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MODELOVANJE ENERGETSKIH UŠTEDA U PROCESU OSMOTSKE DEHIDRATACIJE SVINJSKOG MESA U MELASI

Vladimir Filipović[*1], Biljana Lončar[1], Milica Nićetin[1], Violeta Knežević[1], Jelena Filipović[2], Lato Pezo[3]

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Sažetak: Cilj prezentovanog istraživanja je definisanje matematičkih modela energetskih ušteda u procesu osmotske dehidratacije svinjskog mesa u melasi šećerne repe i analiziranje uticaja primenjenih tehnoloških parametara. Ušteđena količina toplote u procesu osmotske dehidratacije kretala se u opsegu od 891,57 do 1770,92 kJ·kg^{-1} mesa. U radu su prikazani razvijeni matematički modeli energetskih ušteda u procesu osmotske dehidratacije svinjskog mesa u melasi. Kao najuticajniji tehnološki parametar na razvijene matematičke modele pokazalo se vreme procesa, pa zatim koncentracija osmostskog rastvaora i na kraju temperatura procesa. Maksimalna vrednost uštede količine toplote ostvarena je u procesu osmotske dehidratacije svinjskog mesa na temperaturi procesa od 20°C, nakon 5 časova procesa u melasi šećerne repe maksimalne koncentracije. Rezultati prikazani u ovom istraživanju ukazuju na niskoenergetski profil procesa osmotske dehidratacije koji upotrebom melase kao osmotskog rastvora još više doprinosi ekološkom karakteru procesa.

Ključne reči*: osmotska dehidratacija, melasa šećerne repe, svinjsko meso, energetska ušteda, metoda odzivne površine*

UVOD

U poređenju sa drugim oblicima sušenja, osmotska dehidratacija je energetski nisko zahtevan proces, [1, 2] jer se zasniva na uklanjanju vode iz dehidrirajućeg materijala bez fazne transformacije, te stoga i bez utroška energije za zagrevanje sirovine i latentne tolpote isparavanja vode [3, 4].

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U procesu osmotske dehidratacije energija se troši za zagrevanje materijala i hipertoničnog rastvora do potrebne temperature procesa, kao i za održavanje postignute temperature i uparavanje razređenih osmotskih rastvora za količinu vode koja je uklonjena iz materijala u prethodnom ciklusu osmotske dehidratacije. Enegija koja se troši za pumpanje i cirkulaciju osmotskog rastvora (oko 10 $kJ \cdot kg^{-1}$ uklonjenje vode) i za rastvaranje rastvorka u vodi (oko 1 $kJ \cdot kg^{-1}$ uklonjenje vode) može se zanemariti jer je mnogo manja u poređenju sa energijom potrebnom za zagrevanje osmotskog rastvora i isparavanje vode koja je migrirala iz materijala [5].

Potrošnja energije tokom osmotske dehidratacije na 40ºC, sa uparavanjem osmotskog rastvora, najmanje je dva puta niža u odnosu na konvektivno sušenje na 70 ºC [6].

Povećanje temperature dehidratacije povećava efikasnost prenosa mase i skraćuje vreme trajanja procesa. Energija koja se troši na mešanje ili cirkulaciju rastvora iznosi oko 17,2 $kJ \cdot kg^{-1}$ uklonjene vode na temperaturama 20°C; 10 $kJ \cdot kg^{-1}$ uklonjene vode na 30°C i 4,3 $kJ \cdot kg^{-1}$ uklonjene vode na 40°C, odnosno povećanjem temperature procesa, smanjuje se potrebna energija za mešanje i cirkulaciju, prvenstveno usled smanjenja viskoznosti osmotskih rastvora. Veća količina energije potrebna je za održavanje definisane temperature tokom procesa osmotske dehidratacije koja u zavisnosti od količine vode koja se uklanja, iznosi 180-240 $kJ \cdot kg^{-1}$ na 30 ºC i 380-500 $kJ \cdot kg^{-1}$ uklonjene vode na 40 °C [7].

Cilj ovog istraživanja je definisanje matematičkih modela energetskih ušteda u procesu osmotske dehidratacije svinjskog mesa u melasi šećerne repe i analiziranje uticaja primenjenih tehnoloških parametara temperature i vremena procesa i koncentracije osmotskog rastvora na definisane matematičke modele.

MATERIJAL I METODE RADA

Za proračun i prikaz energetske efikasnosti procesa osmotske dehidratacije, konvektivno sušenje je uzeto kao osnova za poređenje, a gubitak vode (*WL*) iz dehidiranog mesa kao odziv procesa osmotske dehidratacije jedini je pogodan za poređenje energetske efiksanosti dva različita tipa režima sušenja kakvi su osmotsko sušenje i konvektivno sušenje

Eksperimentalna zavisnost dinamike isparavanja vode, u paralelnim probama mesa i destilovane vode, kao i proračun koji je korišten za dobijanje vrednosti ušteđene količine toplote (*Q*) u procesu osmotske dehidratacije u odnosu na konvektivno sušenje svinjskog mesa prikazani su u radu [8].

Metoda odzivne površine (*RSM*) je odabrana za procenu generalnog uticaja tehnoloških parametara (temperatura procesa (t), vreme trajanja procesa (τ) i koncentracije osmotskog rastvora (C)) na promenu količinu uštеđene toplote u procesu.

Na osnovu eksperimentalnih rezultata formiran je model zavisnosti odziva sistema od ispitivanih nezavisno promenljivih veličina:

$$Y = f\,(temperatura,\ vreme,\ koncentracija) \qquad (1)$$

Polinom drugog stepena (*SOP*) je korišćen za fitovanje eksperimentalnih podataka. Dobijena odzivna funkcije za Q (Y) u zavisnosti od 3 ispitana faktora (X) (T, t i C):

$$Y = \beta_0 + \sum_{i=1}^{3} \beta_i X_i + \sum_{i=1}^{3} \beta_{ii} X_i^2 + \sum_{i=1}^{2} \sum_{j=i+1}^{3} \beta_{ij} X_i X_j \quad (2)$$

gde su:
β_{ij} - regresioni koeficijenti.

Značajnost uticaja pojedinačnih faktora kao i njihovih interakcija, za svaki od odziva, utvrđena je anlizom varijanse (ANOVA) i primienom post-hoc Tukey-evog HSD testa. Za analizu ANOVA i RSM korišćenjen je softverski paket Statistica [9].

REZULTATI ISTRAŽIVANJA I DISKUSIJA

U Tab. 1, prikazani su rezultati proračunatih *Q* u procesu osmotske dehidratacije svinjskog mesa u odnosu na procese konvektivnog sušenja za iste nivoe *WL*. Podaci o vrednostima *WL* u procesu osmotske dehidratacije svinjskog mesa prikazani su i u radovima [10-12].

Na osnovu prikazanih rezultata vidi se da se *Q* u procesu osmotske dehidratacije kretala u opsegu od 891,57 ±106,79 kJ·kg^{-1} mesa do 1770,92 ±8,48 kJ·kg^{-1} mesa.

Tabela 1. Srednje vrednosti i standardne devijacije Q u procesu osmotske dehidratacije u odnosu na konvektivno sušenje svinjskog mesa u zavisnosti od primenjenih tehnoloških parametara

Table 1. Average values and standard deviations of quantity of saved energy in the process of osmotic dehydration compared the convective drying of pork meat in dependence of applied technological parameters

t (°C) *t (°C)*	τ (č) *τ (h)*	C (% suve materije) *C (% dry matter)*	WL (g·g^{-1} $_{početnog\ uzorka}$) *WL (g·g^{-1} $_{initial\ sample}$)*	Q (kJ·kg^{-1} svinjskog mesa) *Q (kJ·kg^{-1} pork meat)*
20	*1*	*60*	*0,2413±0,0124*	*994,61 ±42,04^{a}*
20	*3*	*60*	*0,3651±0,0123*	*1414,29 ±41,70^{b}*
20	*5*	*60*	*0,4188±0,0223*	*1596,33 ±75,60^{c}*
20	*1*	*70*	*0,2400±0,0117*	*990,20 ±39,66^{a}*
20	*3*	*70*	*0,3959±0,0062*	*1518,70 ±21,02^{cd}*
20	*5*	*70*	*0,4567±0,0098*	*1724,81 ±33,22^{e}*
20	*1*	*80*	*0,2247±0,0142*	*938,33 ±48,14^{af}*
20	*3*	*80*	*0,4183±0,0199*	*1594,64 ±67,46^{c}*
20	*5*	*80*	*0,4703±0,0025*	*1770,92 ±8,48^{e}*
35	*1*	*60*	*0,2889±0,0148*	*948,52 ±50,17^{af}*
35	*3*	*60*	*0,4227±0,0075*	*1402,10 ±25,43^{b}*
35	*5*	*60*	*0,4596±0,0067*	*1527,19 ±22,71^{cg}*
35	*1*	*70*	*0,2721±0,0315*	*891,57 ±106,79^{f}*
35	*3*	*70*	*0,4295±0,0198*	*1425,15 ±67,12^{b}*
35	*5*	*70*	*0,4715±0,0253*	*1567,53 ±85,77^{c}*
35	*1*	*80*	*0,2846±0,0049*	*933,94 ±16,61^{af}*
35	*3*	*80*	*0,4747±0,022*	*1578,38 ±74,58^{c}*
35	*5*	*80*	*0,5207±0,0115*	*1734,32 ±38,99^{e}*

50	1	60	0,3349±0,0093	897,01 ±31,58^{f}
50	3	60	0,4545±0,0154	1302,45 ±52,21^{h}
50	5	60	0,4822±0,0159	1396,36 ±53,90^{b}
50	1	70	0,3754±0,0264	1034,30 ±89,50^{ai}
50	3	70	0,5035±0,0197	1468,56 ±66,78^{bdg}
50	5	70	0,5501±0,0175	1626,54 ±59,33^{c}
50	1	80	0,3922±0,0123	1091,26 ±41,70^{i}
50	3	80	0,5526±0,0038	1635,01 ±12,88^{c}
50	5	80	0,5843±0,0090	1742,48 ±30,51^{e}

^{abcdefghi} Različita slova u eksponentu u tabeli ukazuju na statistički značajne razlike između vrednosti, pri nivou značajnosti od <0,05 (na osnovu post-hoc Tukey-evog HSD testa)

^{abcdefghi} Different letters in superscript in table indicate on statistically significant difference between values, at significance level of p<0.05(based on post-hoc Tukey HSD test)

Na osnovu ANOVA testa količina toplote koje su ušteđene u procesu osmotske dehidratacije svinjskog mesa u odnosu na procese konvektivnog sušenja za iste nivoe *WL* koje su prikazane u Tab. 2 vidi se da na vrednost *Q* su statistički značajno uticala sva tri tehnološka parametra temperature, vremena i koncentracije, sa tim što se kao najuticajniji parametar pokazalo vreme, pa zatim koncentracija osmotskog rastvaora i na kraju temperatura.

Tabela 2. ANOVA *Q* u procesu osmotske dehidratacije svinjskog mesa u odnosu na procese konvektivnog sušenja za iste nivoe *WL*

Table 2. ANOVA quantity of saved energy in pork meat osmotic dehydration process compared to the convective drying for the same WL levels

Član *Term*	Tehnološki parametri *Technological parameters*	df^{+}	Zbir kvadrata *Sum of squares*
Kvadratni *Quadratic*	*t*	1	9583*
	τ	1	1983,03*
	C	1	0,00^{ns}
Linearni *Linear*	*t*	1	6761^{ns}
	τ	1	1977887*
	C	1	131827*
Proizvod *Cross product*	*t. x τ*	1	15132*
	t x C	1	27482*
	τ x C.	1	30445*
Greška *Error*	Ostatak varijanse *Residual variance*	17	28764^{ns}
	Ukupan zbir kvadrata *Total sum of squares*	26	2426184
R^2			0,9881

$^{+}$ Broj stepeni slobode

$^{+}$ *Degrees of freedom*

* Statistički značajno na nivou p<0.05

** Statistically significant at level of p<0.05*

^{ns} Nije statistički značajno

^{ns} *Statistically not significant*

Kvadratni članovi SOP-a za t i τ statistički značajno doprinose formiranju modela procesa, dok kvadratni član C nije statistički značajan. Linearni članovi za vreme trajanja procesa i koncnetraciju osmotskog rastvora su statistički značanjni, dok linearni član za temperaturu procesa nije statistički značajan.

Sva tri člana proizvoda $t{\cdot}C$, $\tau{\cdot}C$ i $\tau{\cdot}t$, su statistički značajni i doprinose formiranju modela procesa. Ostatak varijanse, kao mera odstupanja matematičkog modela od izmerenih eksperimentalnih vrednosti odziva, nije statistički značajna, što ukazuje da je primenjeni model za Q u procesu osmotske dehidratacije svinjskog mesa u odnosu na procese konvektivnog sušenja adekvatno prikazuje proces osmotske dehidratacije mesa. Vrednost koeficijenta determinacije R^2 koja se definiše kao odnos opisane varijacije sa ukupnom varijansom sistema [13], je takođe visoka (0,9881) što još jednom ukazuje na dobro poklapanje modela SOP-a sa izmerenim eksperimentalnim vrednostima.

U Tab. 3 prikazani su regresioni koeficijenti SOP-a jednačine (2) za Q u procesu osmotske dehidratacije svinjskog mesa u odnosu na procese konvektivnog sušenja za iste nivoe *WL*. U tabeli su naznačene i statističke značajnosti pojedinačnih koeficijenata koji se mogu koristiti za formiranje kvadratnih jednačina koje opisuju model energetskih ušteda procesa osmotske dehidratacije. Na osnovu ovih jednačina i poznatih ulaznih veličina, odnosno tehnoloških parametata tremperature, vremena i koncentracije računskim putem mogu se dobiti vrednosti energetskih ušteda.

Tabela 3. Regresioni koeficijenti SOP za Q u procesu osmotske dehidratacije svinjskog mesa u odnosu na procese konvektivnog sušenja za iste nivoe *WL*

Table 3. Regression coefficients for quantity of saved heat in pork meat osmotic dehydration process compared to the convective drying for the same WL levels

	Y/Q
β_0	$1408,318^{ns}$
β_{11}	0,178*
β_{22}	-45,450*
β_{33}	$0,002^{ns}$
β_1	-32,507*
β_2	303,574*
β_3	$-10,428^{ns}$
β_{12}	-1,184*
β_{13}	0,319*
β_{23}	2,518*

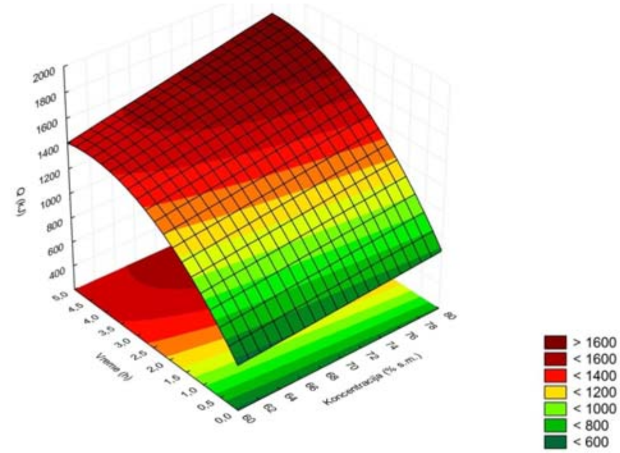
* Statistički značajno na nivou od p<0,05

** Statistically significant at level of p<0,05*

^{ns} Nije statistički značajno

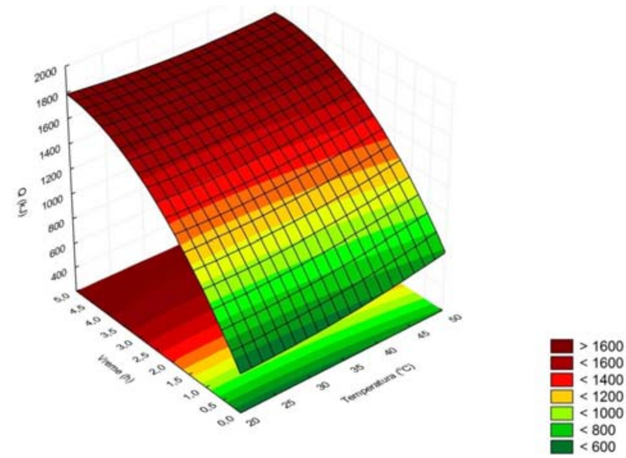
^{ns} Statistically not significant

Na Graf. 1 dat je grafički prikaz jednačine SOP koja opisuje model Q u procesu osmotske dehidratacije svinjskog mesa u odnosu na procese konvektivnog sušenja za iste nivoe *WL*, u zavisnosti od tehnoloških parametara τ i C. Na osnovu praćenja trendova uticaja tehnoloških parametara na energetske uštede u procesu i na osnovu Tab. 1 u kojoj su prikazane statistički značajne razlike između vrednosti ušteđenih količina toplote, može se primetiti da τ statistički značajno utiče na porast Q u procesu, jer na isti način utiče i na porast *WL* iz dehidrirajućeg materijala [11].



Grafik 1. Zavisnost Q u procesu osmotske dehidratacije svinjskog mesa od τ i C melase

Figure 1. Dependance of quantity of saved energy in pork meat osmotic dehydration process from time of the process and molasses concentration



Grafik 2. Zavisnost Q u procesu osmotske dehidratacije svinjskog mesa od τ i T

Figure 2. Dependance of quantity of saved energy in pork meat osmotic dehydration process from time and temperature of the process

Porast C melase kao osmotskog rastvora statistički značajno utiče na porast Q, Graf. 1. i Tab. 1. Ovaj trend je takođe u saglasnosti sa trendovima uticaja C osmotskih rastvora na glavne odzive procesa osmotske dehidratacije, koji dovode do porasta efikasnosti procesa osmotske dehidratacije [12], a u skladu sa tim i do povećanja energetskih ušteda u procesu.

Temperatura procesa osmostske dehidratacije nije iskazala statistički značajan uticaj na Q u procesu, Graf. 2 i Tab. 1, odnosno dodatni utrošak toplote za potrebe zagrevanja sistema meso/osmotski rastvor na povećane temperature procesa (35°C i 50°C) nije doprineo dovoljno izraženom porastu efikasnosti procesa kroz povećanje vrednosti *WL* koje bi nadomestile utrošenu toplotu za zagrevanje.

ZAKLJUČAK

Primenom metode odzivne površine proračunate su jednačine polinoma drugog reda koje su definisale model uštеđene količine toplote u procesu osmotske dehidratacije svinjskog mesa u zavisnosti od primenjenih tehnoloških parametara koncentracije osmotskog rastvora, vremena trajanja i temperature procesa.

Maksimalna vrednost uštede količine toplote ostvarena je u procesu osmotske dehidratacije svinjskog mesa na temperaturi procesa od 20°C, nakon 5 časova procesa u melasi šećerne repe maksimalne koncentracije.

Tehnološki parameter koji je imao najviše uticaja na energetske uštede procesa je bilo vreme trajanja procesa, zatim po značajnosti uticaja je sledila koncentracija osmostskog rastvora i na kraju temperatura.

Rezultati prikazani u ovom istraživanju ukazuju na niskoenergetski profil procesa osmotske dehidratacije koji upotrebom melase kao osmotskog rastvora još više doprinosi ekološkom karakteru procesa.

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ENERGY SAVINGS MODELING OF OSMOTIC DEHYDRATION PROCESS OF PORK MEAT IN MOLASSES

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Abstract: The goal of the presented research is defining energy savings mathematical models of the osmotic dehydration process of pork meat in sugar beet molasses and analysing the effects of applied technological parameters in the process. Quantity of saved energy in the process of osmotic dehydration ranged from 891,57 to 1770,92 kJ·kg^{-1} meat. In this paper developed mathematical models of energy savings in the process of pork meat osmotic dehydration are presented. Time of the process was the most influential technological parameter on developed models, than osmotic solution concnetration, and temperature of the process was the least influential technological parameter. Maximal value of the energy savings was achived in the process of osmotic dehydration of pork meat at the temperature of 20°C, after five hours of the process in sugar beet molasses of the maximal concentration. Presented results indicate on low energy profile of osmotic dehydration process which, by utilisation of molassses as an osmotic medium, even more contributes to the ecological properites of the process.

Key words: *osmotic dehydration, sugar beet molasses, pork meat, energy savings, responce surface methodology*

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DEVELOPMENT OF BULLOCK DRAWN DRY PADDY SEED CUM FERTILIZER DRILL

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Abstract: A study was carried out on development of bullock drawn dry paddy seed cum fertilizer drill for upland cultivation. Based on the physical characteristics of seed, development of dry paddy seed cum fertilizer drill was done. The seed and fertilizer box was made trapezoidal for free flow of seeds and fertilizer without bridging. The cup feed mechanism was selected for metering paddy seeds as there is no seed damage and hence does not affect germination. For fertilizer metering, an adjustable orifice type mechanism was provided. A clutch is provided for disengaging power to the metering mechanism during turning. For seed and fertilizer placement, shoe and shovel type of furrow openers were used. A provision was made to adjust the row to row spacing as per requirement. The average theoretical field capacity, effective field capacity and field efficiency was 0.151 ha·h^{-1}, 0.11 ha·h^{-1} and 75.96% respectively.

Key words: *upland, field capacity, efficiency*

INTRODUCTION

The traditional rice farming system in India broadly includes direct seeding and transplanting. The primary difference between the two methods is that in the transplanting method, seedlings are first raised in the seedbed before they are planted in the main field whereas in direct seeding, the seed is sown directly in the main field wither by broadcasting or row seeding in wet or dry field. Transplanting is most labour consuming operation during paddy cultivation. The cost of puddling and transplanting share 50 per cent of total production cost. The man days required for transplanting

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ranges from 50-60 man-days·ha^{-1}. The transplanting operation produced maximum paddy yield of 7875 kg·ha^{-1} whereas the highest paddy yield of 8666 kg·ha^{-1} was recorded by direct rice cultivation on dry soils with an increase of 10% over transplanting [9]. Direct seeding of rice on dry soils has been found most appropriate alternative to transplanting. It not only avoids puddling operations, raising and transplanting of nursery seedlings but also resulted in better yield than existing manual transplanting in some areas of the country. It involves less drudgery and labor and does not require preparation of nursery, care for it and pull the seedlings [7]. Drum seeders are developed for direct seeding of pregerminated paddy. The main problem observed in case of drum seeders is that the proper seed rate is not maintained and also uneven seed delivery is observed. Many seeds are dropped when the operator stops, and then no seeds are dropped until the seeder has moved forward for a small distance. This uneven seeding leads to an uneven plant stand and follow-up transplanting may be required. Drum seeding requires puddling and leveling of field, drainage as well as better methods of fertilizer application.

Direct dry seeding of paddy results in better yield of crop and water saving. The problem observed in case of dry seeding of paddy is weed infestation, lodging of plants because of less root anchorage. Sometimes the exposed seeds are lost due to birds and pests. The need for appropriate agricultural machine for direct dry seeding is felt as there is reduction in farm labor due to migration to urban areas and the labors are very costly and scares. Dry seeding of paddy along with the use of fertilizers is carried out to maintain the soil nutrient levels and increase crop yield levels. Considering the need, it is decided to develop three row bullock drawn dry paddy seed cum fertilizer drill for upland cultivation at department of farm machinery and power, CAET, Dapoli.

MATERIAL AND METHODS

The performance of a seed cum fertilizer drill depends on several variables that depend on the dimensions of the ground wheel, metering mechanism, peripheral velocity and uniformity of the seeds.

