field varied from 7.83 to 7.94, 7.82 to 7.86, 7.84 to 7.89, 7.80 to 7.86, 7.61 to 7.74 and 7.60 to 7.75 for day 10, 20, 30, 40, 50 and 60 respectively. Similarly in residue incorporated soil (T3), the soil pH measured in the field varied from 8.08 to 8.15, 8.16 to 8.21, 8.08 to 8.12, 8.01 to 8.09, 8.12 to 8.18 and 8.05 to 8.17 for day 10, 20, 30, 40, 50 and 60 respectively. The field measurements showed that there was variation in soil pH over the field.

This study was undertaken to measure and map the spatial variability in geo-referenced soil pH in the field of 3300 m^2 using a real time soil pH measuring system. The mapping was done using ArcMAP 9.3 software for day 10, 20, 30, 40, 50 and 60 (Fig 7). The ArcMAP clearly showed that the field had variable soil pH and the developed real time tractor operated soil pH measuring system was capable to measure the spatial variation in soil pH in the field. The value of soil pH measured in the conventional tillage and residue incorporated soil was near to the actual pH of soil, while inaccurate in no tillage. The ArcMAP also shows that the spatial variation in soil pH was higher in conventional tillage and residue incorporated soil and least in no tillage. The lesser/inaccurate value of soil pH in no till condition was due to that the soil condition was untilled, unpulverized and presence of clods in the field causes inappropriate engagement of soil pH sensor with the topsoil. The maps generated by developed measuring system can be used for recommended application of lime, organic matter and fertilizers in the field. Researchers predicted that soil pH can be measured directly in the field and several high-resolution soil maps can be obtained for crop production of site-specific crop management on precision agriculture. The developed real time soil pH measuring system provided an efficient tool for predicting and mapping pH of soil within the field. High resolution soil pH field measurement maps generated on the basis of sensor measurements were able to depict the small spatial variability of the soil properties present within the field.

Table 1. Soil pH measured by developed measuring system in the field from day 10 to 60