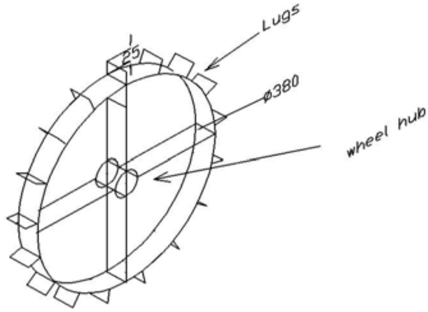

Figure 1. Isometric view of ground wheel of developed bullock drawn dry paddy seed cum fertilizer drill

Physical properties of paddy. Seed properties are important factors for optimizing the parameters of the design of seed drill. Hence attempt was made to study the physical properties of paddy seed in relation to seed metering mechanism. The paddy varieties selected for the study were classified as long and bold, long and medium, long and slender, short and bold, short and fine variety. The physical properties of paddy namely; thousand grain weight, size and surface area, bulk density, angle of repose were required for the design of metering mechanism [11].

Design of drive wheel. The drive wheel rim was made up of MS flat 40×5 mm. considering the lug height of 25 mm, 17 lugs were provided at periphery. Thus the diameter of lugged wheel was taken as 0.43 m.

Design of seed and fertilizer box. The seed cum fertilizer box was made of 16 SWG MS sheet. The cross section of the box is trapezoidal. . The shape of hopper is such that it ensures proper flow of seeds and fertilizer without bridging. Seed and fertilizer boxes have partition provided along the length of the box such that in one box it forms thee hoppers. The angle of inclination of the seed and fertilizer hopper with the vertical were 27˚ and 30˚ considering free flow of seeds and fertilizer respectively. The location of seed cum fertilizer box was 60 cm above the ground. This height of box helps to reduce the angle of inclination of seed delivery tubes.

Box capacity in terms of volume V_s is calculated in m^3 as:

$$V_s = Q_s \cdot \rho^{-1} \quad (1)$$

$$V_s = A \cdot L \quad (2)$$

where:

A [m^2] - cross sectional area,
L [m] - length of box,
Q_s [kg] - box capacity,
ρ [kg·m^3] - density of material filled in box.

The length of the box is calculated as:

$$L_B = nd - 2b \quad (3)$$

where:

n [-] - number of furrow openers,
d [m] - distance between two furrow openers,
b [m] - distance between side wall of the box from the wheel.

For the 3 row paddy seed drill, the row to row spacing is 0.2 m, the actual length of box is 0.4 m. The cross sectional area of the seed and fertilizer box was determined by:

$$A = h\,(B + h \cot \alpha) \quad (4)$$

where:

h [m] - height of seed box,
B [m] - width of box,
α [deg] - angle of slope.

Therefore, $A = 0.22\,(0.25 + 0.22 \cot 63^\circ) = 0.079\ m^2$

Volume of seed box is calculated as:

$$V = A \cdot L_B = 0.079 \cdot 0.4 = 0.0318\ m^3 \quad (5)$$

Box capacity:

$$Q_s = V_s \cdot \rho = 0.0328 \cdot 627 \approx 20\ kg \quad (6)$$

Using above equations, the area and the volume of the fertilizer box was 0.049 m^2 0.0149 m^3, respectively. The length of box was 300 mm. Thus, the box capacity was 16 kg, such that each hopper can be filled with 5.3 kg each.

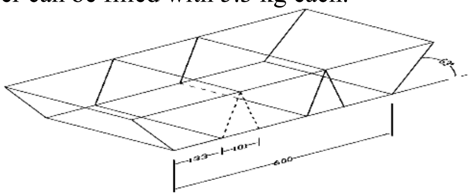

Figure 2. Isometric view of seed box of developed bullock drawn dry paddy seed cum fertilizer drill

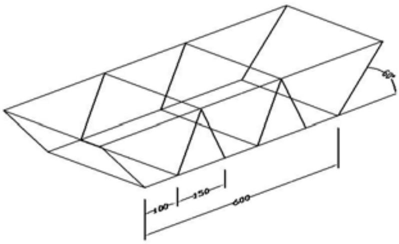

Figure 3. Isometric view of fertilizer box of developed bullock drawn dry paddy seed cum fertilizer drill

Seed metering mechanism. While designing the seed metering mechanism, prime consideration was given to use less sophisticated sowing technology, lower cost and easy to fabricate at a local workshop. Also, the metering mechanism should not cause any mechanical damage to the seed while in operation. Hence, cup feed mechanism was used so that there should not be any mechanical damage due to mechanical handling. A series of cups were fitted on the rim of a vertical rotating plate that dips into a shallow pool of seed, lifting a few at a time and carrying them over a top, where they are dropped into a delivery channel. The diameter of seed plate and the number of cups on the seed plate are determined as follows:

$$dc = \frac{V_c}{\pi \cdot N_c} \tag{7}$$

where:

d_c [cm] - diameter of seed plate,
V_c [m·s^{-1}] - peripheral velocity of plate,
N_c [min^{-1}] - rpm of metering mechanism.

Number of cups on the seed plate is calculated as:

$$n = \frac{\pi \cdot D}{i \cdot x} \tag{8}$$

where:

n [-] - number of cups on the seed plate,
D [cm] - ground wheel diameter,
x [cm] - required seed to seed spacing,
i [-] - gear ratio (1:1).

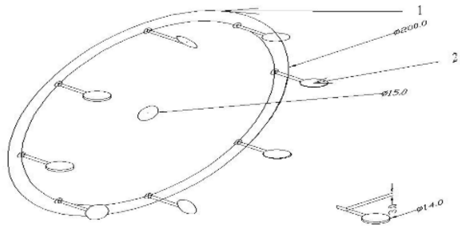

Figure 4. Seed metering mechanism used in developed bullock drawn dry paddy seed cum fertilizer drill

Fertilizer metering mechanism. The fertilizer metering device used in the drill was an adjustable orifice type. So at the bottom of the box a hole was provided and a lever was provided for sliding the plate. Meshing the holes regulates the flow of quantity of fertilizer. A ribbed rubber type agitator is placed over the holes to prevent bridging of granules in front of holes. Hole size on the plate is selected according to the requirement. Adjustable orifices are provided to control the fertilizer rate. The flow rate of fertilizer from the orifice is expressed by:

$$Q = F \cdot \rho_1 \cdot A_0 \cdot (2g \cdot P \cdot \rho_1^{-1})^{0.5} \tag{9}$$

where:

Q [g·s^{-1}] - discharge rate,
F [-] - flow rate index of urea (const, 0.66) [4]
A_0 [mm] - area of opening of orifice,
ρ_1 [kg·m^{-3}] - bulk density of material,
g [m·s^{-2}] - acceleration due to gravity,
P [Pa] - static pressure produced by material.

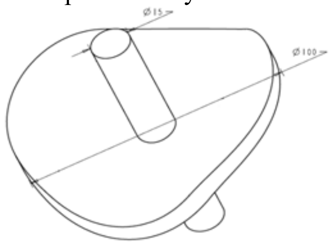

Figure 5. Fertilizer metering mechanism used in developed bullock drawn dry paddy seed cum fertilizer drill

The value of P is expressed as:

$$P = d_1 \cdot \rho_1 \cdot \gamma^{-1} \tan \varphi^{-1} \tag{10}$$

were:

φ [deg] - angle of internal friction of material (25° for MS sheet) ,
$\gamma = tan^2 (45- \varphi \cdot 2^{-1})$
$d_1 = d- d`$
d [cm] - diameter of orifice and $d`$ reduction in d due to flow.

Furrow opener. Furrow openers are used to place the seed at the desired depth with minimum dispersion. For seed placement, shoe type furrow openers were used as uniform depth of sowing was required [10]. Row to row distance can be changed by adjusting holes drilled in the frame. Furrow opener was made of medium carbon steel with 1800 mm^2 cross section. The rake angle is 33° in order to make cut the soil 3 to 5 cm deep. The relief angle of the blade is 8°. Fertilizer was placed in the soil with the help of shovel type opener. The shovel type opener is a narrow pointed shovel, small l00 mm sized shovels were used for placing fertilizer at a depth of 5 cm. The leading edge of the opener is a sharp pointed triangle.

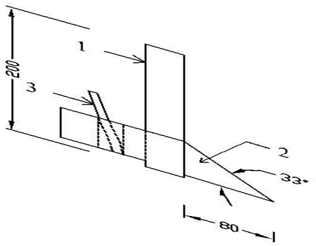

Figure 6. Isometric view of shoe type furrow opener of developed bullock drawn dry paddy seed cum fertilizer drill

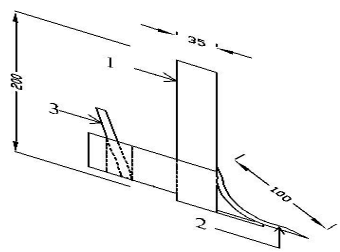

Figure 7. Isometric view of shovel type furrow opener of developed bullock drawn dry paddy seed cum fertilizer drill

Seed delivery tube. Polyethylene tubes of 25 mm diameter and 2 mm thick were used to convey seed from orifice to furrow opener by gravity. The inclination of the tubes from the vertical was kept smaller than 25° [8]. The time of fall of a seed though a tube is affected by the size and type of tube and bouncing of seeds against wall of the seed tube. The velocity of a seed falling freely from a height 'h' is given by:

$$V^2 = V_0^2 + 2gh \quad (11)$$

where:

V [$m \cdot s^{-1}$] - final velocity of seed due to fall,
V_0 [$m \cdot s^{-1}$] - initial velocity of the seed,
g [$m \cdot s^{-2}$] - gravitational acceleration, const. (9.81 m/s^2).

Power transmission unit. The power required to operate the seed and fertilizer metering mechanism was transmitted from the drive wheel though chain drive. Since the power transmitted in the seed drill is very low, the smallest size available chain, i.e. bicycle chain was used for animal drawn seed drill. For power transmission, 19 teeth a medium size 60 mm diameter sprocket of 12.9 mm pitch was fitted on drive wheel. Another sprocket of same size was used for seed and fertilizer metering shaft so that the transmission ratio of 1:1 was maintained.

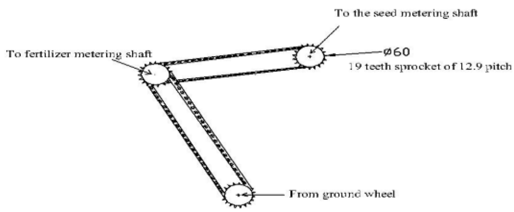

Figure 8. Power transmission system used for developed bullock drawn dry paddy seed cum fertilizer drill

Clutch. A clutch was provided to the ground wheel, so that during turning the power should not be transmitted to the metering mechanism. When the clutch was engaged to the drive wheel, the power was not transmitted to the metering shaft. So there should not be seed and fertilizer losses at the turning. Handle for the clutch was made of MS flat of 25×5 mm, length of 1100 mm connected to the driving wheel to the metering shaft. Dog clutch was used to disconnect the rotation of the drive wheel to the shaft.

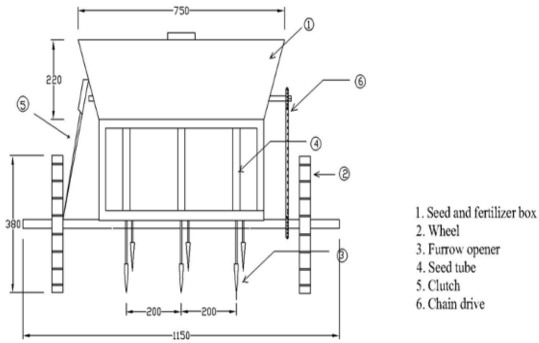

Figure 9. Front view of bullock drawn dry paddy seed cum fertilizer drill

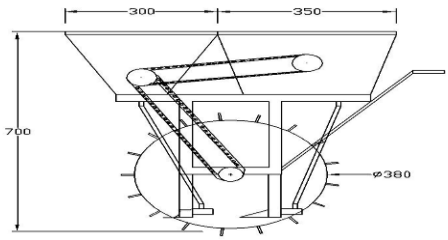

Figure 10. Side view of developed bullock drawn dry paddy seed cum fertilizer drill

Figure 11. Developed bullock drawn dry paddy seed cum fertilizer drill

Frame. The frame of the 3 row seed cum fertilizer drill was made of MS angle of 25×25×5 mm with a square cross section. Provision was made to adjust the spacing between two furrow openers. An adjustable hitch is fabricated having 3 point converging link. It gives ease of attachment and adjustment, uniform depth and stability to the developed bullock drawn dry paddy seed cum fertilizer drill.

RESULTS AND DISCUSSION

The influence of selected variables on operation efficiency, number of seeds per hill, missed hills seed spacing and design concepts of components are discussed. Seed properties are important for optimizing the parameters of the seed drill. Based on the geometrical parameters of the seed, the cup design for metering mechanism was decided. Long and bold variety of paddy was selected for testing the uniformity of seeding and for field performance.

Table 1. Detail specification of developed prototype of bullock drawn dry paddy seed cum fertilizer drill

No.	Components	Specification	Material
1	Ground wheel	Rim diameter: 380 mm, rim width: 40 mm	MS flat40×5 mm
2	Seed box	Trapezoidal shape cross section, height of box 220 mm, upper side 750×350 mm, bottom side 600×250 mm, angle of inclination of 63° with the horizontal, 3 no. 1 for each furrow opener	16 SWG MS sheet
3	Fertilizer box	Trapezoidal shape cross section, height of box 220 mm, upper side 750×300 mm, bottom side 600×100 mm, angle of inclination of 60° with the horizontal, 3 no. 1 for each furrow opener	16 SWG MS sheet
4	Seed metering mechanism	Cup feed metering mechanism, diameter of seed plate 200 mm, 8 cups around the periphery, distance between cups 150 mm.	14 SWG MS sheet
5	Fertilizer metering mechanism	Adjustable orifice type, ribbed rubber 100 mm dia., sliding plate 600×5 mm with holes 5 to 15 mm.	16 SWG MS sheet, MS flat 25×5 mm
6	Clutch	Dog clutch, length of handle 1100 mm	MS flat25x3 mm
7	Power trans-mission unit	Sprocket 19 teeth 60 mm dia., chain pitch 12.9 mm, total chain length 1879 mm.	
8	Main frame	Total length of 2800 mm	MS angle 25×25×5 mm
9	Furrow openers a. Shoe type b. Shovel type	Adjustable row to row spacing between 150 250mm Shoe type: height of shank 200 mm, C.S.A 1800 mm^2, rake angle 33°. Shovel type: height of shank 200 mm, length of shovel 100 mm	Medium carbon steel
10	Seed delivery tube	Diameter 25 mm, thickness 2 mm	Polythene tube

The average geometrical parameters of long and bold variety which was observed were 9.03, 2.97, and 2.13 of length, breadth and thickness respectively. The size, surface area and sphericity were 3.91, 56.73 mm^2 and 0.43 respectively. The mean thousand grain weight and angle of repose of all the varieties of paddy were observed as 23.58 g and 27˚ respectively. The bulk density of fertilizer was 1.079 g·cc^{-1}. The angle of repose of fertilizer was measured as 30˚. Hence the slope of the seed hopper was designed as per the angle of repose of paddy which is 27˚ for free flow of the seeds from hopper. The slope of fertilizer hopper was 30˚ with the vertical. The hopper capacity for seed and fertilizer is 20 kg and 16 kg respectively. Fertilizer hopper is placed at the front side of the frame and the seed hopper is mounted behind it. Cup feed metering mechanism is used for seed as there is no any mechanical damage to seeds due to mechanical handling. The diameter of seed plate is 20 cm with 8 cups are mounted along the periphery of the seed plate. The seed rate can be varied between between 60 to 65 kg·h^{-1}.

An adjustable type metering mechanism is used for fertilizer. By adjusting the holes, the fertilizer rate can be varied in between 100 to 105 kg·h^{-1}. The metering mechanism is actuated by the ground wheel which transmits power by means of chain and sprocket. A clutch is provided to the ground wheel, so that the power is cutoff from the metering mechanism during turning. Polythene tubes of 25 mm diameter and 2 mm thick are used to convey seed and fertilizer from orifice to furrow opener by gravity. Furrow openers are used to place the seed at the desired depth. A shoe type furrow opener with the rake angle of 33˚ is used to place the seed at a depth of 3 to 5 cm. For placing fertilizer, a narrow pointed shovel type furrow opener is used for placing fertilizer at a depth of 5 cm. A provision is made to change the row to row spacing by adjusting the hole drill on the frame. Row to row spacing can varied between 15-25 cm. An adjustable hitch is fabricated having 3 point converging link. It gives ease of attachment and adjustment, uniform depth and stability to the developed bullock drawn dry paddy seed cum fertilizer drill.

CONCLUSIONS

The developed dry paddy seed cum fertilizer drill has worked satisfactorily in the field. The average theoretical field capacity, effective field capacity and field efficiency was 0.151 ha·h^{-1}, 0.11 ha·h^{-1} and 75.96% respectively. The developed bullock drawn seed cum fertilizer drill was found effective for direct sowing of dry paddy in the Konkan region for upland paddy cultivation. The performance evaluation of seed cum fertilizer drill was satisfactory for working in the well prepared seed bed. An average size of bullock can meet the draft. The average wheel slip was found within the limit. The percentage of missing hills was higher than the requirements. The actual field capacity and the field efficiency were found satisfactory.

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RAZVOJ ZAPREŽNE SEJALICE SA ULAGAČEM ĐUBRIVA ZA SETVU PIRINČA

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Sažetak: Predstavljen je razvoj zaprežne sejalice sa ulagačem đubriva za brdske terene, na osnovu fizičkih osobina semena. Boksovi za seme i đubrivo su trapeznog oblika, za slobodan tok materijala bez zagušenja. Mehanizam sa šoljama za doziranje semena je izabran zato što ne oštećuje seme i ne utiče na klijavost. Za doziranje đubriva ugrađen je mehanizam sa podesivim otvorima. Tokom okreta se pogon kvačilom odvaja od mernog mehanizma. Za otvaranje brazdice i ulaganje semena i đubriva su upotrebljeni podrivači sa ulagačkim motičicama. Međuredno rastojanje se može podešavati prema potrebama. Srednji teorijski poljski kapacitet, stvarni poljski kapacitet i radni učinak su iznosili 0.151 $ha \cdot h^{-1}$, 0.11 $ha \cdot h^{-1}$ i 75.96%, redom.

Ključne reči: *brdski tereni, poljski kapacitet, efikasnost*

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REDUCTION OF SPRAY LOSSES TO SOIL IN SOYBEAN (*GLYCINE MAX* L.) THROUGH OPTIMIZATION OF OPERATIONAL PARAMETERS

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Abstract: Spraying of plant protection chemicals is widely practised for minimizing the losses occurred due to attack of insect pests, and occurrence of diseases. However, indiscriminate and improper use of pesticide has brought up many environmental issues especially the soil pollution. Application of pesticide and its deposition at the target surface has drawn much attention to improve the efficacy of spray. A number of factors affect the deposition of pesticide on the plant surface and its loss to soil. These factors include both morphological characteristics of leaf and operational parameters of spraying. Among the operational parameters type of nozzle, pressure, droplet size, travel speed, etc. are some of the factors responsible for efficacy of spray on plant and losses to soil. Crop growth stage also affects the efficacy of the spray. The study established that spraying of insecticides with a suitable hydraulic sprayer fitted with HCN-80250 nozzle having provision for air supply at an advanced stage of crop growth with a travel speed of 3.5 km per hour ensure minimum spray losses to soil in soybean crop with considerably higher coverage area by the droplets on both sides of the leaves.

Key words: *spray loss, nozzle, spray coverage, crop growth stage, soybean*

INTRODUCTION

Soybean is one of the nine major oilseeds grown in India and it occupies first rank in terms of area under cultivation among oilseeds. During 2010-11, the total area under soybean was recorded as 9.60 million hectare with a production of 12.74 million tons

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[1]. The yield of soybean has however experienced high fluctuation during the last decade with an average yield of around 1006 $kg \cdot ha^{-1}$. About 58% of total area under soybean is in Madhya Pradesh and about 28% area belongs to Maharashtra. Therefore, unfavorable climatic conditions in these states coupled with infestation of pests and pathogens during *kharif* (rainy) season plays an adverse role in soybean production. Chemical control of insect pests and pathogens, which destroy up to one-third of the crop during different stages of crop growth, harvest and storage, is a very crucial field operation. It is generally agreed that the use of pesticides will increase, in spite of the exploitation of alternate methods of pest control. However, the rapidly increasing usage of pesticides, often with insufficient advice, has brought in its wake many environmental problems inimical to the interest of man [2]. Most of the sprayed pesticides usually reach to a destination other than the targeted zones causing an adverse effect on environment. The non-targeted areas like water-bodies, grasslands, residential areas and other habitats can be contaminated with pesticide residues as an outcome of run-off of the spray fluid from the foliage, drift of minute droplets of spray with air velocity, washing down of pesticides from plant to soil with rainwater, spilling of pesticide solution during filling of spray equipment and incorporation of remnants of plant parts treated with pesticide in the soil. The conventional technique for applying pesticides to agricultural crops is through dilution of pesticide with water. The spray solution can then be distributed evenly on the target crop by boom sprayers equipped with an atomizer system. The commonly used atomizer system is hydraulic nozzles where the spray liquid is atomized into droplets forming a spray with a pattern, which enables the even distribution of the spray on the intended targets. The boom and nozzles are placed typically at a height of 40 to 50 cm above the targeted zone. Pimentel stated that that less than 0.1% of pesticide applied for pest control reach their target pest in conventional spraying system [5]. However, some researchers reported absolute increase of deposit of the working fluid for 18% on the target surface with reduction of air flow angle relative to the direction of movement of aggregates, from 90° to 45° at a driving speed of 5 $km \cdot h^{-1}$ using air mist-blowers fan for dispersion of insecticide solution in vineyards [6]. The pesticide solution may also be dropped down through run-off from the leaves. Therefore, even in dense crops, a proportion of the spray liquid will be deposited on the soil below the crop [4].

After reaching to soil, the transport, persistence or degradation of pesticide depends on physical, chemical and biological properties of soil apart from the chemical composition of pesticide. Soil with high organic matter content improves sorption of pesticide molecules with soil particles, prevents the run-off and leaching of pesticides and thereby reduces the incidence of surface and ground water contamination. However, contamination of soil with pesticides result into suppression of population growth of beneficial soil microorganisms, reduction in population of certain soil invertebrates like nematodes and earthworms, predatory arthropods, pollinating insects, etc. It is also harmful for birds, wild and domesticated grazing animals and animals of aquatic ecosystems. It is also a persistent threat to human health and well-being.

A number of factors affect the deposition and retention of pesticide on the plants. The examples of such factors are canopy structure of the target crop, spray application factors and properties of the sprayed liquid and air-assistance to hydraulic boom of the sprayers. Leaf morphological features such as shape, leaf orientation and leaf age may also affect retention. A part of the spray can be lost during the application before the droplets are deposited on plants or soil. Droplets can be transported out of the sprayed field by spray drift. However, this loss is negligible under normal climatic conditions. Another loss comes from evaporation during the travel from nozzle to target. Apart from these factors, the travel speed of the sprayer also affects the retention of spray on the plant surface and the loss of spray chemical to the soil. Hislop highlighted the usefulness of air assistance on spraying at the rate of 0.72 $m^3 \cdot sec^{-1}$ and slower sprayer speed of 0.50 $m \cdot sec^{-1}$ as compared to conventional spraying without air-assistance at a forward speed of 2 $m \cdot sec^{-1}$ for obtaining higher spray deposit on the whole tillers by 66 to 71% and lower soil contamination by 46 to 66% depending upon size of droplets [3]. Therefore, determination of combination of different parameters like crop growth stages, selection of hydraulic nozzles, air assistance and forward speed is necessary for obtaining minimum spray losses to soil. Keeping these factors in view, an attempt was made to assess the quality of spray and the spray losses on soil for different types of nozzles with and without assistance of air at different forward speed and at various growth stages of soybean crop.

MATERIAL AND METHODS

The experiments were conducted using an over-head trolley set-up installed at plant protection laboratory of Central Institute of Agricultural Engineering, Bhopal in year 2012. Two hollow cone nozzles namely, HCN 80250 and HCN 80450 were selected for operating at recommended pressure of 3 $kg \cdot cm^{-2}$. The overhead trolley was fitted with a removable air sleeve attached to a centrifugal blower of 1 $m^3 \cdot s^{-1}$ air discharge capacity to supply the air into sleeves to examine the effect of air assistance on spray. The controller for the movement was programmed to have three levels of travel speed (1.5, 2.5 and 3.5 $km \cdot h^{-1}$) of the trolley for estimating spray deposition efficiency on crop and soil. Two rows of soybean plants were grown in two boxes mounted on a movable trolley filled with soil up to depth of 30 cm for conducting experiment inside the laboratory (Fig. 1) at two different growth stages of the crop viz. 45 days and 80 days after sowing (DAS). The system was mounted on the overhead trolley test setup such that a distance of 45 cm between nozzle and plant canopy is maintained.

Figure 1. Soybean plants grown on portable trolley

An aqueous solution of a red colored dye was used for spraying and the samples of droplet images were collected. The impression of droplets was collected on white paper tags (40 mm x 30 mm) with known spread factor mounted on both the front side and back side of the leaves as well as on soil surface between the rows. During spraying of the dye on one row of soybean plants, the other row was kept covered with polythene sheet to avoid unwanted exposure to spray solution (Fig. 2).

Figure 2. Spraying on one row of soybean plants keeping the other row covered.

After spraying on both the rows one by one, the paper tags were removed from the plants and allowed to dry to obtain the impression of droplets on paper tags (Fig. 3). The images of droplets were analyzed to estimate the coverage of spray using Leica QWin image analysing software after scanning the droplet images obtained on the paper tags. The droplet size of the spray discharge from both the nozzles and their distribution were measured by Spraytec Droplet Size Analyzer made by Malvern Instruments Ltd. U.K. Statistical analysis of the obtained data was done by using SAS 9.3 statistical software.

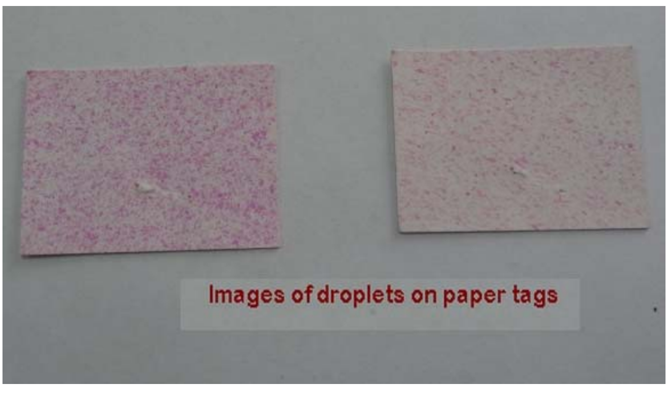

Figure 3. Impression of spray droplets on paper tags

RESULTS AND DISCUSSION

The droplet size and its distribution obtained from hollow cone nozzles at recommended pressure (3 kg·cm^{-2}) and varying forward speed of the overhead trolley were measured using droplet size analyser and the result is given below. In the case of HCN-80250 nozzle, the volume mean diameter (VMD) decreased with increase in forward speed of the system as a result of reduction in exposure time of larger droplets passing through laser beam of droplet size analyzer (Tab. 1). Though a reverse trend was observed while spraying with HCN-80450 nozzle having higher discharge rate where, fragmentation of larger droplets into smaller ones may not be materialized due to momentary period of contact at higher speed (Tab. 2) but this increase in droplet size was statistically insignificant. Most of the droplets were having a diameter of less than 200 micron which was well within the acceptable limit.

Table 1. Performance data of HCN 80250 for distribution of droplet sizes by volume

Forward speed (km·h^{-1})	*Droplet Size Distribution, (%)*					*Min. diameter (μ)*	*Max. diameter (μ)*	*Mean diameter (μ)*	*S.D.*	*C.V.*
	<100 (μ)	*100-200 (μ)*	*200-300 (μ)*	*300-400 (μ)*	*>400 (μ)*					
3.5	0.05	77.25	18.98	0.03	5.46	166.74	195.33	178.88	3.49	1.95
2.5	Nil	75.49	22.94	0.26	1.84	169.28	201.74	183.25	2.69	1.47
1.5	Nil	46.83	49.49	1.23	3.69	188.62	234.02	203.10	4.48	2.21
Tukey's HSD for mean droplet size = 4.60										

Table 2. Performance data of HCN 80450 for distribution of droplet sizes by volume

Forward speed (km·h^{-1})	*Droplet Size Distribution, (%)*					*Min. diameter (μ)*	*Max. diameter (μ)*	*Mean diameter (μ)*	*S.D.*	*C.V.*
	<100 (μ)	*100-200 (μ)*	*200-300 (μ)*	*300-400 (μ)*	*>400 (μ)*					
3.5	0.17	53.72	44.08	1.43	1.18	178.32	231.91	197.03	9.54	4.84
2.5	0.03	55.14	44.01	0.14	0.92	174.46	230.01	193.73	10.6	5.48
1.5	0.12	75.42	23.67	0.46	1.13	161.97	208.16	181.55	12.7	7.01
Tukey's HSD for mean droplet size = 17.57										

Effect of different crop growth stages on area covered by spray in soybean crop

The results obtained on percentage of area covered by droplets on leaves and soil for soybean crop at two different crop growth stages of 45 and 80 DAS revealed that the crop growth stage at 45 DAS displayed significantly higher coverage on front side of the leaves whereas, the effect of crop growth stage was insignificant on coverage of spray on back side of the leaves. However, the area covered by droplets on soil surface was significantly reduced at crop growth stage of 80 DAS Since, no specific conclusion can be drawn from absolute coverage of spray at different locations; it was decided to frame two ratios namely, the ratio of area covered by droplets on plant to area covered on soil and the ratio of area covered by droplets on backside of leaves to front side of leaves, keeping in view the aim of experiment towards reducing the spray loss on soil and increasing the deposit of spray on both sides of the leaves.

Further analysis based on these ratios indicated that crop growth stage exerted insignificant influence on the ratio of coverage on plants to soil but it exhibited significant impact on coverage on backside to front side of leaves (Tab. 3). The analysis also pointed out that at earlier stages of growth, spray discharge reached freely to almost all exposed sides of leaves and also drifted to soil due to the thinner canopy of the plants. At later growth stages, the dense canopy of the plants prevented the drift of spray to the ground. Therefore, it can be concluded that spraying at proliferated canopy ensures more uniformity of spray with reduction of spray being deposited on the ground.

Table 3. Effect of different crop growth stages on area covered by spray

Particulars	*Percentage of area covered at*		*Difference*	*Tukey's HSD at 5% level*
	45 D.A.S.	*80 D.A.S.*		
Front-side of leaves	*14.63*	*9.78*	*4.85*	*1.79*
Back-side of leaves	*3.88*	*3.63*	*0.25*	*0.78*
On soil surface	*15.09*	*9.14*	*5.95*	*2.58*
Ratio of coverage on plant to soil	*1.46*	*1.58*	*0.12*	*0.30*
Ratio of coverage on back-side to front-side of leaves	*0.25*	*0.40*	*0.15*	*0.09*

Effect of different hollow cone nozzles on area covered by spray in soybean crop

On the basis of area covered by droplets discharged from different nozzles, it was observed that HCN-80450 gave significantly higher coverage only on back side of the leaves whereas; HCN-80250 significantly reduced the area covered by droplets on soil. Further analysis indicated that HCN-80250 significantly increased the ratio of area covered on plants to soil while the nozzle HCN-80450 had an insignificantly higher ratio of area covered on backside to front side of leaves (Tab. 4). Therefore, it is advisable to select hollow cone nozzle HCN-80250 to decrease the spray losses to soil without compromising the penetration of spray in crop canopy.

Table 4. Effect of different hollow cone nozzles on area covered by spray

Particulars	*Percentage of area covered from*		*Difference*	*Tukey's HSD at 5% level*
	HCN-80250	*HCN-80450*		
Front-side of leaves	*11.46*	*12.95*	*1.49*	*1.79*
Back-side of leaves	*3.17*	*4.35*	*1.18*	*0.78*
On soil surface	*9.19*	*15.04*	*5.85*	*2.58*
Ratio of coverage on plant to soil	*1.74*	*1.30*	*0.44*	*0.30*
Ratio of coverage on back-side to front-side of leaves	*0.28*	*0.36*	*0.08*	*0.09*

Effect of air supply on area covered by spray in soybean crop

Providing air assistance during spraying of liquid significantly improved the deposition of spray on leaf surface as well as the penetration of spray into crop canopy but it also increased the deposition of sprayed droplets to soil. It was also observed that the ratio of area covered on plants to soil was significantly increased with provision of air supply but it had no significant effect on the ratio of area covered on backside to front side of leaves (Tab. 5).

Table 5. Effect of air supply on area covered by spray

Particulars	*Percentage of area covered*		*Diffe-rence*	*Tukey's HSD at 5% level*
	Without air supply	*With air supply*		
Front-side of leaves	*9.14*	*15.28*	*6.14*	*1.79*
Back-side of leaves	*2.00*	*5.52*	*3.52*	*0.78*
On soil surface	*10.43*	*13.80*	*3.37*	*2.58*
Ratio of coverage on plant to soil	*1.17*	*1.87*	*0.70*	*0.30*
Ratio of coverage on back-side to front-side of leaves	*0.29*	*0.36*	*0.07*	*0.09*

Effect of different travel speed on area covered by spray in soybean crop

Travel speed was found to be significantly affecting the area covered by droplets on soil and penetration of spray into the plant canopy. It was observed that reduction of forward speed to 1.5 $km \cdot h^{-1}$ significantly increased the coverage on both sides of the leaves. But it also increased the droplets reaching on soil due to enhanced exposure time. The results revealed that increasing the forward speed up to 3.5 $km \cdot h^{-1}$ significantly increased the ratio of coverage on plants to soil whereas, the ratio of coverage on backside to front side of leaves was maximum at a forward speed of 1.5 $km \cdot h^{-1}$ (Tab. 6). Again, a trade-off between these two objectives should be attempted looking at the deviation from optimized value of the parameters.

Table 6. Effect of different forward speeds on area covered by spray

Particulars	*Percentage of area covered at*			*Tukey's HSD at 5% level*
	1.5 $km \cdot h^{-1}$	*2.5 $km \cdot h^{-1}$*	*3.5 $km \cdot h^{-1}$*	
Front-side of leaves	*13.64*	*12.41*	*10.57*	*2.65*
Back-side of leaves	*4.84*	*3.13*	*3.30*	*1.15*
On soil surface	*17.31*	*11.23*	*7.80*	*3.80*
Ratio of coverage on plant to soil	*1.20*	*1.46*	*1.90*	*0.45*
Ratio of coverage on back-side to front-side of leaves	*0.40*	*0.26*	*0.31*	*0.13*

It is perceived that the selection of appropriate spraying parameters i.e. nozzle type, crop growth stage, provision for air blast and forward speed of the system can reduce the spray losses to soil and improve the penetration of spray droplets into the plant canopy as well. However, it is necessary to estimate the optimized value for these two ratios at appropriate levels of selected spraying parameters to reveal the precise potential of this technology in reduction of spray losses and improving the spraying efficiency. In this direction, two linear regression equations of crop growth stage, forward speed and provision for air blast on both the ratio of area covered on plant to soil and ratio of area covered on back-side to front-side of leaves were fitted to have two linear objective functions for maximization (Tab. 7). The provision for air support was included in the model as a dummy variable which was assigned the value as 1 when air assistance was provided and zero otherwise, considering only the observations with respect to already selected hollow cone nozzle HCN-80250.

Table 7. Aggregate linear effect of different spraying parameters on dependent variables

Dependent variable	Estimates of parameters for			Coefficient of multiple determination (Adjusted R^2)	F value of the model
	Crop growth stage	Forward speed	Provision for air support		
Ratio of coverage on plant to soil	0.0062	0.3447	0.9453	0.9144	86.49***
Ratio of coverage on back-side to front-side of leaves	0.0048	-0.0163	0.0375	0.7662	27.22***

*** - Significant at 1% level

To maximize the developed equations under constrained condition to have an optimized value of dependent variables, linear programming technique following simplex algorithm was applied with three linear constraints as given below.

Maximizing:

$$Z_1 = 0.0062\, X_1 + 0.3447\, X_2 + 0.9453\, X_3 \tag{1}$$

$$Z_2 = 0.0048\, X_1 - 0.0163\, X_2 + 0.0375\, X_3 \tag{2}$$

Subjected to:

$$45 \leq X_1 \leq 80;\ 1.5 \leq X_2 \leq 3.5 \text{ and } X_3 = 1 \tag{3}$$

Where:

Z_1 [-] - ratio of coverage on plant to soil,
Z_2 [-] - ratio of coverage on back-side to front-side of leaves,
X_1 [D.A.S.] - age of crop,
X_2 [$km \cdot h^{-1}$] - forward speed,
X_3 [-] - dummy variable denoting air supply.

Table 8. Optimization of objective functions under constrained conditions

Objective	Basic variables	Coefficient of basic variables	Optimal level of activity	Optimized value of objective function
Maximization of ratio of coverage on plant to soil	Crop growth stage	0.0062	80	2.6478
	Forward speed	0.3447	3.5	
	Air supply	0.9453	1	
Maximization of ratio of coverage on back-side to front-side of leaves	Crop growth stage	0.0048	80	0.3971
	Forward speed	-0.0163	1.5	
	Air supply	0.0375	1	

The result obtained from the analysis illustrated that the maximum ratio of coverage on plant to soil was 2.6478:1 at a forward speed of 3.5 $km \cdot h^{-1}$ and the maximum ratio of coverage on back-side to front-side of leaves was 0.3971:1 at a forward speed of 1.5 km·h^{-1} with provision of air supply during spraying after 80 days from sowing (Tab. 8).

However, compromising the optimal solution by increasing the forward speed to 3.5 km·h^{-1} will reduce the value of second objective function to a sub-optimal level of 0.3645. Therefore, the system can be operated at a speed of 3.5 km·h^{-1} with provision of air supply to achieve the prime objective of reducing spray deposit on soil surface without losing the penetration capability of the spray droplets to reach on both sides of the leaves.

CONCLUSIONS

Therefore, the objective of minimizing the spray losses to soil in soybean crop can be achieved if spraying of insecticide is carried out using a suitable hydraulic sprayer fitted with HCN-80250 nozzle and blower of suitable size for air supply at a later stage of growth with a travel speed of 3.5 km per hour for ensuring higher field capacity without any significant reduction in coverage of the spray droplets on both sides of the leaves.

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SMANJENJE TROŠKOVA PRI PRSKANJU SOJE (*GLYCINE MAX* L.) OPTIMIZACIJOM RADNIH PARAMETARA

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Sažetak: Pskanje hemijskih sredstava za zaštitu bilja se široko primenjuje za smanjenje gubitaka koje uzrokuju insekti, štetočine i bolesti. Ipak, nepravilna upotreba pesticida ugrozila je životnu sredinu, posebno zagađenjem zemljišta. Primena pesticide i njihovo taloženje na ciljnoj površini privuklo je mnogo pažnje na unapređenje efikasnosti prskanja. Veliki broj faktora utiče na taloženje pesticide na površinu biljke i njihove gubitke u zemljištu. Ovi faktori uključuju, kako morfološke karakteristike lista, tako i radne parametre prskanja. Među radnim parametrima, na efikasnost prskanja i gubitke u zemljište utiču: tip mlaznice, pritisak, dimenzije kapljice, brzina kretanja itd. Stanje porasta useva takođe utiče na efikasnost prskanja. Ovim istraživanjem je utvrđeno da je prskanje insekticida odgovoarajućim hidrauličkim rasprskivačem sa mlaznicama HCN-80250, uz dodatno snabdevanje vazduhom, u naprednom stanju porasta useva i pri radnoj brzini od 3.5 $km \cdot h^{-1}$ obezbedilo minimalne gubitke kroz zemljište pri zaštiti soje. Uz to, postignuta je značajno veća površina pokrivena kapljicama, na obe strane lista.

Ključne reči: *gubici pri prskanju, mlaznica, pokrivenost sprejom, stanje porasta useva, soja*

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MATHEMATICAL MODELING OF PHYSICAL PROPERTIES OF INDIAN MANGOES USING IMAGE PROCESSING METHOD FOR MACHINE VISION SYSTEMS

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***Abstract*:** Mathematical modeling study was carried out with the measured physical properties of two varieties of Indian mangoes as a function of projected area (P_{ip}) calculated using image processing technique. Three models viz. linear, quadratic and cubic were explored. Quadratic model was found to be best suitable to predict weight, volume, surface area, geometric and arithmetic mean diameter with higher accuracy (R^2>0.95). At the same time length (L), width (W) and thickness (T) could not be predicted effectively (R^2<0.90) using projected area (P_{ip}) computed by image processing. These findings would be more useful in machine vision especially in grading and sorting of mango fruits using image processing techniques.

***Keywords*:** *mathematical modeling of mango, mathematical modeling for machine vision, physical properties of mango, image processing of Indian mangoes*

INTRODUCTION

In India, Mango (*Mangifera indica* L.) is called as king of fruit and it has great demand in world market due to its distinct taste, flavor and color. It is being consumed in fresh as well as processed form worldwide. India is one of the major mango producing country and exports fresh mangoes and processed products to more than 50 countries. Commercially mango fruits are being utilized for the production like pickles, chutney or

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mango sauce, *amchoor* (raw mango powder) and green mango beverage (*panna*), making pulp, juice, nectar, squash, mango leather, frozen and canned slices, jam, ready-to-serve beverages, mango puree, mango cereal flakes, mango powder, mango toffee and mango fruit bars

Though the mango processing on large scale is being carried out for past few decades, very few processes were automated like pulping, thermal processing and packing. The cleaning and grading of mangoes based on quality parameters are still carried out either semi automatically or manually. Since its heterogeneous nature, quality evaluation is very much labor intensive, tedious and it needs skilled & trained personnel. In spite of the many possibilities offered by new technologies to accurately measure the quality characteristics, human beings are more flexible and adaptable to evaluate the agricultural products than machines.

Automatic fruit sorting is an emerging area. Sorting of fruits based on color would be appropriate. Marković *et al*. [12] discussed new technologies in fruit color sorting. In designing of automatic machineries for handling, grading, and sorting *etc*. of agricultural produces, the knowledge of physical properties like weight, volume, surface area, bulk density, *etc*., are needed and hence investigating the relationship among them is very essential [8]. Quality prediction is made easy by determining correlation among these physical properties [5]. The prediction of any physical properties from other properties were reported by many researchers for many crops.

Previously mass of an orange was predicted from its projected area, mass grading is possible by knowing the relationship between weight and the diameter and also it is gaining importance and recommended for the irregular shaped products. Fruits with large length to diameter ratio were separated based on the sizing equation.

Projected and surface area are necessary to evaluate the heat transfer rate, respiration rate, water loss, gas permeability, quantity of pesticide applied and ripeness index [2,10,20,21]. Relationship between volume and surface area, mass, diameter and surface area [6,8,14] were studied and empirical equations were developed for different agricultural produces. Eleven models were recommended to predict mass of an apple based on geometrical attributes [18].

Models were developed for sizing of the different fruits based on the relationship between mass, volume, projected area and length. In case of correlation analysis, high correlations were obtained between mass and volume of Iranian grown potatoes and all varieties of kiwi fruit [11]. R. Ghabel *et al.* [3] described the relationship between weight and geometrical mean diameter. Surface area and volume modeling of different shaped fruits can be measured by estimating three mutually perpendicular axes [1].

Using these modeling studies, manual grading systems could be effectively replaced with the help of digital image processing and machine vision system. Digital image processing is one of the promising tools used for industrial automation to predict the external as well as internal quality parameters. Many researchers [16,17,19] reported that the image processing would be a rapid and non-destructive method and one of the best alternatives for grading of fruits and vegetables compared to the regular mechanical grading since they are highly heterogeneous in nature.

However, very limited studies were reported on predicting physical properties of fruits by image processing technique. Volume of the watermelon [9] cantaloupe [15] and orange [7] were estimated by the earlier researchers using image processing technique. Moreda *et al.* [13] reviewed about different electronic-based approaches used for horticultural produce size estimation with emphasis on the dimensional approaches. But the scientific reports about the prediction of many physical parameters using image processing is almost nil. Hence a study was conducted to develop models to predict physical properties like length, width, thickness, volume, surface area, weight, geometrical mean diameter *etc*., for Indian mangoes by image processing technique.

MATERIAL AND METHODS

Sample collection. Raw mangoes viz. Alphonso and Banganapalli were harvested at 100-105 *DFFB* (days from full bloom) from the University orchard and desapping were done in the field itself. Mangoes were arranged in single layer with proper cushioning in a plastic crates and transported to lab. Fully matured mangoes, free from bruises and debris were sorted manually. Thirty raw mangoes in each variety were selected randomly and their physical properties were evaluated at atmospheric temperature of 28 ± 2°C and R.H of 55%.

Physical properties measurement. Weight (M) of the mango was measured using an electronic balance (Ohaus corporation, pine brook, USA) with an accuracy of 0.01 g. Platform scale method was adopted for measuring true volume or actual volume (V). The length (L) width (W) and thickness (T) of the mango were measured using a digital vernier caliper (Mitutoyo digimatic caliper, Japan) with an accuracy of 0.01 mm. The width (W) and thickness (T) which are perpendicular to each other were measured at the middle portion of mango. Geometric mean diameter (D_g) and arithmetic mean diameter (D_a) was calculated using Eq. (1 and 2).

$$\mathrm{D_g} = \sqrt[3]{\mathrm{LWT}} \quad (1)$$

$$\mathrm{D_a} = \frac{LWT}{3} \quad (2)$$

Projected area (P_g) and surface area (S_g) were calculated using graphical method. Projected area was calculated by tracing the whole fruit at natural rest position in a graph paper and then the number of squares was counted. Similarly, the surface area (S_g) was calculated by placing its peel and tracing in the graph.

Imaging chamber. Shade free image capturing chamber was made with the dimension of 20"x20"x18" (Fig.1).

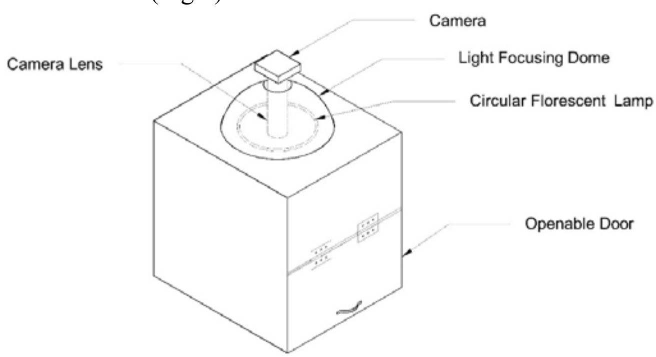

Figure 1. Schematic diagram of image capturing setup

The internal wall surface was made with light reflecting surface. *DSLR* camera (Nikon D60) equipped with *CMOS* sensor was fixed on the top center of the chamber. The circular florescent lamp was fixed concentrically with the camera lens along with the focusing arrangement in order to get proper lighting. Mango fruits were placed in its natural rest position on the flat platform with black background. All the images were taken at constant light intensity (820 lux), constant focal length and constant exposure value.