Plot No	*Treatment*	*Average GPS coordinates in single run*		*Average soil pH*					
		Longitude (E)	*Latitude (N)*	*Day 10*	*Day 20*	*Day 30*	*Day 40*	*Day 50*	*Day 60*
1	*T1S1R1*	*75° 48’65.558”*	*30° 54’65.044”*	*8.10*	*8.09*	*7.98*	*8.02*	*8.03*	*8.05*
2	*T1S1R2*	*75° 48’65.697”*	*30° 54’65.078”*	*8.10*	*8.12*	*8.01*	*8.05*	*8.06*	*8.01*
3	*T1S1R3*	*75° 48’65.935”*	*30° 54’65.302”*	*8.12*	*8.10*	*8.05*	*8.05*	*8.04*	*8.03*
4	*T1S2R1*	*75° 48’66.219”*	*30° 54’65.296”*	*8.14*	*8.10*	*8.08*	*8.15*	*8.13*	*8.02*
5	*T1S2R2*	*75° 48’66.356”*	*30° 54’65.435”*	*8.14*	*8.08*	*8.10*	*8.13*	*8.08*	*8.13*
6	*T1S2R3*	*75° 48’66.601”*	*30° 54’65.296”*	*8.15*	*8.13*	*8.12*	*8.16*	*8.07*	*8.10*
7	*T1S3R1*	*75° 48’66.964”*	*30° 54’65.411”*	*8.13*	*8.09*	*8.10*	*8.14*	*8.14*	*8.11*
8	*T1S3R2*	*75° 48’67.262”*	*30° 54’65.539”*	*8.14*	*8.09*	*8.09*	*8.17*	*8.08*	*8.08*
9	*T1S3R3*	*75° 48’67.606”*	*30° 54’65.576”*	*8.13*	*8.08*	*8.08*	*8.18*	*8.10*	*8.09*
10	*T2S1R1*	*75° 48’67.933”*	*30° 54’65.677”*	*7.94*	*7.85*	*7.85*	*7.82*	*7.73*	*7.74*
11	*T2S1R2*	*75° 48’68.226”*	*30° 54’65.635”*	*7.92*	*7.85*	*7.86*	*7.82*	*7.74*	*7.75*
12	*T2S1R3*	*75° 48’68.477”*	*30° 54’65.752”*	*7.93*	*7.86*	*7.86*	*7.83*	*7.73*	*7.73*
13	*T2S2R1*	*75° 48’68.857”*	*30° 54’65.900”*	*7.85*	*7.83*	*7.85*	*7.80*	*7.62*	*7.60*
14	*T2S2R2*	*75° 48’69.019”*	*30° 54’65.969”*	*7.83*	*7.84*	*7.84*	*7.81*	*7.61*	*7.60*
15	*T2S2R3*	*75° 48’69.300”*	*30° 54’66.078”*	*7.84*	*7.82*	*7.86*	*7.80*	*7.63*	*7.60*
16	*T2S3R1*	*75° 48’69.570”*	*30° 54’66.237”*	*7.88*	*7.84*	*7.88*	*7.84*	*7.62*	*7.61*
17	*T2S3R2*	*75° 48’69.828”*	*30° 54’66.241”*	*7.89*	*7.85*	*7.89*	*7.86*	*7.63*	*7.61*
18	*T2S3R3*	*75° 48’70.119”*	*30° 54’66.243”*	*7.87*	*7.85*	*7.86*	*7.86*	*7.61*	*7.63*
19	*T3S1R1*	*75° 48’70.409”*	*30° 54’66.530”*	*8.15*	*8.21*	*8.08*	*8.06*	*8.12*	*8.14*
20	*T3S1R2*	*75° 48’70.749”*	*30° 54’66.477”*	*8.14*	*8.16*	*8.12*	*8.06*	*8.15*	*8.17*
21	*T3S1R3*	*75° 48’70.898”*	*30° 54’66.581”*	*8.14*	*8.16*	*8.09*	*8.06*	*8.13*	*8.14*
22	*T3S2R1*	*75° 48’71.160”*	*30° 54’66.590”*	*8.15*	*8.17*	*8.09*	*8.09*	*8.18*	*8.10*
23	*T3S2R2*	*75° 48’71.318”*	*30° 54’66.666”*	*8.15*	*8.21*	*8.12*	*8.04*	*8.12*	*8.15*
24	*T3S2R3*	*75° 48’71.644”*	*30° 54’66.721”*	*8.12*	*8.18*	*8.12*	*8.07*	*8.13*	*8.16*
25	*T3S3R1*	*75° 48’71.850”*	*30° 54’66.800”*	*8.10*	*8.19*	*8.09*	*8.05*	*8.16*	*8.05*
26	*T3S3R2*	*75° 48’72.068”*	*30° 54’66.881”*	*8.10*	*8.20*	*8.11*	*8.02*	*8.15*	*8.12*
27	*T3S3R3*	*75° 48’72.363”*	*30° 54’66.755”*	*8.08*	*8.19*	*8.12*	*8.01*	*8.14*	*8.09*