Image processing. The captured images were transferred to the computer and image processing was done using MATLAB (The Math Works, Inc., USA). The captured color images were converted into gray scale image. Threshold technique and morphological operations were done to separate the region of interest (*ROI*) from the background (Fig. 2) and to calculate the number of pixels inside the *ROI*, respectively. Object with known area was kept during image capturing as a reference in-order to convert the no. of pixel into area. The projected area (P_{ip}) was calculated by converting the number of pixels into real time value (area) using this reference.

Statistical analysis and mathematical modelling. Statistical analysis was done in Microsoft Excel and the mathematical modeling in MATLAB R2007a. Three models *viz.* linear, first order (quadratic) and second order (cubic) polynomials were used to develop a relation between projected area (P_{ip}) and other physical properties.

The mathematical modeling of physical properties were carried out with the following regression equations.

$$\text{Linear model: } f(x) = a*x + b \quad (3)$$

$$\text{Quadratic model: } (2^{nd} \text{ order}): f(x) = a*x^2 + b*x + c \quad (4)$$

$$\text{Cubic model } (3^{rd} \text{ order}): f(x) = a*x^3 + b*x^2 + c*x + d \quad (5)$$

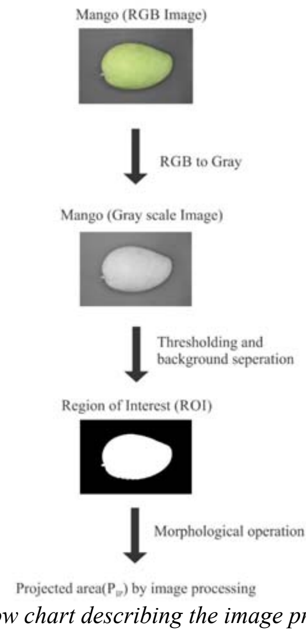

Figure 2. Process flow chart describing the image processing technique

In these models '*x*' denotes the project area by image processing (P_{ip}). The regression models were limited to third order polynomial in order to reduce the robustness and complexity in calculations and prediction. The prediction of projected area by graph (P_g) was done with the project area by image processing (P_{ip}) in order to validate the models and the whole methodology. Then other physical properties were modeled the P_{ip} was correlated with using image processing.

RESULTS AND DISCUSSION

The measured physical properties for two varieties of mangoes were statistically analyzed for its mean, standard deviation (*SD*) and coefficient of variance (*CV*) and given in Tab. 1.

Table 1. Physical properties of mangoes

Parameters	Alphonso				Bangapalli			
	Mean	SD	SE	CV	Mean	SD	SE	CV
PA [cm^2]	53.16	3.56	0.71	6.69	75.90	15.55	2.63	20.48
Weight [g]	256.20	28.22	5.64	11.01	353.49	78.71	13.30	22.27
Volume [cm^3]	256.33	32.15	6.43	12.54	351.74	81.89	13.84	23.28
L [cm]	9.38	0.35	0.07	3.77	11.63	1.33	0.22	11.42
W [cm]	7.18	0.20	0.04	2.79	8.23	0.74	0.12	8.96
T [cm]	6.77	0.34	0.07	5.00	6.82	0.31	0.05	4.48
Size (D_g) [cm]	7.70	0.31	0.06	3.98	8.67	0.68	0.11	7.81
D_a, [cm]	7.79	0.31	0.06	3.95	8.90	0.76	0.13	8.53
SA [cm^2]	192.65	13.93	2.79	7.23	185.93	57.17	9.66	30.75

In all physical properties, Banganapalli was found higher than Alphoso mangoes. The weight of the fruit was found to be 256.20±28.22 g and 353.49±78.71 g and the volume of the fruits was around 256.33±32.15 cm^3 and 351.74±81.89 cm^3 for Alphonso and Banganapalli respectively. The length (*L*), width (*W*) and thickness (*T*) were found to be 9.38±0.35 cm, 7.18±0.20 cm and 6.77±0.34 for Alphonso and 11.63±1.33 cm, 8.23±0.74 cm, 6.82±0.31 cm for Banganapalli respectively. The size of the fruits (geometrical mean diameter) were 7.70±0.31 and 8.67±0.68 for Alphonso and Banganapalli respectively. These dimensions are important in determining the aperture size of the sorting machines and also helpful in applying shear force during slicing and processing.

Table. 2. Regression models to predict the physical properties of Alphonso using image processing technique

	Regression coefficients				Goodness of fit			
	a	b	c	d	R^2	Adj. R^2	RMSE	χ^2
Projected area by graph (P_g)								
Cubic	139.86	-4.22	0.06	-0.0002	0.99	0.99	0.44	0.19
Quadratic	28.60	0.16	0.00		0.99	0.99	0.43	0.19
Linear	17.73	0.45			0.99	0.98	0.44	0.19
Surface area								
Cubic	-791.23	39.76	-0.56	0.00265	0.98	0.98	2.02	4.07

Quadratic	401.89	-7.28	0.06		0.98	0.98	2.10	4.42
Linear	59.14	1.69			0.91	0.91	4.21	17.74
Mass								
Cubic	-2088.85	89.64	-1.18	0.00536	0.97	0.97	5.08	25.82
Quadratic	326.17	-5.56	0.06		0.97	0.97	5.23	26.46
Linear	-20.04	3.50			0.95	0.95	6.37	37.62
Volume								
Cubic	-2572.10	106.45	-1.38	0.00615	0.98	0.98	4.85	23.49
Quadratic	199.37	-2.80	0.04		0.98	0.98	5.04	26.03
linear	-61.25	4.02			0.97	0.97	5.82	33.83
Length								
Cubic	30.22	-0.96	0.01	-0.0001	0.95	0.94	0.09	0.01
Quadratic	2.74	0.13	0.00		0.94	0.94	0.09	0.01
linear	5.95	0.04			0.93	0.93	0.09	0.01
Width								
Cubic	-36.04	1.70	-0.02	0.0001	0.87	0.86	0.08	0.01
Quadratic	8.55	-0.06	0.00		0.84	0.82	0.08	0.01
linear	5.37	0.02			0.81	0.80	0.09	0.01
Thickness								
Cubic	-18.44	0.94	-0.01	0.0001	0.87	0.85	0.13	0.02
Quadratic	6.09	-0.02	0.00		0.86	0.85	0.13	0.02
linear	3.62	0.04			0.86	0.85	0.13	0.02
D_a								
Cubic	-33.78	1.60	-0.02	0.0001	0.91	0.91	0.09	0.01
Quadratic	8.23	-0.05	0.00		0.91	0.90	0.10	0.01
linear	4.80	0.04			0.89	0.89	0.10	0.01
D_g								
Cubic	-29.63	1.44	-0.02	0.0001	0.91	0.91	0.09	0.01
Quadratic	8.22	-0.05	0.00		0.91	0.90	0.10	0.01
linear	4.86	0.04			0.90	0.89	0.10	0.01

Table. 3. Regression models to predict the physical properties of Banganapalli using image processing technique

	Regression coefficients				Goodness of fit			
	a	b	c	d	R^2	Adj. R^2	RMSE	χ^2
Projected area by gra. (P_g)								
Cubic	179.24	-4.95	0.06	-0.00018	0.99	0.99	1.61	2.61
Quadratic	-9.03	0.66	0.002		0.99	0.99	1.64	2.73
linear	-33.82	1.16			0.99	0.99	1.67	2.82
Surface Area								
Cubic	251.38	-6.41	0.07	-0.0001	0.99	0.99	5.29	27.99
Quadratic	117.30	-2.41	0.03		0.99	0.99	5.23	27.34
linear	-218.39	4.26			0.98	0.98	8.79	77.33
Mass								
Cubic	767.96	-20.36	0.23	-0.00065	0.98	0.98	10.71	114.73
Quadratic	69.91	0.44	0.03		0.98	0.98	10.80	116.04
linear	-202.23	5.86			0.98	0.98	12.16	147.77
Volume								
Cubic	-184.31	9.01	-0.07	0.00035	0.99	0.99	8.76	76.72

Quadratic	*192.42*	*-2.22*	*0.04*		*0.99*	*0.99*	*8.73*	*76.29*
linear	*-224.00*	*6.06*			*0.98*	*0.98*	*12.33*	*152.15*
Length								
Cubic	*36.06*	*-0.87*	*0.01*	*-0.00003*	*0.95*	*0.94*	*0.32*	*0.10*
Quadratic	*5.90*	*0.03*	*0.0003*		*0.94*	*0.94*	*0.34*	*0.11*
linear	*2.45*	*0.10*			*0.94*	*0.93*	*0.34*	*0.12*
Width								
Cubic	*-3.42*	*0.25*	*-0.002*	*0.00001*	*0.92*	*0.91*	*0.23*	*0.05*
Quadratic	*2.96*	*0.06*	*-0.00003*		*0.91*	*0.90*	*0.23*	*0.05*
linear	*3.28*	*0.05*			*0.91*	*0.91*	*0.22*	*0.05*
Thickness								
Cubic	*-10.72*	*0.50*	*-0.005*	*0.00002*	*0.82*	*0.81*	*0.14*	*0.02*
Quadratic	*6.73*	*-0.02*	*0.0002*		*0.78*	*0.77*	*0.15*	*0.02*
linear	*4.89*	*0.02*			*0.77*	*0.76*	*0.15*	*0.02*
Da								
Cubic	*2.78*	*0.10*	*-0.001*	*0.00003*	*0.99*	*0.99*	*0.07*	*0.01*
Quadratic	*5.63*	*0.02*	*0.0002*		*0.99*	*0.99*	*0.07*	*0.01*
linear	*3.88*	*0.05*			*0.99*	*0.99*	*0.08*	*0.01*
Dg								
Cubic	*8.79*	*-0.08*	*0.001*	*-0.00003*	*0.99*	*0.99*	*0.08*	*0.01*
Quadratic	*5.40*	*0.02*	*0.0002*		*0.99*	*0.99*	*0.08*	*0.01*
linear	*3.53*	*0.06*			*0.99*	*0.99*	*0.09*	*0.01*

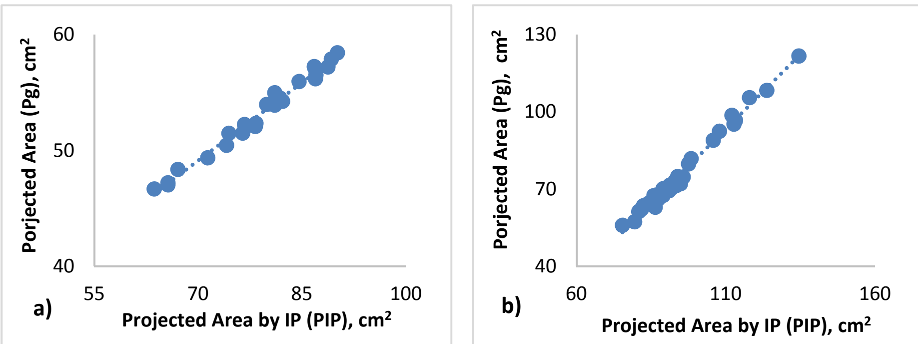

Figure 3. Linear relationship between projected area by graphical method and projected area by image processing method. (a) Alphonso mangoes (b) Banganapalli mangoes

Mathematical modeling. The results of the mathematical modeling viz. model coefficients, coefficient of determination, *RMSE* and chi-square values of physical properties were shown in the Tabs 2 and 3 for both the varieties. The predicted physical properties *viz*. length, width, thickness, weight, volume, surface area, geometrical mean diameter and arithmetical mean diameter were compared with the actual/observed values for computing Root Mean Square and chi-square (goodness of fit) value. Only better predicted models which has higher r^2 and adjusted r^2 values and lower *RMSE* and chi-square values were plotted and shown in Figs 3-7. For selection of better models, the higher weight was given to r^2 followed by *RMSE* then by χ^2 values.

Modelling of spatial parameters. The projected area (P_g) had shown linear relationship with P_{ip} with the R^2 value of 0.99 (Tabs 2, 3). This confirms that the image processing technique can be effectively used to predict the projected area (P_g) with lowest error for both varieties (Fig. 3). In case of *RMSE* and chi-square values, very negligible difference were observed between quadratic and cubic model for Alphonso. Quadratic model had shown higher r^2 value, lower *RMSE* and chi-square values for Banganapalli. So surface area can be better predicted using projected area (P_{ip}) with quadratic model for Alphonso and Banganapalli mangoes which has sown in Fig. 4.

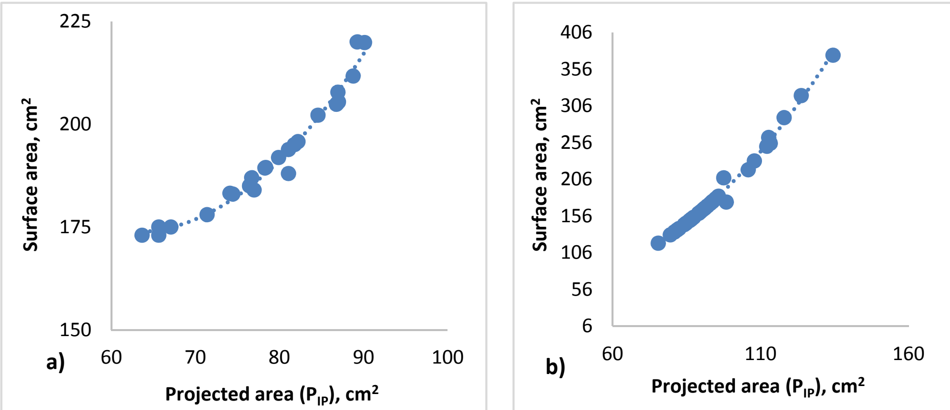

Figure 4. Quadratic relationship between surface area by graphical method and projected area by image processing method. (a) Alphonso mangoes (b) Banganapalli mangoes.

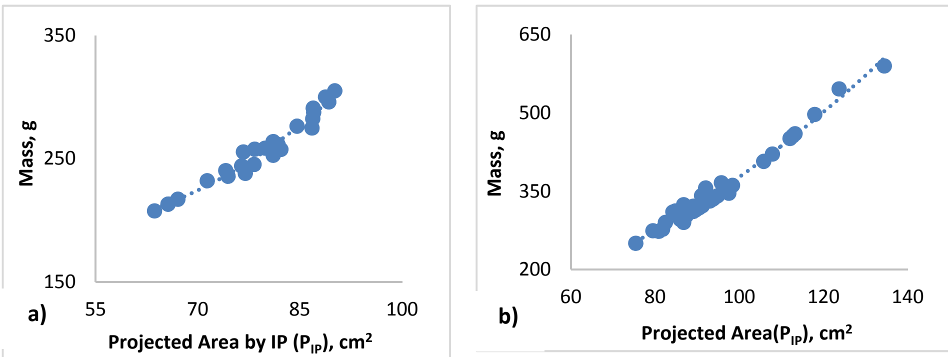

Figure 5. Quadratic relationship between mass of individual fruits and projected area by image processing method. (a) Alphonso mangoes (b) Banganapalli mangoes

Modelling of weight and volume. All the three models had shown good r^2 values (above 0.90) for both weight and volume. In mass modelling, the cubic and quadratic model had shown same r^2 values and cubic model had shown lower *RMSE* and chi-square value for both varieties.

Since the difference between the goodness of fit characteristics of quadratic and cubic model were negligible, moreover to avoid further complication in modelling, quadratic models could be chosen to predict weight of fruits using P_{ip}. Similarly, quadratic model would be more suitable to predict volume since it has lower *RMSE* and chi-square value for both varieties. Selected models were plotted and shown in Figs. 5,6.

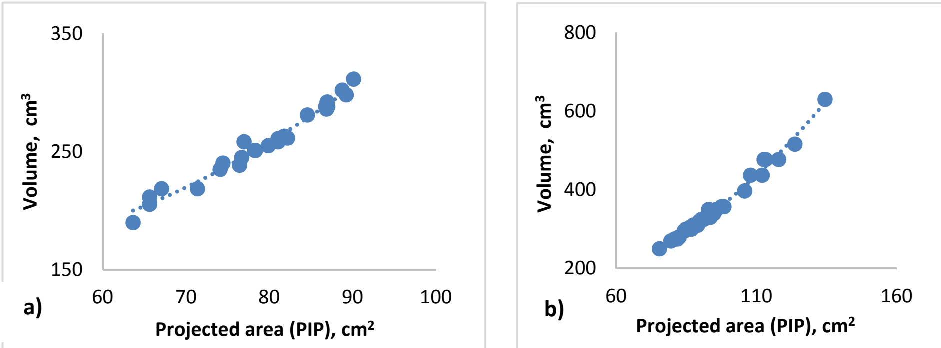

Figure 6. Quadratic relationship between volume of individual fruits and projected area by image processing method. (a) Alphonso mangoes (b) Banganapalli mangoes.

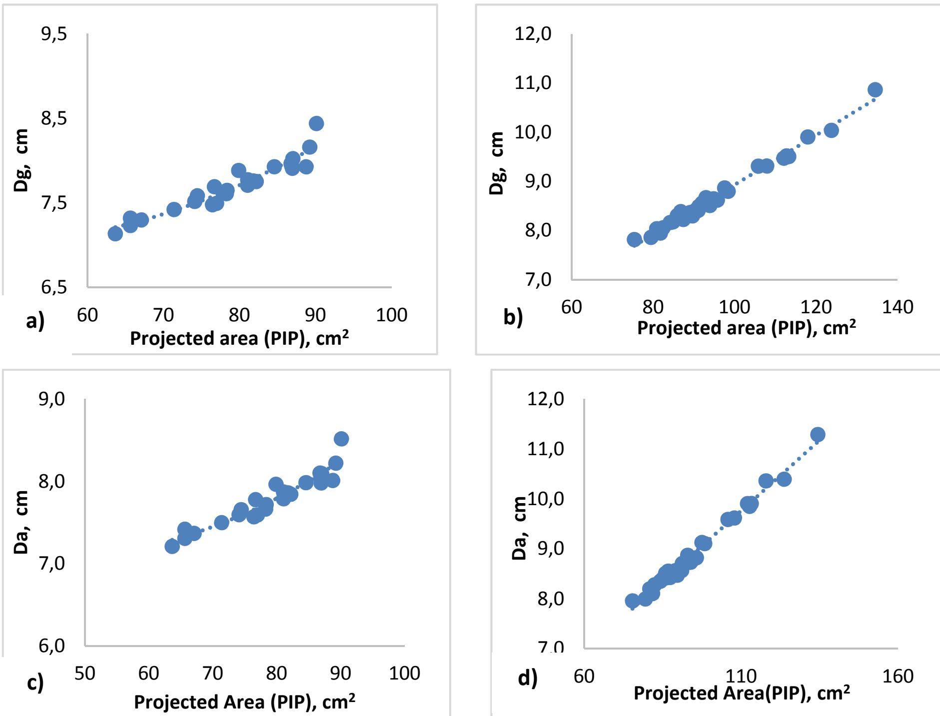

Figure 7. Quadratic relationship between geometrical parameters and projected area by image processing method. (a) and (c) Alphonso mangoes (b) and (d) Banganapalli mangoes

Modelling of geometrical parameters. Among the L, W and T, better prediction using P_{ip} was found in length of the fruit followed by width in both varieties. The thickness of Banganapalli fruits may not be predicted better using P_{ip} since it had shown lower r^2 values (< 0.8) than Alphonso fruits. Predicting the third dimension of mango from the two dimensional image may lead to poor prediction and this may be the reason for poor prediction of thickness of both fruit varieties. As reported by M. Hryniewicz and others

[4], this can be eliminated by passive 3-D machine vision technique using two camera with 90 degree view angle difference. Then both the images can be interpreted to find out the three geometrical parameters (*L,W,T*) effectively.

The second order polynomial (cubic) relations for length, width and thickness with P_{ip} can be used. To overcome this complication, prediction of size (D_g) or arithmetic mean diameters (D_a) of the fruit using P_{ip} would be more appropriate. From the results, higher r^2 values (>0.98) was observed for prediction of D_a and D_g in case of banganapalli mangoes using P_{ip}. At the same time, comparatively lower r^2 value (0.91) were observed for D_a and D_g for Alphonso mangoes. Among geometrical parameters, better prediction would be achieved for length followed by D_a and D_g for Alphonso mangoes. It may be due to sphericity of the mangoes (sphericity were found as 0.83 and 0.70 for Alphonso and banganapalli respectively). Thus, it can be concluded that more spherical shaped fruit leads to poor prediction of geometrical parameters using P_{ip}. In case of banganapalli, no much differences were observed between goodness of fit parameters among the three models (Tab. 3) while predicting the D_a and D_g. So simple linear model may be chosen to predict D_a and D_g which had higher r^2 value (0.99) and lower *RMSE* and chi-square values. The relationship between D_a and D_g to P_{ip} were plotted and given in Fig. 7.

CONCLUSIONS

The physical properties like spatial parameters, geometrical parameters, weight and volume were measured for two varieties of mango. Image processing technique was used to calculate projected area (P_{ip}) of whole fruit. Then the mathematical modeling of physical properties of Alphonso and banganapalli was performed as a function of projected area (P_{ip}). Three models were explored and the suitable model was selected based on coefficient of determination, root mean square error and chi square value. This study revealed that most of the commercially important properties like weight, surface area, geometric mean diameter and true volume were predicted with higher accuracy ($R^2>0.90$). At the same time length (*L*), width (*W*) and thickness (*T*) could not be predicted effectively ($R^2<0.90$) using projected area (P_{ip}) computed by image processing. These findings would be more useful and suitable for process automation especially in grading and sorting of mango fruits using machine vision and image processing techniques.

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MATEMATIČKO MODELIRANJE FIZIČKIH OSOBINA INDIJSKOG MANGA KORIŠĆENJEM METODA OBRADE SLIKE ZA MAŠINSKU VIZUELIZACIJU

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***Sažetak*:** Istraživanje matematičkog modeliranja je izvedeno sa izmerenim fizičkim osobinama dva varijeteta indijskog manga, kao funkcija projektovane površine (P_{ip}) izračunate tehnikom obrade slike. Istraživana su tri modela: linearni, kvadratni i kubni. Kvadratni model je bio najbolje prilagođen za predviđanje mase, zapremine, površine, geometrijskog i aritmetičkog srednjeg prečnika, sa najvišom tačnošću (R^2>0.95). Istovremeno, dužina (L), širina (W) i debljina (T) se ne mogu efikasno predvideti (R^2<0.90) upotrebom projektovane površine (P_{ip}) izračunate obradom slike. Ovi zaključci bi bili korisniji za mašinsku vizuelizaciju, posebno pri gradiranju i sortiranju plodova manga upotrebom tehnika obrade slike.

***Ključne reči*:** *matematičko modeliranje manga, matematičko modeliranje za mašinsku vizuelizaciju, fizičke osobine manga, obrada slike indijskog manga*

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MATHEMATICAL MODELING FOR DRYING OF WHOLE LEAF ALOE VERA (*ALOE BARBADENSIS* MILLER)

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Abstract: The present work aimed to study the effects of different drying methods in terms of drying behavior, drying rate and mathematical modelling of drying process for whole leaf Aloe vera. Open yard sun drying, hot air drying and dehumidified air drying were taken as different drying methods. The whole leaf Aloe vera slices took 20 h to dry under open yard sun drying, 16 h in case of hot air drying, 11 h in dehumidified air drying having initial moisture content ranging from 3115.43% (d.b.) to a final moisture content of 8.6% (d.b.). The different thin layer drying models were applied on the experimental moisture loss data with respect to time to predict the drying pattern properly. On the basis of coefficient of determination (0.9764) and standard error (0.0552), the Page model showed better fit.

Key words: *Aloe vera, dehumidified air drying, hot air drying, open yard drying, drying time*

INTRODUCTION

The Aloe plant (*Aloe barbadensis* Miller) belongs to a member of the family Liliaceae. Total production of aloe in India is estimated to be about 1.00.000 tons [1]. And the annual consumption of aloe extract by Indian pharmaceutical industries is 200 tonnes [2]. There are many industries now concentrated only on processing of Aloe vera

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and earning profit to a remarkable level. Potential use of aloe products often involves some type of processing, e.g. heating, dehydration and grinding [3]. In recent times, whole leaf Aloe vera powder has attracted much attention and is presented by manufactures as providing extra benefits [4]. With increasing demand for herbal cure and cosmetics, there is good prospect for its large-scale production, processing and marketing. Since negligible research work has been reported on Aloe vera, it was decided to study the method to increase the quality of whole leaf Aloe vera powder.

Dehydration is an important unit operation in chemical and food processing industries. Several phenomena related to heat and mass transfers are involved in the dehydration process [5]. The main purpose of drying is to decrease the water activity, inhibiting the development of microorganisms, decreasing spoilage reaction, longer periods of storage, minimize packaging requirements and reduce shipping weights [6]. Today, the whole leaf approach is adding new dimensions to the properties of this remarkable plant. [7]. Owing to the increased preference to herbal cosmetics and cosmaceuticals, the demand for Aloe vera is on the rise every year. It is definitely a crop highly suitable for growing in many parts of India. Controlled drying might also lead to an overall improvement in the quality of the final product. Therefore, the use of different dryers such as freeze dryer, hot air dryer, dehumidified air dryer etc. at optimized condition, is considered to improve the shelf-life compared to liquid products and to eliminate the cost of shipping water.

The different drying processes may cause irreversible modifications to active substances, affecting their original structure, which may promote important changes in the proposed physiological and pharmacological properties of these components [8]. So under factual state of affairs the use of non-standardized processing techniques to obtain aloe powder may fetch poor quantitative and qualitative availability of bioactive compounds in the marketable aloe product. The loss of biological activity at different stages of processing and storage should be studied to ensure the maximum retention of active compounds. Unfortunately, because of improper processing procedures, many of these so-called aloe products contain very little or virtually no active ingredients, namely mucopolysaccharides [9]. In view of the importance of biological activities possessed by the leaves of the Aloe vera, it is necessary that the leaf should be processed with the aim of retaining essential bioactive components. In this respect, a proper processing techniques need to be developed to ensure the biological integrity in the final product. At present, very little is known about the effect of drying method on the quality of aloe leaf in its dried form [10]. So it is important to have a systematic study on the Aloe vera for devising suitable processing method giving longer storage stability and satisfying regional palate.

MATERIAL AND METHODS

Aloe vera leaves of 3-year old were purchased from the "North Karnataka Medicinal and Aromatic Plant Growers' Association" situated in Gadag of North Karnataka, India. The leaves were washed and scrubbed to remove mud, adhering material, sand and bitter exudates on the rind surface. After washing, the leaves were weighed and trimmed using a knife. Trimming was done by cutting the base of the leaves with approximate 25 mm, tip with 30 mm and the sides with 10 mm. The trimmed leaves were cut into slices with approximate 15 to 50 mm thickness and dried in different drying methods. Three different dryers were used for drying, i.e. hot air drying at 50ºC, dehumidified air drying at 55ºC and 18% RH and open yard sun drying.

Mathematical modeling. The moisture contents of Aloe vera slices during the xperiments were expressed in dimensionless form as moisture ratios (*MR*) with the help of the following equation [11,12]. The mathematical models *viz*., Newton, Page and Henderson-Pabis models were selected for fitting the experimental data and these selected models were best models to describe the drying curve equation of whole leaf Aloe vera slices during drying. These are explained here under.

$$\text{Newton model: } MR = \exp(-K\theta) \tag{1}$$

$$\text{Page model: } MR = \exp(-K\theta\ n) \tag{2}$$

$$\text{Henderson- Pabis model: } MR = a*\exp(-K\theta) \tag{3}$$

where:

MR [-] moisture ratio.

$$MR = \frac{M - M_e}{M_o - M_e} \tag{4}$$

where:

M_e [%] - equilibrium moisture content (d.b.),
M [%] - moisture content at any time θ (d.b.),
M_o [%] - initial moisture content (d.b.),
K,n,a [-] - constants,
Θ [min] - drying time.

The constants of the selected models were estimated by non-linear regression [13] and the parameters of all the models were estimated by using MATLAB version 7.0 software package. The fit quality of the proposed models on the experimental data was evaluated using linear regression analysis using curve fitting tool in MATLAB 7.0.

Statistical analysis. The goodness of fit of different models under different drying methods was evaluated based on values of coefficient of determination (R^2) and the model was characterized by root mean square error (*RMSE*), coefficient of determination (R^2) and sum of square error (*SSE*). These parameters can be calculated as follows.

$$RMSE = \sqrt{\frac{\sum_{i=0}^{N}\left(MR_o - MR_p\right)}{df}} \tag{5}$$

$$SSE = \frac{1}{N}\sum_{i=1}^{N}\left(MR_o - MR_p\right)^2 \tag{6}$$

where:

MR_o [-] - observed moisture ratio,
MR_P [-] - predicted moisture ratio,
Df [-] - degrees of freedom,
N [-] - No. of data points,
Z [-] - No. of constants.

RESULTS AND DISCUSSION

Drying characteristics. The reduction in moisture content of whole leaf Aloe vera dried under open yard sun drying, hot air drying and dehumidified air drying were recorded (Fig. 1 and 2). The whole leaf Aloe vera sample took 20 h to dry the sample under open yard sun drying having initial moisture content from 3115.43% (d.b.) to a final moisture content of 8.66% (d.b.), respectively. In this drying, temperature depends on the climatic conditions of the day. Open yard sun drying is widely practiced in tropical countries, but the method is extremely time-consuming, weather dependent and has the problem of contamination, infestation and microbial attack [14].

In case of hot air drying, the moisture content of whole leaf Aloe vera slices was decreased from 3115.43% (d.b.) to 8.61% (d.b.) in 16 hours at 50°C. As the temperature increased, the drying time decreased. The present results are similar to the findings reported by [5] who reported the variation of moisture content as a function of time. At a temperature of 50 °C in convective dryer, the time required for drying at 50°C was 800 min. [5] reported about the drying of Aloe vera slab at 60°C with initial moisture content of 69.23±1.13 g water·g d.m^{-1} and concluded that the drying curve showed a clear tendency of equilibrium moisture content of 0.071±0.002 g water·g d.m^{-1}. The results of hot air dried whole leaf Aloe vera were also similar to the results of [15] who reported that a drying temperature of 60-70°C resulted in production of high quality gel.

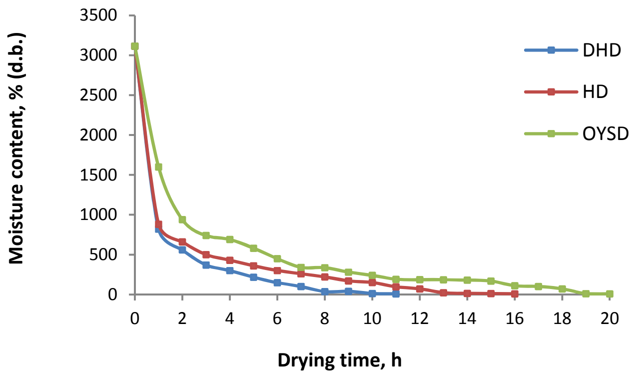

Figure 1. Moisture content variation of whole leaf Aloe vera slicesin different drying methods

In dehumidified air drying method, the moisture content of whole leaf Aloe vera slices was decreased from 3115.43% (d.b.) to 8.57% (d.b.) in 11 hours at 55±1°C and 18±1% RH. The result are in agreement with the findings of [11] using dehumidified air drying of Aloe vera inner gel at optimum temperature of 64°C and 18% RH and at air velocity of 0.8 m·s^{-1}. Similar results were found by [16]; [5]; [17]; and [8], working with kale, red bell pepper, various vegetables and kiwis, respectively.

The drying rate was calculated as quantity of moisture removed per unit time per unit dry matter. It can be seen that drying process mainly consisted of three drying periods i.e., heating up, constant rate and falling rate period. While in hot air drying at temperature of 50°C showed only the falling rate period which was due to moderate temperature of drying. In hot air drying, the drying rate period started from 47.04 to 0.04% (d.b.) min^{-1} at 50°C. [5] also reported that in hot air drying process of products of vegetal origin, the constant rate period was not observed and there was a marked falling rate period due to quick moisture removal from samples.

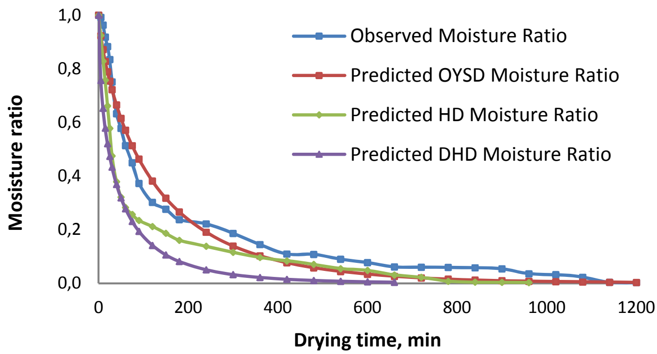

Figure 2. Experimental and Page model predicted moisture ratio for different drying methods of whole leaf Aloe vera

In dehumidified air drying process at temperature of 55±1°C and 18±1% RH only falling rate period was detected and the drying rate was observed from 65.09 to 0.06 per cent (d.b.) min^{-1}, due to higher temperature and lower RH of drying. Similar results were reported by [17; 18] that only falling rate period was observed in microwave drying of banana and kiwi fruit and [19] in Aloe vera gel powder. The drying rate of whole leaf Aloe vera dried under open yard sun drying at different temperatures was varied from 5.14 per cent (d.b.).min^{-1} in the initial stage of drying to 0.14 per cent (d.b.).min^{-1}. In this drying, the drying rate is mainly depends on varying drying temperature. Here temperature varies according to the climatic condition.

Mathematical modeling of drying of whole leaf Aloe vera in different drying methods. The moisture ratio versus time data were fitted to the selected thin layer drying models namely Newton, Page and Henderson-Pabis model. The model coefficients for all the three models were estimated by nonlinear regression technique using MATLAB 7.0 version software. The estimated values of statistical parameters obtained under different drying methods and varieties for these models are shown in Tab. 1 and 2. The Page model gave the best fit to the experimental data with higher R^2 value of 0. 9675 and lowest root mean square error (*RMSE*) and sum of square error (*SSE*) values of 0.051 and 0.055, respectively. Experimental and Page model predicted moisture ratio for different drying methods of whole leaf Aloe vera were shown in Fig.2. The Newton model described a poor fit to the experimental data with lowest R^2 value of 0.9239 higher root mean square error (*RMSE*) and sum of square error (*SSE*) values of 0.1381 and 0.079, respectively. These results are in good agreement with the results obtained by [5] for Aloe vera gel. These results showed positive dependence on temperature. Similar results were obtained by [10] working with grapes, kale and okra. The good fit of the experimental data using the Page model may be due to the incorporation of exponential parameter '*n*' which provides a better mathematical approximation of drying curves [5]. [21] also reported that the page model gives the best fit with high values for the coefficient of determination R^2 (0.9811-0.9859) and lower *SSE* (0.0557-0.0779) for the drying of Aloe vera gel.

Table 1. Constants of drying models

Sl. No.	Method	Newton	Page		Henderson-Pabis	
		K	K	n	K	a
1	Open yard sun drying	0.0089	0.0227	0.783	0.024	0.921
2	Hot air drying	0.0195	0.0638	0.674	5.83	0.003
3	Dehumidified air drying	0.0277	0.1040	0.613	3.60	0.025

Table 2. Estimated values of statistical parameters of Newton, Page and Henderson-Pabis models used for different drying methods

Sl. No.	Parameter	Method	Newton	Page	Henderson Pabis
1	R^2	OYSD	0.9682	0.9695	0.9682
		HD	0.9481	0.9675	0.9492
		DD	0.9239	0.9764	0.9295
2	SSE	OYSD	0.1181	0.0875	0.1181
		HD	0.1285	0.0804	0.1258
		DD	0.1381	0.0552	0.1285
3	RMSE	OYSD	0.0617	0.0540	0.0627
		HD	0.0689	0.0556	0.0695
		DD	0.0792	0.0512	0.0782

CONCLUSION

The reduction of moisture content of whole leaf Aloe vera slices took less drying time of 11 h in dehumidified air drying to dry the sample from an initial moisture content ranging from 3115.43% (d.b.) to final moisture content of 8.57% (d.b), respectively as compared to open yard sun drying and hot air drying methods. The drying rate was higher in the beginning of the drying processes and gradually reduced through the end of the drying process. Page model gave better fit to the experimental data with higher R^2 value of 0.9675 and lowest root mean square error (*RMSE*) and sum of square error (*SSE*) values of 0.051 and 0.055, respectively over the other two models.

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MATEMATIČKO MODELIRANJE SUŠENJA CELOG LISTA ALOE VERA (*ALOE BARBADENSIS* MILLER)

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Sažetak: U ovom radu su predstavljeni uticaji različitih metoda sušenja na postupak sušenja, intenzitet sušenja i matematičko modeliranje procesa sušenja celog lista Aloe vera. Sušenje na suncu, sušenje vrelim vazduhom i sušenje suvim vazduhom su ispitivani kao različiti postupci sušenja. Ceo list Aloe vera se sušio 20 h pod suncem na otvorenom, 16 h vrelim vazduhom i 11 h suvim vazduhom, sa početne vlažnosti od 3115.43% na konačni sadržaj vlage od 8.6%. Primenjeni su različiti modeli sušenja tankog sloja na eksperimantalne rezultate gubitka vlage i vremena sušenja, da bi se pravilno predvideo postupak sušenja. Na osnovu koeficijenta determinacije (0.9764) i standardne greške (0.0552), najbolje slaganje pokazao je Page model.

Ključne reči: *aloe vera, sušenje suvim vazduhom, sušenje vrelim vazduhom, sušenje na otvorenom, vreme sušenja*

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DEVELOPMENT AND EVALUATION OF A CONTINUOUS TYPE TAMARIND DESEEDER

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***Abstract**:* A continuous type tamarind deseeder with a capacity of 75 kg·h^{-1} has been fabricated and evaluated at the Department of Agricultural Process Engineering, Tamil Nadu Agricultural University, Coimbatore, India. The machine consists of a seed separation unit and separate outlets for the seeds and deseeded fruits. In the seed separation unit, the fruits were subjected to impact and simultaneous shearing force by pegs mounted on the wooden roller to break open the fruit and to push the seeds out of the oblong sieve. After deseeding, the seeds and fruit pulp were collected separately through their respective outlets. The performance of the developed machine was evaluated based on deseeding efficiency. Evaluation was done by conducting experiments at different operating conditions including different moisture content of tamarind fruit (20.0, 22.5 and 25.0% on dry basis) and varying wooden roller speed (2.5, 3.4 and 4.2 m·s^{-1}), feed rate (45, 60 and 75 kg·h^{-1}) and horizontal clearance (14, 16 and 18 mm). The test results of the machine showed that a maximum deseeding efficiency of 89.15% was found at 22.5 percent moisture content on dry basis, with the wooden roller speed of 3.4 m·s^{-1}, feed rate of 45 kg·h^{-1} and 16 mm horizontal clearance. As compared to existing manual methods of deseeding, the continuous type tamarind deseeder unit recorded 93.34 % saving in time and 74.9 % saving in operation cost.

***Key words**: Tamarind deseeder, seed separation unit, wooden roller, deseeding efficiency*

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INTRODUCTION

Tamarind (*Tamarindus indica* L.) is native to tropical Africa and is quite common in wild regions. India is the largest producer and consumer of tamarind and producing 2,75,500 tonnes of tamarind annually, and are chiefly subsistence crop for the semi-arid zones of the country. It is generally grown as avenue trees in highways, wastelands, backyards and forestlands [1].

The Tamarind tree bears pods (fruits) containing about 3-10 brown seeds surrounded by an abundant acid pulp. On an average, tamarind fruit contains 55 % pulp, 34 % seeds and 11 % shell and fibres [2]. It is valued mostly for its fruit pulp and seed which are used for a wide variety of domestic and industrial purposes. The edible pulp of a ripe fruit is used as flavouring agent in soups, jams, chutneys, sauces and juices. The fruit pulp is the richest natural source of tartaric acid and is the main acidulant used in the preparation of South Indian foods today. Tamarind juice, concentrate, powder, pickles and paste are the other well-known end products of tamarind processing.

Tamarind processing commonly includes the unit operations of drying of pods, dehulling, deseeding, pressing into cakes and storage. Traditionally, deseeding of tamarind involves manual harvesting of mature fruits which are then sun dried and then the pod is removed from the pulp by beating the dried fruit with sticks. The current practice of tamarind deseeding is to impact the vertically oriented fruits manually with a hammer or wooden mallet by women labourers. It is also deseeded by the process of hand pounding in which a stone mortar is sprayed with oil, generally castor oil, and a wooden pestle is used to exert impact load over the fruits. In some areas, a knife is used to deseed. The conventional methods followed are crude, unhygienic, labour intensive and time consuming. This drudgery can be alleviated by introducing a mechanical deseeder for tamarind [3].

There were few attempts made to deseed tamarind mechanically. The pulp-squeezing unit developed by [4] consisted of a serrated roller mounted on a Mild Steel (MS) frame. Adjoining to the roller, stationery rasp bar was provided. The tamarind was passed through the clearance between serrated roller and rasp bar to separate seed out of pulp. The main drawback is that the mechanical machine has to be stopped intermittently to scrap away the deposits of tamarind pulp over the mechanism. Three different mechanisms [5] to shear and squeeze the tamarind pulp out of seeds such as two wooden identical plain rollers, wooden rasp-bar drum with concave and metal rasp-bar drum with concave were studied. The end-product out of the machines was collapsed and the compartmental arrangement of tamarind was detached. A tamarind seed remover [3] with the principle of impact and simultaneous shear on the tamarind fruit by the pegs mounted rotor that encased with oblong sieve was developed and evaluated for its performance. The machine resulted in 82 % deseeding efficiency for small sized fruits and effective separation of seed and deseeded pulp was the main lacuna observed.

Even though there were few mechanisms studied so far, they have their own pitfalls in popularizing among the farming community. These machines cannot be operated continuously because of the sticky nature of tamarinds with the mechanisms adopted and the collapsed end product is sold at throwaway prices. Final output of the existing deseeding machines is a mixture of pulp and seed and separation of the seed out of pulp is again laborious and time consuming. With the intention of alleviating these constraints in the processing field, a tamarind deseeder was developed and evaluated at the

Department of Food & Agricultural Process Engineering, Tamil Nadu Agricultural University, Coimbatore, India. The paper deals with developmental procedure of tamarind deseeder and evaluation of the machine besides optimization of process parameters like materials used for fabrication, clearance and speed of the unit.

MATERIAL AND METHODS

Development of Tamarind Deseeder

The developed tamarind deseeder consisted of hopper, deseeding unit, outlets and power transmission system and the descriptions of each component are illustrated.

All the components of deseeder were supported over a frame made up of mild steel L - angle section of size 50 x 50 x 6 mm. It has a trapezoidal shape. The size of the frame at the top was 1170 x 410 mm and at the bottom, it was 1170 x 970 mm. The height of the frame was 860 mm from the ground level. The frame was well braced to provide rigidity to mount and support other parts of the machine and to withstand vibrations during operation. A sub frame was made to fix the motor. Two mild steel flats of 5 x 50 mm size were welded on the bottom of the main frame. The space between the two flats was 260 mm. The sub frame was welded to the main frame to provide rigidity and to withstand vibration during operation.

The hopper has rectangular upper and base openings of 300 x 200 mm and 230 x 100 mm, respectively. It was made of 1.5 mm thick mild steel sheet. The main components of the deseeding unit are pegs mounted on wooden roller, concave, cutting blade and drum.

The wooden roller (Fig.1) is an important component of the deseeding machine. It consists of a helical blade (screw auger) to convey the feed and pegs of 80 x 8 mm, fixed on the wooden roller in a zigzag manner for imparting impact load over the fruits. The wooden roller was selected instead of mild steel rotor shaft for easy resizing and modification. Square wood (Botanical name: *Terminalia crenulata*, Tamil name: Karumaruthu) of 17.5 x 17.5 x 1200 mm was sized into a wooden roller of 1070 mm length and 160 mm diameter. At the end of the wooden roller, mild steel round flat (6 mm thickness) plates were fastened with projecting shaft on both sides. In the mild steel round flat plate, the shaft was inserted up to 50 mm inside and 100 mm projected outside. Sleeves were attached at both the ends for a length of 100 mm. Both ends of the wooden roller were supported suitably using two pillow block bearings mounted on the frame. One end of the wooden roller was coupled to the power transmission system.

Pegs were made up of coach screw of size 12.5 x 125 mm. The pegs were inserted in to the wooden roller in a zigzag manner with a projection of 80 mm from the wooden roller. The linear distance between two successive pegs was fixed as 50 mm. The radial angle between adjacent pegs was 90^{o}.

Concave mesh is a semi-circular shaped mesh surrounded below the drum, constructed from a perforated mild steel sheet of 5 mm thickness with a dimension of 600 x 1000 mm. It has oblong holes (openings) of 9 x 25 mm to allow only the seeds to pass through the holes. It was welded at both the sides with a half round mild steel flat sheet of 6 mm thickness and 350 mm diameter at the bottom of the frame.

To make additional impact force during the operation, a mild steel cutting blade of dimensions 50 x 6 x 1050 mm was fixed on the rear end of the wooden roller. It was fixed with an adjustable arrangement through bolt and nuts and the front end was fixed with screw auger.

Figure 1. Wooden roller with pegs

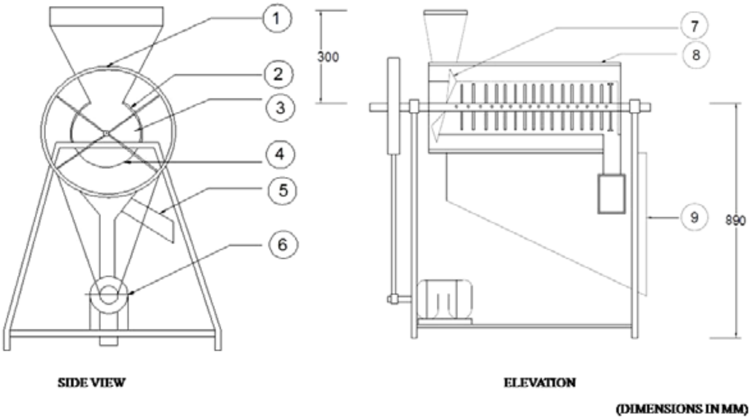

Figure 2. Schematic view of tamarind deseeder
1. feed hopper, 2. outer cover, 3. wooden roller, 4. concave, 5. pulp outlet,
6. motor, 7. screw conveyor, 8. deseeding unit, 9. seed outlet

The screw auger was made out of 6 mm thick and 320 mm diameter of mild steel round flat sheets by cutting and stretching it suitably. The diameter and pitch of the auger were 320 mm and 160 mm, respectively.