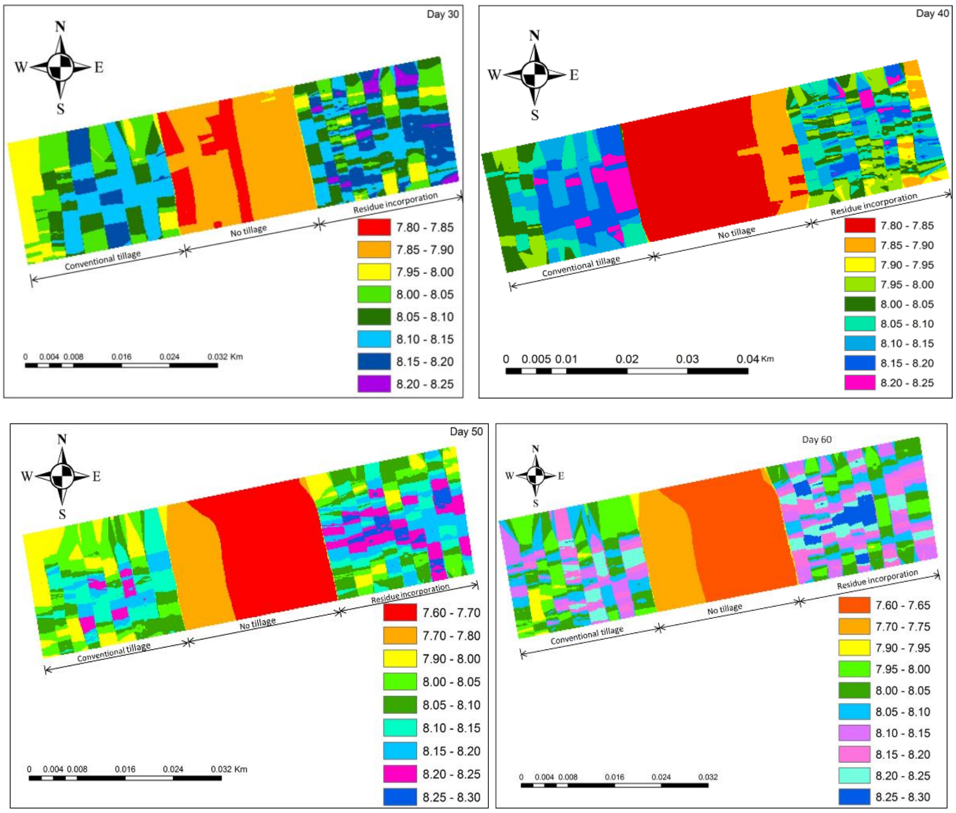


Figure 7. Spatial variation in soil pH measured by developed measuring system in the field for day 10, 20, 30, 40, 50 and 60

CONCLUSIONS

- Structural mechanism was developed for attaching the real time soil pH measuring system on a tractor operated bund former for measuring the real time geo-referenced soil pH directly in the field.
- The developed real time soil pH measuring system provided an efficient tool for predicting and mapping the pH of soil within the field.
- The geo-referenced soil pH measured in the field mapped by ArcMAP clearly showed that the field had spatial variation in soil pH and the developed measuring system was capable to measure the spatial variation of soil pH in the field.
- It was observed that in T1, the soil pH measured with developed measuring system in the field varied from 8.10 to 8.15, 8.08 to 8.13, 7.98 to 8.12, 8.02 to 8.18, 8.03 to 8.14 and 8.01 to 8.13 for day 10, 20, 30, 40, 50 and 60 respectively.

- In T2, the soil pH measured in the field varied from 7.83 to 7.94, 7.82 to 7.86, 7.84 to 7.89, 7.80 to 7.86, 7.61 to 7.74 and 7.60 to 7.75 for day 10, 20, 30, 40, 50 and 60 respectively.
- Similarly in T3, the soil pH measured in the field varied from 8.08 to 8.15, 8.16 to 8.21, 8.08 to 8.12, 8.01 to 8.09, 8.12 to 8.18 and 8.05 to 8.17 for day 10, 20, 30, 40, 50 and 60 respectively.

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RAZVOJ TRAKTORSKOG MERNOG SISTEMA ZA MAPIRANJE PROSTORNE PROMENLJIVOSTI pH ZEMLJIŠTA U REALNOM VREMENU

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Sažetak: pH zemljišta je važna karakteristika zemljišta koja igra važnu ulogu u utgoju biljaka. Zemljišni pH utiče na prinos useva, dostupnost nutrienata korenu biljaka i aktivnost mikroorganizama u zemljištu. Merenje prostornih promenljivosti pH vrednosti na manjim oblastima je izvodljivo. Ipak, za velike oblasti, određivanje pH većeg broja uzoraka zemljišta na uuobičajeni način u laboratoriji je naporno i dugotrajno. Imajući u vidu potrebe i opseg precizne poljoprivrede u Indiji razvijen je merni sistem za sakupljanje podataka u realnom vremenu, radi određivanja pH zemljišta direktno na parceli na pojedinačnim GPS lokacijama, integracijom pH senzora i GPS prijemnika sa prenosivim data logerom. Mapiranje zemljišta je vršeno radi praćenja prostorne promenljivosti pH zemljišta korišćenjem ArcGIS. Rezultati su pokazali promenljivost pH zemljišta i omogućili da se razvije merni sistem za merenje prostorne promenljivosti. Srednja pH vrednost izmerena ovim sistemom u različitim sistemima obrade zemljišta varirala je od 7.98 do 8.18, 7.60 do 7.94 i 8.01 do 8.21, redom.