Drum was made up of 1.5 mm thick mild steel sheet and it was provided over the entire length of the main frame to enclose the deseeding section. Two semi circular mild steel sheets of 6 mm thick and 152 mm radius were used as enclosure for the deseeding unit. The drum was fixed on the frame by means of nuts and bolts.

After deseeding the fruits, seeds and fruit pulp were collected through separate outlets. The deseeded pulp outlet was made up of a rectangular closed channel fixed below the concave sieve at an angle of 60° to the horizontal. The seed outlet was mounted on the tool frame below the sieve. The both outlets were made up of 1.5 mm thick mild steel sheet. The partly dismantled tamarind deseeder machine is given in Fig.3.

A pulley of 400 mm diameter was attached at one end of the wooden roller to reduce the speed from 1440 rpm to 280 rpm. A V-belt of 800 mm length was used to transmit the power from the motor to the wooden roller. A five hp three phase electric motor of 1440 rpm was selected. Two dimensional views of tamarind deseeder are given in Fig. 2 and deseeder at working condition is given in Fig.4.

Working principle

Tamarind fruits are fed into the deseeding unit through feed hopper. After the impact load exerted by pegs mounted on wooden roller, the tamarind is ready to shed its seed out of its pulp. Since the impacted fruit is conveyed and sheared simultaneously, the seeds are removed through the concave screen and pulp are conveyed and collected at the separate outlet.

Figure 3. Tamarind deseeder (partly dismantled)

Performance Evaluation of Tamarind Deseeder

The developed tamarind deseeder was tested for its performance under four variable conditions. Three different feed rates *viz.,* 45 kg·h^{-1} (F_1), 60 kg·h^{-1} (F_2) and 75 kg·h^{-1} (F_3), three different moisture contents of tamarind fruits *viz.,* 20 % (M_1), 22.5 % (M_2) and 25 % (M_3) on dry basis with three different rotational speeds of the wooden roller *viz.*, 2.5 m·s^{-1} (S_1), 200 rpm (S_2) and 4.2 m·s^{-1} (S_3) and three concave clearances *viz.,*14 mm (C_1), 16 mm (C_2) and 18 mm (C_3) were considered for optimizing the parameters to get high deseeding efficiency. The effect of processing parameters on deseeding efficiency is presented in the Tab. 1.

Figure 4. Tamarind deseeder (working condition)

Table 1. Number of levels and values of Independent and Dependent variables

Independent Variables	Symbol	Levels	Values	Dependent Variable
Moisture content, % (db)	M	3	25, 22.5, 20	Deseeding Efficiency (%)
Peripheral Speed ($m \cdot s^{-1}$)	N	3	4.2, 3.4, 2.5	
Concave Clearance (mm)	C	3	18, 16, 14	
Feed rate ($kg \cdot h^{-1}$)	F	3	75, 60, 45	

No. of treatments = 3 x 3 x 3 x 3 = 81

Deseeding efficiency

Deseeding efficiency of the newly developed machine was determined by standard procedure [6]. Deseeding efficiency was calculated by the following formula.

$$D.S = \frac{S_1 + S_2}{S_1 + S_2 + S_3 + S_4} X\, 100 \tag{1}$$

Where:
D.S [%] - deseeding efficiency,
S_1 [g] - weight of seeds that are collected in the seed outlet,
S_2 [g] - weight of seeds that are collected in the pulp outlet,
S_3 [g] - weight of seeds taken manually from opened fruits,
S_4 [g] - weight of seeds taken in the unopened fruits.

These results were statistically analyzed using Completely Randomized Block factorial design.

RESULTS AND DISCUSSION

The effect of all processing parameters on deseeding efficiency is presented in Tab. 1. Mainly the effect of speed on deseeding efficiency with three different feed rates of 75 $kg \cdot h^{-1}$, 60 $kg \cdot h^{-1}$ and 45 $kg \cdot h^{-1}$, for different moisture content and clearances is depicted in Fig. 5-7.

From Fig. 5, it is noted that the deseeding efficiency was initially increased with increase in moisture content due to little softening of the tamarind fruit and then it gradually decreased with increase in moisture content at different feed rates, speed and clearances. This decrease in deseeding efficiency at higher moisture content is attributed to the fact that at 25%, tamarind fruit becomes very soft. Among the three moisture contents studied, the maximum deseeding efficiency was obtained at 22.5% moisture content on dry basis for all feed rates. The minimum deseeding was noted at 25% moisture content on dry basis for all feed rates.

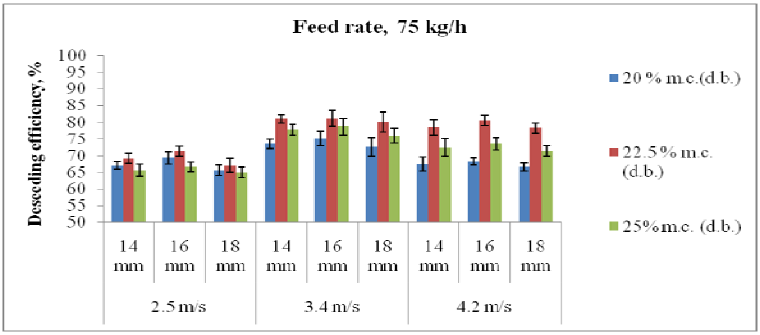

Figure 5. Effect of speed on deseeding efficiency at 75 kg·h^{-1} feed rates

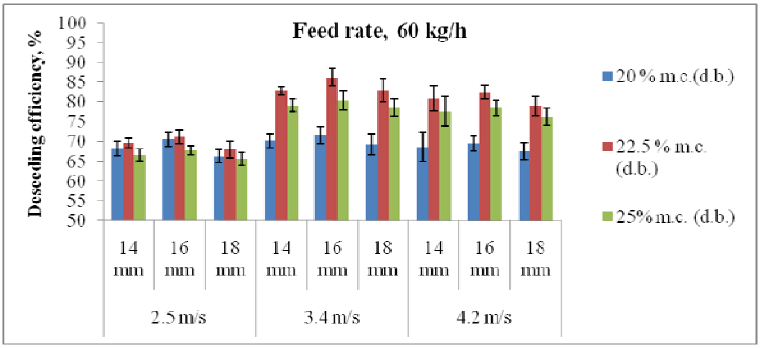

Figure 6. Effect of speed on deseeding efficiency at 60 kg·h^{-1} feed rates

It is also observed that the deseeding efficiency initially increased with increase in speed and then decreased, while the moisture content, feed rate and clearances were kept constant. The low deseeding efficiency at minimum speed was because of the low impact force applied on to the tamarind fruits which leads to partially shelled or unshelled condition of fruits at the outlet. Reduced efficiency at higher speed was due to shorter residence time of tamarind fruit in the deseeding unit. Among the three speeds, the maximum deseeding efficiency was obtained at 3.4 m·s^{-1} for all feed rates and the minimum deseeding efficiency was observed for the speed of 2.5 m·s^{-1} for all feed rates. Analogous results of increase in deseeding efficiency with increase in speed and then decrease with further increase in speed was observed for cashew nut shelling [7], water chestnut [8] and grain legumes [9].

It is also noted that the deseeding efficiency decreases with increase in feed rate at a given speed, moisture content and clearance. The lesser deseeding efficiency with higher feed rate was due to reduction in the residence time. High deseeding efficiency with lower feed rate was because of tamarind fruit has got enough time to be impacted. From Fig.7, among the three feed rates, the maximum deseeding efficiency was obtained at 45 kg/h with the peripheral speed of 3.4 $m \cdot s^{-1}$ and minimum deseeding efficiency at 75 $kg \cdot h^{-1}$ with the peripheral speed of 2.5 $m \cdot s^{-1}$. Results obtained in this study are on par with the results observed for bambara groundnut [10] sheanut [11] and mango stone [12].

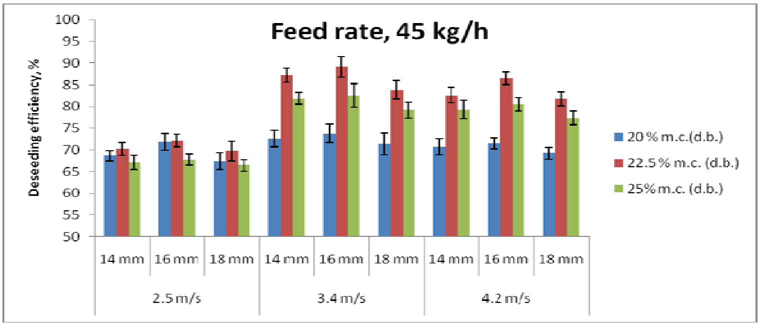

Figure 7. Effect of speed on deseeding efficiency at 45 $kg \cdot h^{-1}$ feed rates.

It can be also observed that the deseeding efficiency initially increased with an increase in clearance and then decreased when the moisture content and speed were kept constant. The lower deseeding efficiency at maximum clearance is attributed to less impact force applied on the tamarind fruits which leads to partially shelled or unshelled condition of fruits at the outlet. For the minimum clearance, more amounts of damaged fruit were noticed when compared to other two clearances. The results found were supported by the findings [13] for paddy threshing where the damage was found increasing with increasing impact load exerted by different materials on paddy and for wheat in case of thresher [14].

Analysis of variance (Tab. 2) shows that the effects of single factors namely moisture content, speed and feed rate were significant at 1 % level and clearance was significant at 5% level. Two factor interactions namely moisture content x speed, moisture content x feed rate and speed x feed rate were found to be significant at 5% level. Interactions namely moisture content x clearance, speed x clearance and clearance x feed rate were found to be non significant. Three factor interactions namely moisture content x speed x feed rate was found to be significant at 1 % level. Interactions namely speed x clearance x feed rate and moisture content x speed x clearance were significant at 5 % level and moisture content x clearance x feed rate was found to be non significant. Four factor interactions namely moisture content x speed x clearance x feed rate was also found to be non significant.

From the four factorial completely randomized block design, it was obtained that the treatment which includes the combination of wooden roller running at 3.4 $m \cdot s^{-1}$ with the feed rate 45 $kg \cdot h^{-1}$, irrespective of the moisture contents considered for the analysis was found to be the best among all the treatments tested. The combination of feed rate 45 kg/h with the wooden roller of 3.4 $m \cdot s^{-1}$ and clearance of 16 mm to deseed the tamarind at the moisture content of 22.5% on dry basis ($M_2S_2F_1C_2$) was considered as the best, since the maximum deseeding efficiency was obtained as 89.15%. Minimum deseeding efficiency (60.57%) was observed when the moisture content of feed is 25% on dry basis and speed, feed rate and clearance were 2.5 $m \cdot s^{-1}$, 75 $kg \cdot h^{-1}$ and 18 mm, respectively.

Table 2. Analysis of variance for the efficiency of tamarind deseeder for various speed, moisture content, feed rate and clearance

Source of variation	*Degrees of freedom*	*Sum of squares*	*Mean squares*	*F-ratio*
Total	*80*	*18733.5545*	*77.4113*	*17.8941*
Treatment	*26*	*18041.3809*	*225.5170*	*52.1296***
Error	*54*	*692.1735*	*4.3261*	*1.00*
Moisture content (M)	*2*	*13297.8103*	*6648.9051*	*1536.9335***
Speed (S)	*2*	*3513.0000*	*1756.5000*	*406.025***
Feed rate (F)	*2*	*248.7212*	*124.3606*	*28.7467***
Clearance (C)	*2*	*470.1052*	*235.0526*	*54.3338**
M x S	*4*	*136.2021*	*34.0505*	*7.8710***
M x C	*4*	*57.6181*	*14.4045*	*3.3297 NS*
M x F	*4*	*195.4819*	*48.8704*	*11.2967***
S x C	*4*	*10.6223*	*2.6555*	*0.6139 NS*
S x F	*4*	*30.0587*	*7.5146*	*1.737***
C x F	*4*	*5.4895*	*1.3723*	*0.3172 NS*
M x S x C	*8*	*13.7160*	*1.7145*	*0.3963**
M x S x F	*8*	*30.1872*	*3.7734*	*0.8722***
M x C x F	*8*	*17.001*	*2.1250*	*0.4913NS*
S x C x F	*8*	*5.5414*	*0.6920*	*0.1601**
M x S x C x F	*16*	*9.8245*	*0.6140*	*0.1419 NS*

**Significant at 5 %level, ** Significant at 1 %level, NS non- significant*
SED: 0.00227 CD (0.05): 0.00450 CD (0.01): 0.00596

Cost Economics

The capacity of the developed tamarind deseeder was 45 $kg \cdot h^{-1}$ and the cost of operation of tamarind seed remover was \$0.019$\cdot kg^{-1}$, whereas the conventional manual deseeding process, the cost was found to be \$ 0.07$\cdot kg^{-1}$ of tamarind fruit. The conventional method of deseeding is nearly 4 fold more expensive than mechanical deseeding. Mechanical deseeding saves 74.9 % of operation cost and 93.34% of operation time.

CONCLUSIONS

A tamarind deseeder was developed in this study. The performance evaluation of the deseeder showed that fruit moisture content, material feed rate and machine speed had significant effect on its performance indices.

The combination of feed rate 45 $kg \cdot h^{-1}$ with the wooden shaft of 3.4 $m \cdot s^{-1}$ and clearance of 16 mm to deseed the tamarind at the moisture content of 22.5% on dry basis was considered as the best among the eighty one different treatments tested in Agres package, since the maximum deseeding efficiency was obtained as 89.15%.

The deseeder has a compact design and a robust outlook. It will contribute to the enhancement of tamarind processing as it could be used to eliminate the tediousness of the present traditional methods of tamarind deseeding.

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RAZVOJ I ISPITIVANJE KONTINUIRANOG TIPA SEPARATORA SEMENA MAHUNARKI

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Sažetak: Kontinuirani tip separatora semena iz mahuna kapaciteta 75 kg·h^{-1} konstruisan je i ispitivan u Institutu za inženjering prehrambenih i poljoprivrednih procesa Poljoprivrednog univerziteta Tamil Nadu, Coimbatore, India. Mašina se sastoji od separatorske jedinice i izlaza za izdvojeno seme i prazne mahune. U separatorskoj jedinici mahune su istovremeno izlagane silama udara i sečenja od klinova postavljenih na drveni valjak, koji lome i otvaraju mahune i istovremeno guraju seme napolje iz duguljastog sita. Posle izdvajanje semena, seme i prazne mahune se skupljaju odvojeno iz razdvojenih izlaznih otvora. Performanse razvijene mašine su ocenjivane na osnovu efikasnosti separacije. Pri ispitivanju su izvođeni ogledi u različitim uslovima rada, uključujući različite: vlažnosti plodova (20.0, 22.5 i 25.0%), brzine valjka (2.5, 3.4 i 4.2 m·s^{-1}), protoke mase (45, 60 i 75 kg·h^{-1}) i horizontalne zazore (14, 16 i 18 mm). Rezultati ogleda su pokazali da je mašina postigla maksimalnu efikasnost separacije od 89.15% pri: vlažnosti od 22.5%, brzini valjka od 3.4 m·s^{-1}, protoku mase od 45 kg·h^{-1} i zazoru od 16 mm. U poređenju sa postojećim ručnim postupcima separacije, kontinuirani tip separatora postigao je skraćenje radnog vremena od 93.34% i smanjenje troškova rada od 74.9%.

Ključne reči: *separator semena, separatorska jedinica, drveni valjak, efikasnost separacije*

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RESPONSE OF MAIZE *(Zea mays L)* CROP TO DIFFERENT PLANTERS

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Abstract: Maize (*Zea mays* L) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Tillage and crop establishment is the key for achieving the optimum plant stand and the method of planting and machinery plays a vital role for better establishment of crop under a set of growing situation. Therefore, three planters namely tractor operated raised bed planter, inclined plate planter and manually operated multicrop planter were evaluated in field for sowing of maize. The mean quality of feed index was maximum for raised bed planter as 82.04% and for inclined plate planter and manually operated multicrop planter was 80.83% and 76.67% respectively. The mean multiple index for raised bed, inclined plate and manually operated multicrop planter was 9.26%, 6.39% and 10.75% respectively. The mean miss index for raised bed planter, inclined plate planter and manually operated multicrop planter were 8.70%, 12.78% and 12.58% respectively. The mean grain yield per ha was found maximum for raised bed maize planter as 7.017 $t.ha^{-1}$ and for inclined plate planter and manually operated planter it was 5.778 $t \cdot ha^{-1}$ and 6.097 $t \cdot ha^{-1}$ respectively. The number of cobs per ha were also maximum for raised bed maize planter as 66,431 and for inclined and manually operated planter number of cobs per ha were 61,945 and 62,992 respectively. The per cent saving in labor cost and time in maize sown with raised bed planter was 89.90% and 91.80% as compared to maize sown with traditional manual method and was highest amongst three planters. There was saving of 10-15% water in maize sown with raised bed planter as compared to maize sown on flat with other planters.

***Key words**: raised bed planter, inclined plate planter, maize, germination, yield*

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INTRODUCTION

In India, maize is the third most important food crops after rice and wheat. According to advance estimate it is cultivated in 8.7 million ha (2010-11) mainly during *Kharif* season which covers 80% area. Maize in India, contributes nearly 9% in the national food basket and more than R_s. 100 billion to the agricultural GDP at current prices apart from the generating employment to over 100 million man-days at the farm and downstream agricultural and industrial sectors. In addition to staple food for human being and quality feed for animals, maize serves as a basic raw material as an ingredient to thousands of industrial products that includes starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceutical, cosmetic, film, textile, gum, package and paper industries etc.

Maize is mainly sown directly through seed by using different methods of tillage and establishment but during winters where fields are not remain vacant in time (till November), transplanting can be done successfully by raising the nursery. However, the sowing method (establishment) mainly depends on several factors *viz* the complex interaction over time of seeding, soil, climate, biotic, machinery and management season, cropping system, etc. Therefore it is very important that different situations require different sowing methods for achieving higher yield. Sowing/planting should be done on the southern side of the east-west ridges/beds, which helps in good germination. Planting should be done at proper spacing.

The effect of ameliorative tillage on the dynamics of some important productive morphological characteristics on two crops of sunflower and maize was studied. Ameliorative tillage systems had better effect for all investigated morphological properties (root distribution, biomass stalk, leafs, head of sunflower, ear maize, and grain yield) on this heavy soil type. Ameliorative tillage system increased significantly grain yield of maize 629 $kg \cdot ha^{-1}$ compared with conventional tillage systems on control variants. [1].

A prototype punch planter was developed for no-till corn to provide different seed spacing. Plant population was adjusted by changing planter punch wheels. Seed spacing of 136, 165, and 210 mm were obtained by constructing three punch wheels with different punch lengths, represented by external diameters of 650, 825, and 1,000 mm, respectively. Laboratory and field tests were conducted at speeds of 1.5, 2.0, and 2.5 $m \cdot s^{-1}$ to evaluate the effect of the punch lengths and speeds. Field tests were conducted in three different residue covers (corn, grain sorghum, and soybean). Overall, high values for quality of feed index (spaces between seeds or plants within 0.5 and 1.5 the theoretical seed spacing) were observed. Despite problems with synchronization between the seed meter and punch wheels, the length of the punches offered no performance limitations at the speeds tested. A soil cleaning device was designed to reduce soil sticking to the punches and reduce soil disturbance. The volume of soil displaced by the smallest punch wheel (650 mm) was less than half of that displaced by a commercial no-till planter. Differences in planting depth due to residue cover and punch wheel diameter were minimal. Emergence was delayed under the corn residue cover and may have influenced the lower performance of the planter prototype as compared to the other two residue types [2].

A three - row bullock drawn multi-crop inclined plate planter was developed at C.I.A.E Bhopal for sowing different type of crops. The calibration for the seed and fertilizer rate was done in the laboratory of C.A.E. , R.A.U., Pusa, Samastipur. The seed rate was found 20.60 kg·ha^{-1} for the maize crop and fertilizer rate was found from 9.3 kg·ha^{-1} to 124.3 kg·ha^{-1}. The wheel skid was in tolerable limit as it was recorded 4.53 %. The field capacity was 0.23 ha·hr^{-1} and field efficiency was 51.1%. The plant population was found 10-12 plants per square meter. The cost of sowing per hectare was 3.5 times economical than traditional method [3].

No-tillage and raised beds are widely used for different crops in developed countries. A field experiment was conducted on an irrigated maize-wheat system to study the effect of field layout, tillage and straw mulch on crop performance, water use efficiency and economics for five years (2003–2008) in northwest India. Straw mulch reduced the maximum soil temperature at seed depth by about 3ºC compared to the no mulch. During the wheat emergence, raised beds recorded 1.3ºC higher soil temperature compared to the flat treatments. Both maize and wheat yields were similar under different treatments during all the years. Maize and wheat planted on raised beds recorded about 7.8% and 22.7% higher water use efficiency than under flat layout, respectively. Straw mulch showed no effect on water use and water use efficiency in maize. The net returns from the maize-wheat system were more in no tillage and permanent raised beds than with conventional tillage. Bulk density and cumulative infiltration were more in no tillage compared with conventional tillage [4].

In rain fed conditions the success of crop production depends on timely seeding. The seed rate for various dry land crops varies from 4 to 140 kg kg.ha^{-1}. Availability of a multi crop planter with replaceable metering plate is crucial to meet the seed rate requirements and to reduce the cost involved in machinery management. Though different types of planters having different seed metering mechanisms were evolved, their performance is not up to the mark.

An inclined plate metering mechanism and newly developed horizontal metering plate was tested on a grease belt test rig developed at CRIDA for their comparative performance at three speeds, 2.5, 3.5 and 5 km·h^{-1} with castor and maize seeds. The average number of seeds metered at different forward speeds for selected variety of maize varied from 367.5 to 239 for inclined plate and 308 to 281 for horizontal plate when compared to theoretical metered seed of 270. In horizontal plate, the seed metering was more consistent and did not varied much with respect to speed of rotor and delivered 14.02 to 4.03% higher seed rate for castor. The mean seed spacing ranged from 19.3 to 23.1 cm. The horizontal rotor metered 94-98 frequency percentile seeds within 15-30 cm spacing intervals at operation speeds of 2.5 to 3.5 km·h^{-1}. It is concluded that, correct seed rate can be achieved with the selected speed ranges by re-designing the seed cells in horizontal plate rotor [5].

A horizontal rotor seed metering plate mechanism was developed and tested both under laboratory (2.5, 3.5 and 5 km·h^{-1} speeds) and field conditions. The mean number of seeds metered at different forward speeds for maize and castor crop varied from 184.8 to 192.6; 185.8 to 187.6, respectively when compared to theoretical metered seeds of 180. The quality of feed index of the planter ranged from 85 to 90.5% and 82.7 to 97% clearly indicated the frequency distribution of seeds with in space intervals > 10 to < 30 cm. The horizontal rotor metered 85 – 93 frequency percentile seeds within 15 – 30 cm spacing intervals at operation speeds of 2.5 to 3.5 km·h^{-1}. At average field speeds of 2 and 3.5 km·h^{-1}, 70 and 65 per cent of the seeds were sown, respectively in a spacing interval of 15-30 cm, which also indicated the higher quality of feed index for the developed planter [6].

Seed metering device is a heart of seed sowing machine which is evaluated for seed distance, seed size between seed varieties. Seed metering devices meter the seed from the seed box and deposit it into the delivery system that conveys the seed for placement on or in the seedbed. The major functional requirements of seed metering systems are to meter the seed at a predetermined rate/output (e.g. $kg{\cdot}ha^{-1}$ or seeds/meter of row length) meter the seed with the required accuracy (spacing) to meet the planting pattern requirements (i.e. drill seeding, precision drilling, etc); and cause minimal damage to the seed during the metering process. The seed sowing machine is a key component of agriculture field. The performance of seed sowing device has a remarkable influence on the cost and yield of agriculture products. Therefore present study was conducted to evaluate field performance of three different type of planters for sowing of maize crop.

Inclined plate seed metering device was designed and evaluated in laboratory for singulation and uniform placement of maize and soybean seeds at three different cell shapes and sizes. The performance parameters like average spacing, multiple index, quality of feed index and precision were measured. Among the combinations of design variables, the seed metering plate with semi-circular cell shape having cell size 7 mm diameter was found to be the optimum for metering maize seed. Average spacing, quality of feed index, multiple index, miss index and precision were 17.48 cm, 79.33%, 18.67%, 2% and 10.5%, respectively [7].

MATERIAL AND METHODS

The three planter's viz. tractor operated raised bed planter, tractor operated inclined plate planter and manually operated multicrop planter selected for the sowing of maize. The planters were calibrated in the laboratory to give a seed to seed spacing of 0.20 m and row to row spacing of 0.60 m (as per recommendations of PAU, Ludhiana) for maize variety PMH-2 at seed rate of 20 $kg{\cdot}ha^{-1}$. A germination test was carried out for the variety of maize seed to be sown which was used for the field evaluation of the unit. The weight of the 100 numbers of seeds was 30 g. The 100 seeds were placed in the incubator for three days on a blotting paper under controlled conditions. The germination was found to be 85%. The specifications and calibration method of of three planters used for the present study are shown in Tab. 1.

The raised bed planter had vertical plates with spoon type metering arrangement (Fig. 1). This machine makes two beds and sows 1-3 lines (adjustable) on each bed during operation and it was set to sow one line on each bed. The cost of this machine is R_s 60,000 per unit (US $ 950) and it is developed by Department of Farm Machinery and Power Engineering, P.A.U. Ludhiana. In inclined plate planter, planting attachment has been added to seed - cum - fertilizer drills (Fig. 2). The planter has 6 inclined plates and there were 24 grooves of spherical pattern on each plate. The groove to groove spacing was 12 mm and diameter of each groove was 10 mm. The cost of this machine is R_s 50,000 per unit (US $ 800).

In manually operated multicrop planter (Fig. 3), the planting mechanism has been mounted over the existing wheel hand hoe, used for intercultural operation and consists of a vertical plate with spoons. The capacity of the hopper is about 3.0 kg. The plant spacing can be varied by varying the number of spoons on the periphery of the vertical plate. The planting spoons are also available for sowing different crops like peas, cotton, maize and soybean. It requires two people for sowing i.e. one for pulling the machine from forward side and other for pushing it from backward side so as to make its operation comfortable. The desired seed rate and plant to plant spacing was achieved by changing the driven sprocket or planter plate laboratory calibration. The manually operated planter sows one row in single pass operation. The cost of this machine is Rs. 3000 per unit (USD 50). This machine was developed by Department of Farm Machinery & Power Engineering, P.A.U., Ludhiana.

Figure 1. Raised bed maize multicrop planter

Figure 2. Inclined plate planter

Figure 3. Manually operated planter

Table 1. Various specifications and calibration detail of three planters

Name of machine	*Raised bed planter*	*Inclined plate planter*	*Manually operated multicrop planter*
HP required	*35 HP*	*35 HP*	*1.0 HP*
Seed metering mechanism	*Vertical plate with spoons*	*Inclined plate with grooves*	*Vertical plate with spoons*
Ground wheel diameter (mm)	*410*	*410*	*410*
Diameter of seed metering plate (mm)	*180*	*160*	*190*
Number of spoons/ grooves on each plate	*12*	*24*	*12*
Spacing between two consecutive spoons/ grooves, mm	*50*	*12*	*50*
Seed rate and spacing adjusted	$20\ kg \cdot ha^{-1}$ *0.60 x 0.20 m*	$20\ kg \cdot ha^{-1}$ *0.60 x 0.20 m*	$20\ kg \cdot ha^{-1}$ *0.60 x 0.20 m*
Seed rate calibration method used	*By changing the driving sprocket and planter plates*	*By changing the inclination of planter box and by changing driving sprocket and planter plates*	*By changing the driving sprocket and planter plate*

After the laboratory calibration these planters were operated in field for sowing of maize. After the germination of maize crop miss index, multiple index and quality of feed index was recorded. The criteria for these three indices are given below.

Miss index. Plant missing is an indicator of how often the seedling skips the desired spacing. If the spacing between two plants was greater than 1.5 times the theoretical spacing, then it was considered as a miss.

Quality of feed index. The quality of feed index is measure of how often the plant spacing was closed to the theoretical spacing. If the spacing between two plants was more than half but not more than 1.5 times the theoretical spacing, then it was considered quality of feeding.

RESULTS AND DISCUSSION

Planting of maize was done with the machines viz. raised bed (ridge) planting as well as inclined plate planter and manual planter at the departmental research farm in sandy loam soil. The three machines were operated in the field and parameters like width, forward speed, depth of seed placement and fuel consumption were measured and are shown in Tab. 2. It is clear from Tab. 2 that average fuel consumption for raised bed planter was 4.95 $l \cdot hr^{-1}$ whereas for inclined plate planter it was 6.03 $l \cdot hr^{-1}$. The average field capacity of raised bed planter was 0.49 $ha \cdot h^{-1}$, for inclined plate planter was 0.48 $ha \cdot h^{-1}$, whereas for manually operated planter it was 0.23 $ha \cdot h^{-1}$, and the effect of different machines was significant on field capacity, as well as on forward speed at 5% level of significance. The depth of seed placement varied from 20-50 mm for three planters and the effect of different their effect on depth of seed placement was non-significant at 5% level of significance.

Table 2. Field parameters for three different planters

Name of machine	*Raised bed planter*	*Inclined plate planter*	*Manually operated multicrop planter*	*CD at 5 %*
Width of machine (m)	*1.80*	*1.80*	*0.04*	*---*
Mean forward speed ($km \cdot h^{-1}$)	*2.72*	*2.68*	*0.48*	*0.151757*
Mean effective field capacity ($ha \cdot h^{-1}$)	*0.49*	*0.48*	*0.23*	*0.0256957*
Mean depth of seed placement (mm)	*40.00*	*33.33*	*23.33*	*NS*
Mean fuel consumption ($l \cdot h^{-1}$)	*4.95*	*6.03*	*--*	*--*

Figure 4. Maize sown with manually operated planter

Figure 5. Maize sown with inclined plate planter

Figure 6. Maize sown with raised bed planter

For raised bed planter and inclined plate planter only one person was required whereas for manually operated multicrop planter two persons were required. After the maize crop germination (Fig. 4, 5, 6), data for number of singles, multiples and missing hills was also recorded and are shown in Tab. 3. The effect of three different planters on these indices was non-significant at 5% level of significance. The mean number of plants per ha for raised bed, inclined plate and manually operated multicrop planter were 71,394, 68,171 and 69,615 respectively and the effect was significant at 5% level of significance. The more number of plants in raised bed planter may be attributed to fact that more fertile soil is available for plant on beds.

The mean miss index was found to be maximum in inclined plate planter as 12.78% which occurred normally due to seed struck in any hole of metering plate. The mean multiple index values for raised bed, inclined plate and manually operated multicrop planter were 9.26%, 6.39% and 10.75% respectively. The maximum mean multiple index were found in manually operated planter. Quality of feed index value was maximum for inclined plate planter as 82.04% and values for raised bed planter and manually operated multicrop planter were 80.83% and 76.67% respectively.

The different indices i.e. mean quality of feed index, multiple index and missing index for three different planters have been shown in Fig. 7.

Table 3. Germination data for the three different planters

Machine used for sowing of maize	*Raised bed planter*	*Inclined plate planter*	*Manually operated planter*	*CD at 5 %*
Mean plant to plant spacing (mm)	*190.30*	*201.30*	*182.30*	*NS*
Mean number of plants per ha	*71394*	*68171*	*69615*	*0.257984 E-05*
Mean miss index (%)	*8.70*	*12.78*	*12.58*	*NS*
Mean quality of feed index (%)	*82.04*	*80.83*	*76.67*	*NS*
Mean multiple index (%)	*9.26*	*6.39*	*10.75*	*NS*

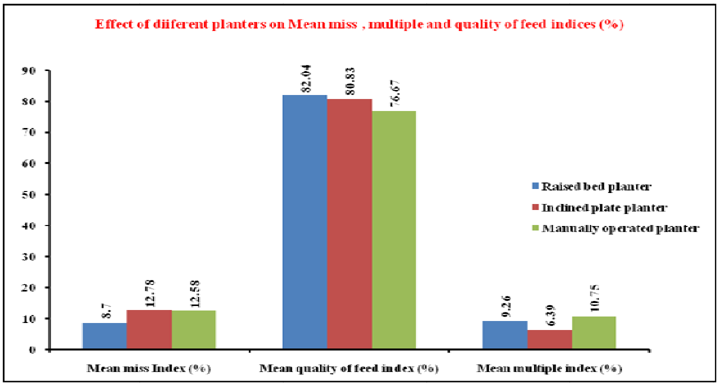

Figure 7. Effect of different planters on mean miss, quality of feed and multiple indices

After the crop maturity, maize samples were taken from three plots and various parameters like stalk height, girth, weight, grain weight per cob, yield etc were recorded. The average moisture content of maize was 22% (w.b.). The data recorded is shown in

Tab. 4. The mean stalk height, girth and stalk weight for maize sown with raised bed planter were 2.29 m, 60.30 mm and 12.22 t·ha^{-1} and were maximum for it, and mean number of cobs per ha were 66,431 (Fig. 8) for maize sown with raised bed planter and for inclined and manually operated planters were 61,945 and 62,992 respectively. The effect of three planters on mean stalk height, mean stalk girth, mean number of cobs per ha were significant whereas for mean stalk weight was non-significant at 5% level of significance. The mean cob length was maximum for raised bed planter with value 152.567 mm and mean cob diameter was maximum for manually operated planter with the value 23.63 mm. The effect of three planters on mean cob length and mean cob diameter was non-significant at 5% level of significance. The mean grain yield, mean grain weight per cob and mean 1000 grain weight were maximum for maize sown with raised bed planter and values were 7.017 t·ha^{-1}, 0.106 kg and 0.313 kg respectively The mean grain yield for inclined plate planter and manually operated multicrop planter were 5.778 and 6.097 t·ha^{-1} respectively and effect of three planters was found to be significant on mean grain yield at 5% level of significance. The mean grain yield per ha, mean 1000 grain weight and mean grain weight per cob for three planters are shown in Fig. 9. The water requirement or total number of irrigations applied were also lesser for raised bed planter sown maize as compared to other two treatments. The mean grain weight and mean 1000 grain weight for maize sown with inclined plate planter and manually operated multicrop planter were 0.093 kg, 0.296 and 0.097 kg, 0.299 kg respectively and effect of three different planters was found to be significant on these two parameters at 5% level of significance. The effect of three different planters were found to be significant on mean weight of empty cobs and non-significant on mean husk weight at 5% level of significance and values of these two parameters were minimum for maize sown with inclined plate planter. A graph was also plotted between mean grain weight per cob, mean 1000 grain weight and mean grain yield as shown in Fig. 10.

Table 4. Maize plant analysis for three different planter

Machine used for sowing of maize	*Raised bed planter*	*Inclined plate planter*	*Manually operated planter*	*CD at 5 %*
Mean stalk height (m)	*2.290*	*2.160*	*2.210*	*0.102313*
Mean stalk girth (mm)	*60.300*	*49.230*	*48.530*	*8.74917*
Mean stalk weight (t· ha^{-1})	*12.220*	*10.620*	*11.710*	*NS*
Mean number of cobs·ha^{-1}	*66431*	*61945*	*62992*	*52.12*
Mean cob length (mm)	*152.567*	*134.933*	*137.833*	*NS*
Mean cob diameter (mm)	*21.333*	*23.100*	*23.633*	*NS*
Mean weight of empty cobs (t· ha^{-1})	*1.982*	*1.440*	*1.745*	*0.291190*
Mean husk weight (t·.ha^{-1})	*1.118*	*0.626*	*0.661*	*NS*
Mean number of grains per cob	*347*	*316*	*325*	*8.13007*
Mean grain weight per cob (kg)	*0.106*	*0.093*	*0.097*	*0.00511590*
Mean 1000 grain weight (kg)	*0.313*	*0.296*	*0.299*	*0.00457233*
Mean grain yield (t· ha^{-1})	*7.017*	*5.778*	*6.097*	*0.00780599*

The equation for mean 1000 grain weight as a function mean grain weight per cob:

$$y = 61.96\,x^2 - 11.02x + 0.785 \qquad (1)$$

The equation for mean grain yield as a function of mean grain weight per cob:

$$y = 1728x^2 - 248.6\,x + 13.95 \qquad (2)$$

Eq. (1) shows relation between mean grain weight per cob and mean 1000 grain weight and Eq. (2) shows relation between mean grain weight per cob and mean grain yield per ha.

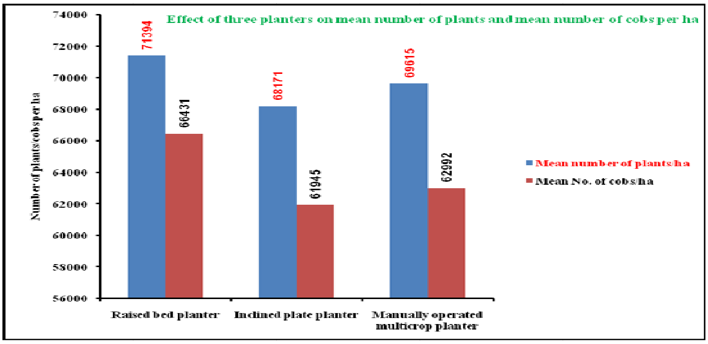

Figure 8. Effect of three different planters on germination of plants and cobs per ha

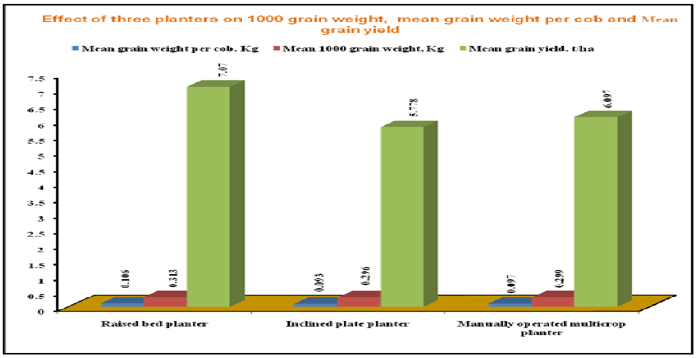

Figure 9. Effect of three planters on mean grain weight per cob, 1000 grain weight and grain yield

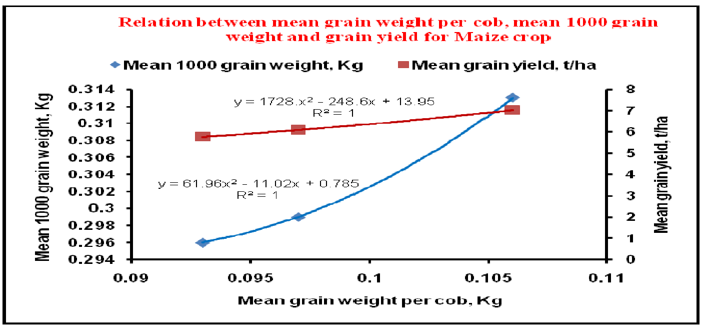

Figure 10. Relation between mean grain weight per cob, mean 1000 grain weight and mean grain yield

Economics of machines. The economics of three different planters was calculated and are shown in Tab. 5. The cost of manually operated multicrop planter was found to be minimum. The field capacity of traditional manual sowing was 0.04 $ha \cdot h^{-1}$. The per cent saving in time was found to be maximum for raised bed planter as compared with traditional method. The per cent saving in time with raised bed planter and inclined plate planters were 91.74% and 82.46% as compared with traditional manual method as shown in Tab. 5.

Table 5. Economics analysis of different planters used for sowing of maize

Method of planting	*Bed planting*	*Flat planting*	
Planter used for sowing maize	*Raised bed planter*	*Inclined plate planter*	*Manually operated planter*
Cost of machine operation , $Rs \cdot ha^{-1}$ (Including fixed and variable costs)	*472.39 (USD 8)*	*538.81 (USD 9)*	*115.19 (USD 2)*
% saving in labor cost as compared to traditional method	*89.90 %*	*87.98 %*	*75.96 %*
% Saving in time as compared to manual method	*91.80 %*	*91.74 %*	*82.46 %*
% Saving in irrigation water with bed planting as compared with flat planting	*10-15 %*	----	----

CONCLUSIONS

1. The mean quality of feed index was maximum for raised bed planter as 82.04 % and for inclined plate planter manually operated multicrop planter was 80.83 % and 76.67% respectively.
2. The mean multiple index for raised bed, inclined plate and manually operated multicrop planter was 9.26%, 6.39% and 10.75% respectively.
3. The mean miss index for raised bed planter, inclined plate planter and manually operated multicrop planter were 8.70%, 12.78% and 12.58% respectively.
4. The mean grain yield per ha was found maximum for raised bed maize planter as 7.017 $t \cdot ha^{-1}$ and for inclined plate planter and manually operated planter it was 5.778 $t \cdot ha^{-1}$ and 6.097 $t \cdot ha^{-1}$ respectively.
5. The number of cobs per ha were also maximum for raised bed maize planter as 66,431 and for inclined and manually operated planter number of cobs per ha were 61,945 and 62,992 respectively.
6. The cost of operation per ha with raised bed, inclined and manual planters were Rs. 472.39, 538.81 and 115.19 respectively.
7. The per cent saving in labor cost and time in maize sown with raised bed planter was 89.90% and 91.80% as compared to maize sown with traditional manual method and was highest amongst three planters
8. Also there was saving of water from 10-15% in maize sown raised bed planter as compared to maize sown on flat with other planters.

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ODGOVOR KUKURUZA *(Zea mays L)* NA RAZLIČITE SEJALICE

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Sažetak: Kukuruz (*Zea mays* L) je jedan od najrasprostranjenijih useva koji se lako prilagođava različitim agro-klimatskim uslovima. Obrada i setva su ključni za postizanje optimalnog stanja useva. Zato su ovde ispitivane dve traktorske i jedna ručna sejalica. Indeks srednjeg kvaliteta bio je najveći kod setve u leje (82.04%), kod sejalice sa nagnutom pločom i ručne sejalice iznosio je 80.83% i 76.67%, redom. Srednji višestruki indeks za sve sejalice, istim redom, iznosio je 9.26%, 6.39% i 10.75%. Srednji indeks gubitaka bio je 8.70%, 12.78% i 12.58%, redom. Srednji prinos zrna bio je 7.017 $t.ha^{-1}$, 5.778 $t{\cdot}ha^{-1}$ i 6.097 $t{\cdot}ha^{-1}$, redom. Broj klipova/ha iznosio je 66.4, 61.95 i 62.99, redom. Smanjenje troškova i vremena rada iznosilo je 89.9% i 91.8% u poređenju sa tradicionalnom ručnom setvom. Ušteda vode od 10-15% je ostvarena kod kukuruza sejanog sejalicom za leje u poređenju sa setvom na ravnu podlogu sa druge dve sejalice.

Ključne reči: *sejalica u leju, sejalica sa nagnutom pločom, kukuruz, nicanje, prinos*

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IMPROVING PRODUCTIVITY OF CITRUS ORCHARDS WITH RAINWATER HARVESTING AND MICRO-IRRIGATION IN A SUB-HUMID REGION

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Abstract: Scarcity of water is one of the major factors affecting productivity and decline of citrus orchards. The uneven distribution of rain in space and time induces abundant runoff in tropics. The higher runoff in monsoon period and soil moisture shortage in post monsoon induces sub-optimum yield of citrus orchards. Rainwater harvesting and its efficient utilization in citrus orchards is need of the hour for sustainable citriculture. Keeping this in view, the study was conducted to explore the feasibility of rainwater harvesting and it's use through drip irrigation in citrus orchards. Various in-situ rainwater conservation treatments viz., continuous trenching, continuous bunding, staggered trenching between the rows across the slope (4.2%) and control (without any soil and water conservation treatment) were evaluated in citrus orchards of central India during 2006-2009. The continuous trenching produced the best response conserving 38% runoff and 32.28% soil besides 15.7% higher fruit yield with better fruit quality. Moreover, rainfall runoff from 3.2 hectare of land with continuous trenches was harvested in a tank of size 35m×35m×3m and recycled with drip irrigation with black plastic mulch in 1ha of Nagpur mandarin. The harvested water also recharged the groundwater in the nearby wells and water from wells was used for irrigation purpose during dry period. Over all, the fruit yield was enhanced up to 110% with better quality fruits under rainwater conservation practices and groundwater use over rain-fed trees. The study suggested for the combine use of rainwater harvesting and drip irrigation with plastic mulch for sustainable production of citrus in the regions having similar agro-climates of the study region.

Key words*: citrus, water harvesting, micro-irrigation, yield*

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INTRODUCTION

Citrus is the widely cultivated fruit crop in world. Water scarcity is one of the major causes of low productivity and decline of citrus orchards in tropical and sub-tropical regions. In India it is the third important fruit crop after banana and mango. Nagpur mandarin (Citrus reticulata Blanco), one of the premier citrus cultivar, is grown in around $4.85 \cdot 10^5$ hectares of central India [12]. The crop is mostly grown on Vertisol of gently sloppy lands, which is characterized with producing abundant runoff during monsoon on one hand and soil moisture shortage for sustaining the crop in post monsoon period on the other. Although, some in-situ runoff conservation measures for different crops such as lemon [2] and acid lime [5] were advocated for better growth and production, the information such as this is lacking for Nagpur mandarin. Moreover, rainwater harvesting in tank and recycling it in orchards is one of the potential options for enhancing productivity of citrus in water scarce region.

The citrus in central India is basically irrigated by bore well or dug well through basin or furrow irrigation method. For last few years, the water level in wells is declined alarmingly creating water shortage in summer for sustaining the crop. So every year thousand hectares of the orchard is permanently wilted due to short of water, which is a great economical loss for the orchard growers of this region. Hence, proper irrigation water management by optimum use of available water resource along with water resource development in the region is quite necessary. Drip has been found as a water and energy efficient irrigation technique in horticultural crops [3,11]. Water management studies in Nagpur mandarin show that optimum soil water regime under drip irrigation could increase its growth and yield to a better extent [8, 9]. Also mulching by plastic polythene [4, 6] and deficit irrigation [7, 10] had proved their effectiveness in conserving the soil moisture and increasing the growth, yield and quality of different citrus cultivars. However, the information on rainwater harvesting and recycling it through drip irrigation and mulching for citrus is meager. Keeping this in view, a study was undertaken to evaluate the performance of rainwater harvesting and recycling the harvested water through drip irrigation and plastic mulch in Nagpur mandarin. The impact of rainwater harvesting on groundwater of the study site was also studied.