Ključne reči: *merenje pH zemljišta, pH senzor, data loger, mapiranje, prostorna promenljivost*

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DEVELOPMENT OF GROUND BASED MULTI-SOURCE INFORMATION COLLECTION SYSTEM BY CONVERTING PADDY TRANSPLANTER

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Abstract: Precision agriculture has created a technology revolution in production agriculture and it requires reliable technology to acquire accurate information on crop conditions. A ground-based integrated sensor and instrumentation system was developed to measure real-time crop conditions. The integration system included multispectral camera and N-sensor for real time Nitrogen application. The system was interfaced with a DGPS receiver to provide spatial coordinates for sensor readings. Before mounting of the sensors on modified paddy transplanter, different mountings and frames were attached with the paddy vehicle to mount the sensors, camera and power source. Battery mounting plate was required to fit imported 12 V & 80 A battery on vehicle. New bracket had fabricated to suit the new battery and it can be adjusted vertically 25~30 mm as per the requirement. For overturning balancing of rice transplanter extra weights of 100 kg were added at the rear of the rice transplanter. Trails were done in puddle rice field. By adding additional weight, there was no problem of over turning in the field in normal operations. The results showed that the integration sensor and instrumentation system supports multi-source information acquisition and management in the farming field except high clearance of tractor.

Key words: *ground based integration system, multi-spectral camera, N-sensor, paddy transplanter*

INTRODUCTION

Precision agriculture demands intensive field data acquisition. Frequent data acquisition and interpretation can be the key to understand variability in the field. Wireless

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sensor networks are a technology that can provide real time field data from sensors physically distributed in the field [1]. In developed countries, it is common to find combine harvesters with on-board data collection systems for mapping yield and moisture content of harvested crop. The agricultural equipment industry is moving towards controller area networks for agricultural equipment communication systems. These are basic factors that have led to increased opportunity for automation of agricultural guidance. With the advances of electronic and information technologies, various sensing systems have been developed for especially for crop production around the world. Accurate and reliable information technology is the basis of precision agriculture. Information on crop condition can be used to assess and monitor crop growth status, predict crop yield, or develop program for optimizing application of various inputs like nitrogen fertilizer, fungicide, and growth regulator for precision agriculture. Successful information acquisition relies on the ability of sensors and instrumentation to detect these crop canopy variables, which are indicative of crop growth [2].

[4] developed a guidance system by the sensor fusion integration with a machine vision, an RTK-GPS and a geometric direction sensor (GDS). The developed navigation planner involved a priority scheme of the control strategies using a knowledge-based approach. [5] developed an intelligent vision system for autonomous vehicle field operations. Field trials confirmed that the method developed was able to accurately classify crop and weeds through the entire growing period. After segmenting out the weed, an artificial neural network was used to estimate crop height and width. Finally, geographic information system (GIS) was used to create a crop growth map. [3] developed a multifunctional sensor node that can collect many kinds of data for agricultural applications. These sensor-intensive technologies include some benefits like sensing is non contact, large amount of information is collected quickly and the potential exists to be both cheap and powerful. But there are some difficulties also such as moving of ground vehicle within the submerged crop like rice, storing and processing the data, extracting usable information from images, dealing with natural objects and operating under natural lighting conditions.

Combinations of sensors provide data for crop management in addition to guidance functions. The combination of various sensors with Global Positioning System (GPS) provides opportunities for mapping crop responses as the vehicle performs field tasks. Rice crop being submerged, it is difficult to move a tractor or platform within the crop. Paddy transplanter available commercially can be used for mounting of different sensors and cameras. In relation to above view a ground-based integrated sensor and instrumentation system was developed to measure real-time conditions by converting paddy transplanter into a vehicle.

MATERIALS AND METHODS

Development of ground based integration system. The ground-based multi-source information system was developed to measure real time rice crop conditions through of N-sensor and Multi-spectral camera. The system is interfaced with a DGPS (Differential Global Positioning System) receiver to provide spatial coordinates for sensor data. N-sensor, multispectral camera and DGPS were mounted over the developed vehicle explained in following section. Individual sensor components has been calibrated and tested under laboratory and field conditions prior to system integration. The integrated system collected multi-sensor data and store the spatial information and crop property information in database. The different components and how they were unified are described in the following sections.

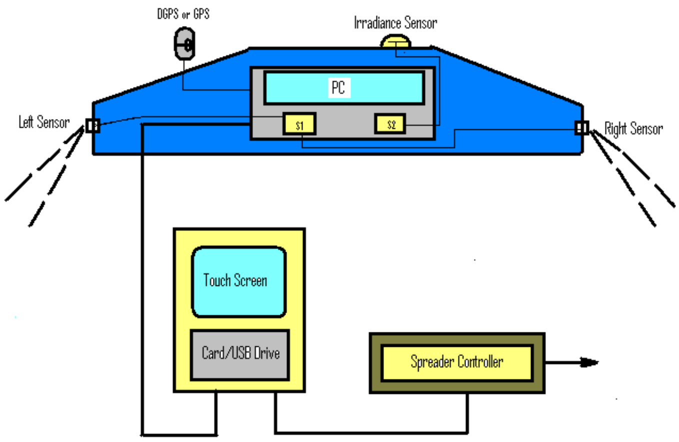


Figure1. System flow chart of N-sensor

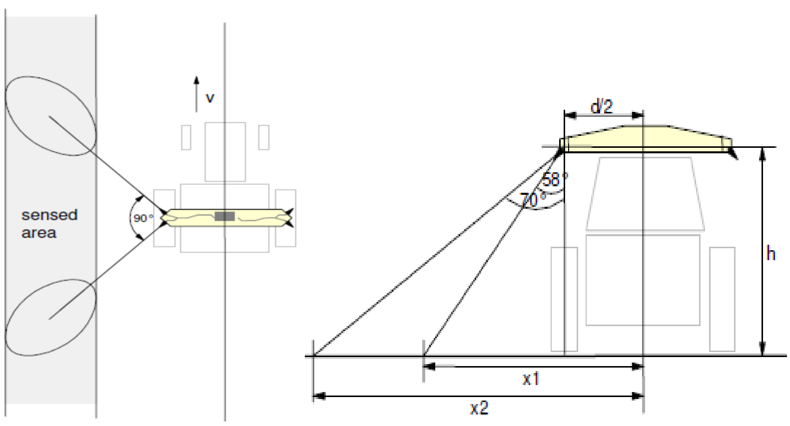


Figure 2. Geometry of N-sensor

N-sensor. A frame was developed to mount N-sensor with the vehicle (Fig.1 and Fig.2). The N sensor was installed on the vehicle at 2.74 m height (h) (Fig. 3) which made the scanning area 46.56 m2. N-sensor consists of two diode spectrometers, fiber optics and microprocessor in a hard shell, built on the roof of the vehicle. A spectrometer collects reflectivity of wavelengths from 620 to 1000 nm with four points, which are around the vehicle. A fifth sensor positioned skywards measures the intensity of light allowing the sensor system to compensate for different light conditions while operating. System flow chart and geometry of N sensor is shown in Fig. 1 and 2.

$$x1 = d/2 + h \tan 58° / \mathrm{sqrt}(2) = 0.5\, d + 1.13\, h$$

$$x2 = d/2 + h \tan 70° / \mathrm{sqrt}(2) = 0.5\, d + 1.94\, h$$

where:
d: width of the sensor rig
h: height of the sensor rig

Multi-spectral Camera. A frame to mount the Multi-spectral camera was developed and attached with the vehicle (Fig.1 and Fig. 2). The height of Multi-spectral camera was kept equal as the N-sensor. But its mounting height can increased or decreased by moving the frame upward or downward. The information available can be maximized by combining information found in multiple spectral bands. The photonic spectrum includes energy at wavelengths ranging from the ultraviolet through the visible, near infrared, far infrared, and finally, x-rays. The color image from a Charge Coupled Device (CCD) array is acquired by sensing the wavelengths corresponding to red, green, and blue light. CCD sensors are capable of detecting light beyond the visible wavelengths out to 1100 nm.

Differential Global Positioning System (DGPS). The N-Sensor and Multi-spectral camera system was connected to a Differential Global Positioning System (DGPS) signal to allow Location, sensor and application information to be plotted enabling the production real time crop information. The DGPS was mounted at the height of 2.5 m on the frame of Multi-spectral camera and its serial console was connected to the N-sensor display.

RESULTS AND DISCUSSION

Development of vehicle. Paddy transplanter used for the transplanting of mat type rice seedlings is available in the Japan, Korea and other Asian Countries. It can be used as a vehicle for other operations, if transplanting mechanism mounted at the rear of the transplanter is removed. It may become unstable after removing the transplanting mechanism but extra weight can be added to make it stable. Before mounting of the sensors, different mountings and frames were attached with the paddy vehicle to mount the sensors, camera and power source. Battery mounting plate was required to fit imported 12 V & 80 A battery on vehicle. New bracket had fabricated to fit the new battery and it can be adjusted vertically 25~30 mm as per the requirement. Battery positive cable had been replaced to suit the new battery. Separate MS sheet had been welded to support the foam of the operator seat. Hinges had been welded to the MS sheet. For balancing of rice transplanter extra 100 kg weights were added at the rear of the rice transplanter. By adding additional weight, there was no problem of over turning in the field in normal operations. It was observed that while entering into the field from main road (big bunds between field and road), rice transplanter has tendency to little lift from rear. A DC (12 V) to AC (230 V) converter was required for the frame grabber used to store the multi-spectral images acquired by the multi spectral camera.

Field operation of ground vehicle. The N sensor gives the data in the form of log file which can be converted into the CSV file format with the help of log converter software or with N sensor card writer software. This CSV file can be opened in excel format which contain the real time information of the crop. Vehilce was opeared in the Five wheat crop plot having inceasing nitrogen level rate (0, 40, 80, 120 and 150 kgN/ha) with N-sensor and Multi-spectral installed on it to measure real-time crop conditions. The data was taken after 60 days after sowing (DAS). The N-sensor Nitrogen recommendation map prepared after the operation of N-sensor (Fig.4). The recommendation map was also located on the Google Earth. The map showed that the minimum and maximum nitrogen recommendation rate were 16 and 105 kgN/ha.

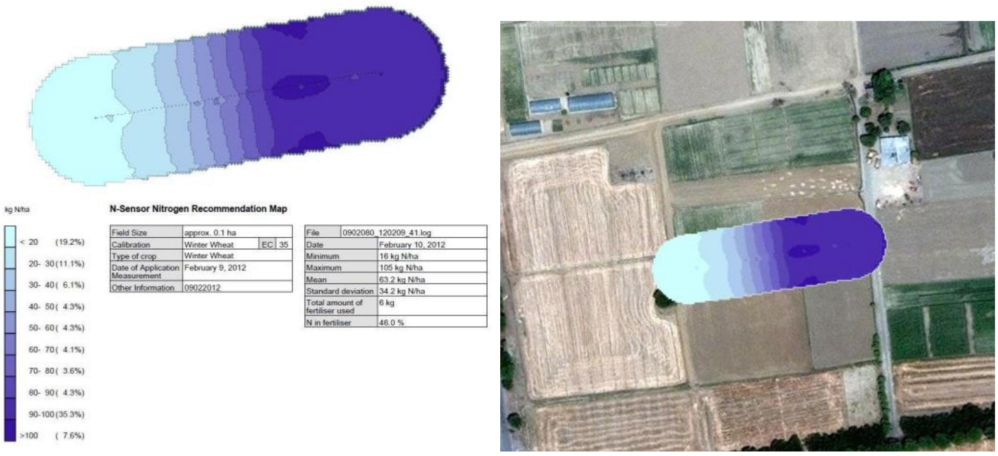
Multispectral camera was also operated during the operation. Images (Fig. 5) taken at 0 and 80 kgN/ha level plot showed that, there is textural difference between the images. Darker the red color of the canopy more is the nitrogen uptake. Brown color in the images depicts shadow of plant and white color showed reflectance of the bare soil. There is difference in terms of density of the canopy at different level of nitrogen.

Change in NDVI can be referred through change in scatter diagrams of NIR and R level. Multispectral images need to be first pre-processed by using various image enhancement techniques. Later, specific band information need to be extracted from the processed image and plotted in the form of graph.

Figure 1. Multispectral camera and N Sensor holding frame

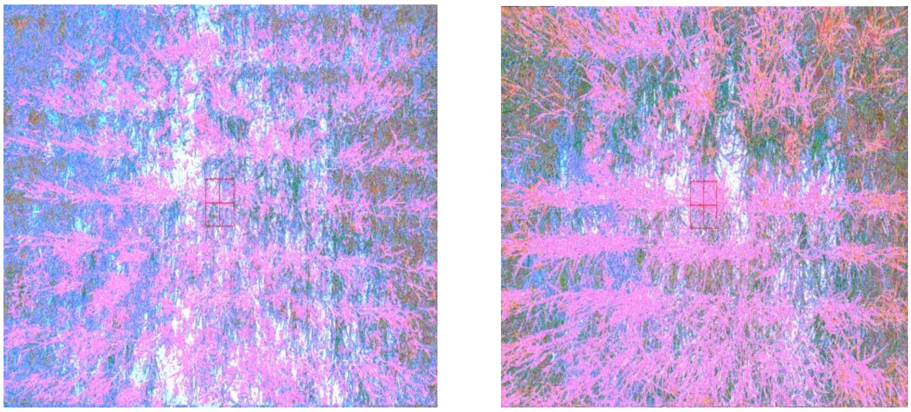
Figure 2. Different frames mounted to the developed vehicle

Figure 3. View of developed vehicle with installed sensor working in the field



(a) (b)

Figure 4. (a) N-sensor Nitrogen Recommendation Map and (b) its location on Google Earth



(a) (b)

Figure 5. Images of multispectral camera at (a) 0 and (b) 80 kgN/ha level plot

Nitrogen can be co-related with NDVI as written below:

NDVI= (NIR –R)/(NIR+R) ……..(1)

CONCLUSIONS

Experimental work to determine the best use of sensors in crop production is still in its infancy. Machine vision gives promising results, but is sensitive in field work still. The integration system included Multi-spectral camera and N-sensor for real time crop information. Before mounting of the sensors on modified paddy transplanter, different mountings and frames were attached with the paddy vehicle to mount the sensors, camera and power source. Battery mounting plate was required to fit imported 12 V & 80 A battery on vehicle. New bracket had fabricated to suit the new battery and it can be adjusted vertically 25~30 mm as per the requirement. For overturning balancing of rice transplanter extra weights of 100 kg were added at the rear of the rice transplanter. By adding additional weight, there was no problem of over turning in the field in normal operations. This preliminary study indicates that the potential of the integration sensor and instrument system to realize multi-source information acquisition and management in the field.

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RAZVOJ INFORMACIONOG SISTEMA ZA SAKUPLJANJE PODATAKA IZ VIŠE IZVORA

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Sažetak: Precizna poljoprivreda je dovela do tehnološke revolucije u poljoprivrednoj proizvodnji, koja zahteva pouzdanu tehnologiju za sakupljanje tačnih informacija o stanju useva. Zemaljski integrisani senzor i sistem instrumenata su razvijeni za određivanje stanja useva u realnom vremenu. Ovaj integrisani sistem je uključio multispektralnu kameru i N senzor za primenu azota u realnom vremenu. Sistem je povezan sa DGPS prijemnikom za određivanje prostornih koordinata očitavanja senzora. Pre postavljanja senzora na modifikovanu sadilicu postavljeni su razni sklopovi i ramovi koji nose senzore, kameru i izvor napajanja. Napajanje je obezbeđeno sa akumulatorske baterije na vozilu, 12V-80A. Za obezbeđenje vozila od prevrtanja postavljeni su dodatni tegovi od 100 kg na zadnju stranu.

Ključne reči: *integracioni sistem, multi-spektralna kamera, N-senzor, sadilica*

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