MATERIAL AND METHODS

The experiment was carried out at research farm of National Research Centre for Citrus, Nagpur, India during 2006-09 on one-year-old Nagpur mandarin plants budded on rough lemon root stock with 6 × 6 meter plant spacing. The treatments imposed were T_1: continuous bunding, T_2: continuous trenching, T_3: staggered trenching between rows and control (C): without any soil and water conservation measure, in randomized block design with seven replications in blocks of size 36×18 m^2 on slope of 4.2%. The soil type was clay loam with field capacity and permanent wilting point of 24.8% (weight basis) and 15.7% (weight basis) respectively. Runoff was measured through multi-slot divisor and well-stirred runoff samples were collected for estimation of sediment yield and nutrients loss after each rainfall under different treatments. Runoff sample analysis consisted of alkaline $KMNO_4$ distillation for available N, $NaHCO_3$ (pH 8.3) extractable-

P as Olsen-P, *1N* neutral NH_4OAc – K [13]. The moisture content at 0-30 cm depth was recorded each week by neutron moisture probe (Troxler model-4300) in various treatments.

A water harvesting tank of size 35m×35m×3m was constructed in 2005. Prior to construction of the tank, the groundwater level in the wells present in the orchards were taken. The plants were irrigated by groundwater in initial years (2003–2005). The irrigation systems studied in the orchards were traditional surface irrigation and drip irrigation with and without mulch and compared with rain-fed treatment. After construction of the tank, the harvested water was used at the best level of drip irrigation (60% of pan evaporation) with black plastic mulch (100 micron thickness). Mulching was done by one piece of 1.0 m × 1.0m size polythene sheets on each tree basin keeping the tree at the centre in 1ha of Nagpur mandarin. The harvested water also recharged the groundwater and water from wells was used for irrigation purpose after drying of tank during May and June. The volume of water required was computed using the equation:

$$V = Ep \times Kc \times Kp \times Wp \times (\pi D^2/4) \tag{1}$$

where:

V [l] - daily volume of water per plant,
Ep [mm] - cumulative pan evaporation for two consecutive days,
Kc [-] - crop factor,
Kp [-] - pan factor,
Wp [-] - wetting factor,
D [m] - canopy diameter observed at noon.

The crop factor was taken as 0.6 and pan factor as 0.7 in winter and 0.8 in summer as per FAO-24 [1]. Recommended dose of fertilizers was applied. The vegetative growth parameters such as plant height, stem height, canopy diameter, stock and scion girth were measured and their incremental magnitudes under different treatments were compared.

The fruits were harvested from each plant and their weight was measured to estimate the yield in different treatments. Five fruits per tree were taken randomly for determination of fruit quality (juice percent, acidity and total soluble solids) parameters. Juice was extracted manually by juice extractor and it's percent was estimated on weight basis with respect to fruit weight. The total soluble solid (*TSS*) was determined by digital refractometer and acidity was measured by volumetric titration with standardized sodium hydroxide, using phenolphthalein as an internal indicator. The economics of citrus cultivation under different treatments was determined by the indices such as net return and benefit-cost ratio (*B/C*). The data generated were subjected to analysis of variance (ANOVA), and significance of the data within the treatments was determined using SAS-9.2 statistical software.

RESULTS AND DISCUSSION

Runoff, soil and nutrient conservation. The mean annual rainfall, runoff and soil loss observed under different treatments indicated that the maximum runoff (38.15%) and soil loss (4.98 t·ha^{-1}) occurred in control, whereas the minimum (runoff 27.3%; soil loss 3.74 t/ha) was under continuous trenching, followed by continuous bunding (Tab. 1). The runoff and soil loss, occurred under staggered trenching, were 10 and 6% lower over control. Continuous trenching conserved the maximum runoff (28.4%) and soil (24.9%) among the conservation measures over control due to higher runoff conservation in trenches between the rows.

The analysis of runoff samples under different treatments for available N, P and K (Tab. 1) showed that all the nutrients loss was maximum in control (1.08 kg N·ha^{-1}, 0.24 kg P·ha^{-1} and 2.08 kg K·ha^{-1}), and lowest in continuous trenching (0.62 kg N·ha^{-1}, 0.13 kg P·ha^{-1} and 1.09 kg K·ha^{-1}) followed by continuous bunding. The lowest nutrients loss under continuous trenching was attributed to the lowest soil loss. Due to heavy loss of upper fertile soil through runoff, the nutrient concentration in eroded soil was invariably higher than the original soil, irrespective of the treatments.

Table 1. Runoff, soil and nutrients loss under different soil and water conservation measures in Nagpur mandarin

Treatment	*Run off (mm)*	*Soil loss (t/ha/yr)*	*Nutrients loss (kg·ha^{-1})*		
			N	*P*	*K*
Continuous bunding	*263 (28.8)****	*4.11*	*0.75*	*0.15*	*1.24*
Continuous trenching	*249 (27.3)*	*3.74*	*0.62*	*0.13*	*1.09*
Staggered trenching	*313 (34.3)*	*4.67*	*0.87*	*0.17*	*1.57*
Without conservation measure (Control)	*348 (38.15)*	*4.98*	*1.08*	*0.24*	*2.08*

***ARF, Annual Rainfall, ***Figures in parenthesis indicate runoff as % of mean annual rainfall.*

Soil moisture variability and groundwater recharge. The mean monthly moisture content at 0-30 cm soil profile revealed that the soil moisture status improved considerably in various conservation treatments over control (Tab. 2).

*Table 2. Soil moisture content (%, v / v) at 0.30 m depth under different soil and water conservation measures in Nagpur mandarin**

Treatment	*Month*								
	Oct.	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*Jun.*
Continuous bunding	*28.33*	*28.26*	*27.94*	*26.76*	*28.24*	*27.45*	*26.45*	*26.15*	*24.25*
Continuous trenching	*30.52*	*30.31*	*28.86*	*28.45*	*30.37*	*27.75*	*26.57*	*26.35*	*24.55*
Staggered trenching	*24.36*	*24.18*	*23.85*	*23.74*	*25.69*	*26.92*	*25.88*	*24.20*	*23.43*
No conservation (Control)	*23.63*	*23.38*	*21.84*	*21.54*	*23.46*	*25.88*	*23.85*	*22.80*	*22.33*
***CD (P=0.05)*	*NS*	*1.92*	*2.21*	*2.40*	*2.97*	*NS*	*NS*	*NS*	*NS*

***CD, Critical difference at 5% probability, NS, Not significant.*

Among different treatments, the highest soil moisture content (24.55-30.52%, v/v) was observed under continuous trenching followed by continuous bunding (24.25-28.33%, v/v). The moisture content under staggered trenching was 23.43-26.92% (v/v) in various months. The higher moisture content in continuous trenching was due to maximum rainwater conservation during the rainy period. The moisture content under various conservation measures and control reduced with time, except during the month of February, due to some unseasonal rainfall (11 mm) in the month. This was due to more consumptive use of water by the plants under increased soil moisture content under various conservation treatments. Moreover, the moisture content under different treatments did not vary significantly at the initial period (October) of observation. But during the period between November and February, the moisture content under various conservation measures was significantly higher over control.

The groundwater level in the wells present in the orchards was increased by 1.5-2.3 m after construction of water harvesting tanks compared to water level before construction.

Vegetative growth, yield, fruit quality and economics. The incremental growth of vegetative parameters viz., plant height, canopy volume, and stem girth (Tab. 3) showed that all the parameters were significantly higher under various conservation measures over control. The highest magnitude of the incremental plant growth parameters was observed in continuous trenching. Similarly, all the conservation measures produced higher fruit yield (7-29%) with better fruit quality over control. The highest fruit yield (9.60 kg/plant) was observed in continuous trenching. Quality assessment of fruits showed that the juice contents (40.42%) and *TSS* (10.10 ^{0}Brix) were significantly higher under continuous trenching treatment. The higher vegetative growth and fruit yield with better fruit quality in various conservation measures was due to better availability of soil moisture to mandarin plants during flowering and fruiting stages during the post-monsoon period.

Table 3. Incremental vegetative growth, fruit yield and fruit quality of Nagpur mandarin under various soil and water conservation measures

Treatment	*Vegetative growth*			*Fruit yield*			*Fruit quality*		
	PH (m)	*SG (cm)*	*CV (m^3)*	*Per plant*	*Weight (g)*	*Yield (kg/plant)*	*Juice (%)*	*Acidity (%)*	*TSS (^{0}Brix)*
Continuous bunding	*0.28*	*2.23*	*0.76*	*65*	*136*	*8.88*	*39.3*	*0.83*	*10.00*
Continuous trenching	*0.35*	*2.40*	*0.85*	*69*	*139*	*9.60*	*40.4*	*0.82*	*10.10*
Staggered trenching	*0.24*	*1.80*	*0.56*	*59*	*135*	*7.98*	*37.6*	*0.84*	*9.98*
No conservation (Control)	*0.19*	*1.35*	*0.40*	*55*	*135*	*7.43*	*35.4*	*0.86*	*9.94*
CD (P =0.05)	*0.08*	*0.3*	*0.03*	*2.5*	*NS*	*0.31*	*3.6*	*NS*	*0.05*

PH: Plant height, SG: stem girth, TSS: Total soluble solids, # CD: Critical difference at 5% probability

The economics of citrus production (Tab. 4) under continuous trenching, water harvesting tank, drip irrigation and mulch was found superior (net return Rs. 1.8 and B/C, 2.0) compared to that under rain-fed condition (net return: Rs. $1.1 \cdot 10^5$, B/C, 1.7)

Table 4. Economics of citrus cultivation under rainwater harvesting and drip irrigation

Treatments	*Yield ($t \cdot ha^{-1}$)*	*Gross return (10^5Rs.)*	*Net return (10^5Rs.)*	*B/C*
#RWHT + CT + DI + Mulch	*13.0*	*2.4*	*1.8*	*2.0*
Rain-fed system	*8.5*	*1.5*	*1.1*	*1.7*

#RWHT: rainwater harvesting tank,
CT: continuous trenching; DI: drip irrigation

CONCLUSIONS

Continuous trenching was found to be a superior soil and water conservation technique for cultivation of Nagpur mandarin. The method warrants it's adoption in mandarin orchards of Central India and elsewhere having similar agro-pedological conditions. Moreover, the citrus cultivation under continuous trench, drip irrigation and plastic mulch using water from rainwater harvesting tank was found more productive and economical compared to rain-fed citriculture in central India. The technique therefore suggested to be adopted in the study region and elsewhere having similar agro-climates for improving the quality production of citrus without bringing any sizeable reduction in soil fertility.

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UNAPREĐENJE PRODUKTIVNOSTI CITRUSNIH VOĆNJAKA SAKUPLJANJEM KIŠNICE I MIKRO-IRIGACIJOM U SUB-HUMIDNOM REGIONU

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Sažetak: Nedostatak vode je jedan od najvažnijih faktora koji utiču na smanjenje produktivnosti citrusnih voćnjaka. Nejednak raspored kiše u vremenu i prostoru uzrokuje značajan gubitak vode u tropima. Visok gubitak u periodu monsuna i nedostatak zemljišne vlage posle monsuna smanjuje prinos voćnjaka. Sakupljanje kišnice i njena efikasna upotreba u voćnjacima je hitna potreba održivog uzgoja citrusa. Ova studija je ispitivala izvodljivost skupljanja kišnice i njene upotrebe za navodnjkavanje voćnjaka. Ispitivani su različiti načini čuvanja kišnice u citrusnim voćnjacima centralne Indije u periodu 2006-2009. Neprekidni rovovi dali su najbolji rezultat sa 38% sačuvane kišnice i 32.28% zemlje uz 15.7% veći prinos i kvalitet voća. Pored toga, kišnice sa 3.2 hektara terena sa neprekidnim rovovima sakupljana je u rezervoar dimenzija 35m×35m×3m i korišćena za navodnjavanje kap po kap sa crnim plastičnim malčom na 1ha Nagpur mandarina. Sakupljenom vodom takođe su dopunjavani okolni podzemni izvori, a voda iz ovih izvora je zatim korišćena za navodnjavanje tokom sušnog perioda. Konačno, prinos voća je povećan do 110% uz poboljšanje kvaliteta voća. Ova studija je pokazala da se kombinovana upotreba skupljanja kišnice i navodnjavanja kap po kap, sa plastičnim malčom, može preporučiti za postizanje održive proizvodnje citrusa u regionima koji imaju slične agro-klimatske uslove kao region koji je ispitivan.

Ključne reči: *citrusi, sakupljanje vode, mikro-irigacija, prinos*

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DEVELOPMENT OF SOIL PROFILE TEMPERATURE PREDICTION MODELS FOR BARE AND SOLARIZED FIELD CONDITIONS

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Abstract: Soil solarization is a simple and effective technique for controlling problems like weeds and soil borne pathogens by means of increasing moist soil temperature through trapping heat by using the thin transparent polyethylene sheet for few weeks. The soil temperature models 'SOILTEMP' were developed to predict the diurnal variation of soil profile temperature at various depths for solarized (mulch covered) and bare soil by incorporating different types of input data. The accuracy of models was evaluated using model efficiency coefficient (*E*). Except for bare soil at 15 cm depth, positive values of *E* were obtained whereas at 15 cm depth for bare soil negative *E* values of *E* were observed. The highest *E*=0.92 was obtained at 5 cm depth for solarized soil and weekly average data whereas lowest one (*E*= 0.39) obtained at 10 cm depth for bare soil and biweekly data. The developed models will be useful to predict the soil profile temperature and to study the effect of various input parameters to achieve desired effect of soil solarization without conducting the experiments and thereby to save cost and time.

***Key words**: soil solarization, soil profile temperature, energy balance equations, mathematical models, model efficiency.*

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INTRODUCTION

Soil solarization, involves the use of sun heat as a lethal agent for pest and weed control through the use of transparent thin (25 micron) polyethylene sheet for capturing the solar energy, has potential advantages. It is non-chemical method hence not hazardous to the user and does not involve substances toxic either to consumer or host plant or other organisms. Soil temperature also has direct effect on biological process like seed germination, seeding emergence and growth, root development, nutrient and water uptake and the microbial activity. Further, it is less expensive than other methods and easy to implement in large or small areas.

Soil temperature prediction simulation models are very useful to the users to predict the soil profile temperature under solarized and non-solarized conditions using the various weather, soil and polyethylene mulch input parameters which could save cost and time for conducting the experiment. Many researchers [1,5,6,8] studied the soil profile temperature characteristics for bared and solarized conditions and its benefits. The soil was covered with transparent plastic sheeting prior to planting increased the soil temperature 5cm below the surface by 12°C. They found that 40°C could be maintained for 119 hours under solarized condition whereas for uncovered control plot it could never achieved. The highest and lowest temperatures were found to be 51° and 27°, respectively, for covered soil and 39° and 23°, respectively, for the control plot [9]. The Maximum temperature in upper soil layers under ideal conditions was achieved within 3-4 days after solarization. Typical maximum soil temperature in solarization plots was 8-12 ^{o}C higher than the corresponding non-solarized plots [4].

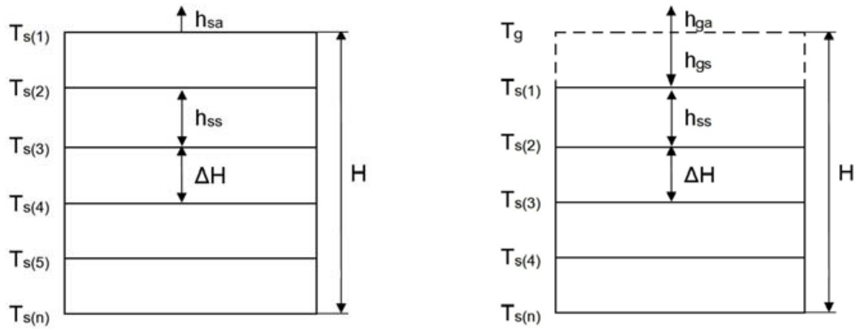
The soil temperature simulation models 'SOILTEMP' were developed to predict the soil profile temperature at various depths and different time interval under solarized (mulch covered) and non-solarized (bare) conditions. The models can be used to study the effect of weather parameters, soil properties and mulch properties on soil profile temperature.

MATERIAL AND METHODS

Theoretical Analysis

Fig. 1 shows the various heat transfer coefficients occurring at different components of the soil profile system considered for the study i.e. at transparent glazing, soil surface and subsequent layers of the soil profile. The mathematical models were developed by writing the energy balance equations for different components of the soil solarization system and solving it by adopting the finite difference technique. The computer program in FORTRAN language was prepared to obtain predicted results. The following assumptions were made for the development of mathematical models.

1. There is no heat loss perpendicular to the direction of flow of heat in the soil.
2. The heat flows in the soil profile among soil particles through conduction only.
3. The properties of plastic sheet and soil profile remains unchanged with time lapse.
4. The soil bed consists of number of thin layers stacked upon each other.



a. Uncovered *b. Covered*

Figure 1. Schematic view of the soil profile temperature prediction system for uncovered (a) and transparent polyethylene covered (b) conditions

Energy Balance Equations

1. Uncovered soil

For surface layer

$$\Delta H\ \rho_s C_s(1\text{-}\varepsilon)\ dT_{s(1)}/dt = \alpha_s I - h_{as}(T_{s(1)}\text{-}T_a) - K_s/\Delta H\ (T_{s(1)}\text{-}T_{s(2)}) \quad (1)$$

Where:

ΔH	[m]	- spacing between two successive soil layers,
H	[m]	- depth of soil bed,
ρ	[$kg\cdot m^{-3}$]	- density,
C	[$J\cdot kg^{-1}{}^\circ C^{-1}$]	- specific heat,
ε	[-]	- porosity, decimal,
T	[°C]	- temperature,
t	[sec]	- time,
α	[-]	- solar absorbance,
I	[$W\cdot m^{-2}$]	- solar flux,
h	[$W\cdot m^{-2}{}^\circ C^{-1}$]	- heat transfer coefficient,
K	[$W\cdot m^{-1}{}^\circ C^{-1}$]	- thermal conductivity,

For subsequent layers (I=2,n)

$$\Delta H\ \rho_s C_s(1\text{-}\varepsilon)\ dT_{s(1)}/dt = h_{ss}(T_{s(I\text{-}1)}\text{-}2T_{s(I)}+T_s(I+1)) \quad (2)$$

2. Covered soil

For glazing

$$M_g C_g dT_g/dt = \alpha_g I + h_{sg}(T_{s(1)}\text{-}T_g) - h_{ga}(T_g\text{-}T_a) \quad (3)$$

Where:

M [$kg\cdot m^{-2}$] - mass,

For surface layer of soil

$$\Delta H\ \rho_s C_s(1\text{-}\varepsilon)\ dT_s(1)/dt = \tau_g \alpha_s I - h_{sg}(T_{s(1)}\text{-}T_g) - h_{ss}(T_{s(1)}\text{-}T_{s(2)}) \quad (4)$$

For subsequent layers of soil (I=2,n)

$$\Delta H\ \rho_s C_s(1-\varepsilon)\ dT_{s(I)}/dt = h_{ss}(T_{s(I-1)} - 2T_{s(I)} + T_s(I+1)) \qquad (5)$$

3. Boundary conditions

$T_g(0) = T_s(1)$, and
$T_s(H,0) = T_a(1)$

Heat Transfer Coefficients

The various heat transfer coefficients i.e. radiative and wind related convective heat transfer coefficients, h_{ga} and h_{as}; the radiative and natural convective heat transfer coefficient, h_{sg} and the conductive heat transfer coefficients between soil particles, h_{ss} were calculated by using the standard heat transfer relations given by [2].

Input Parameters

For the numerical calculations, weather parameters i.e. solar radiation and ambient temperature and properties of soil were measured whereas the properties of polyethylene mulch were obtained from the manufacturer's catalog and literature.

Weather Data: The daily hourly variation in ambient air temperature (T_a) and solar flux during the experimental period (11-25 May) at Junagadh (21.52° N, 70.47° E), Gujarat, India were measured by using copper constant *K*-type thermocouple wire sensor and pyranometer sensors attached with the computerized DT-600 Data-Taker data logger. The hourly average data for typical day (19th May), weekly average (11-18 May) and biweekly i.e. 15 days average (11-25 May) are presented in Fig.2.

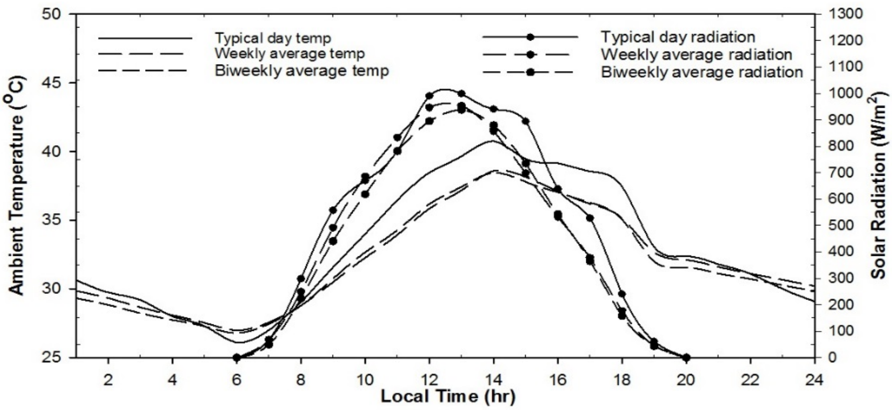


Figure 2. Average hourly weather data for the month of May in Junagadh.

Physical properties of soil: The soil samples from three locations of each experimental plots were drawn by using the core-cutter just before covering of plastic sheet and just after removal of the *PE* sheet. The samples were analyzed for evaluating the physical properties i.e. moisture content, bulk density, particle density, and porosity.

The moisture content of soil samples was determined using the hot air oven method. The bulk density of soil was calculated on the basis of weight of the sample and volume of core cutter. Particle density was determined by using picnometer method. Based on bulk and particle density the porosity of soil samples was calculated. The relationship between bulk density, porosity and moisture content and porosity was established to incorporate into the model.

Optical and thermal properties of soil: The values of optical properties of the soil i.e. absorbtivity (α_s) and emissivity (ε_s) were considered as 0.7 and 0.9 respectively. The thermal properties i.e. specific heat and thermal conductivity of soil were computed by using the following relationships.

Specific heat

$$C_{soil} = f_m\, C_m + f_o\, C_o + f_w\, C_w \tag{6}$$

Where:

$f_m = (1-\varepsilon)\, x$ - mineral content in solids

$f_o = (1-\varepsilon)\, x$ - organic matter content in solids

Thermal Conductivity

$$K_s = A + B\theta - (A-D)\, exp[-(C\theta)^E] \tag{7}$$

Where:

θ [-] - moisture content,

τ [-] - solar transmittance,

V [-] - volumetric fraction,

f [-] - fraction,

A, B, C, D and *E* are constants. The constants are calculated as follows:

$A = 0.65 - 0.78\, \rho_{soil} + 0.6\, \rho_{soil}^2$

$B = 2.8\, V_s\, \theta$

$C = 1.0 + 2.6 f_{cl}^{-1/2}$

$D = 0.03 + 0.7 V_s^2$

$E = 4.0$

Properties of mulch cover: Various properties of 25 micron polyethylene sheet i.e. bulk density, specific heat, solar radiation absorbtivity, transmissivity and emissivity were obtained from manufacturer catalog. These were considered as $\rho_s = 920$ kg·m^{-3}, $C_s = 2300$ J·kg^{-1}°C^{-1}, $\alpha_{tg} = 0.05$, $\alpha_{bg} = 0.9$, $\tau_{tg} = 0.85$, $\tau_{bg} = 0.85$, $E_g = 0.9$, respectively.

Experimental Details and Soil Profile Temperature Measurements

The soil and farmyard manure (*FYM*) were sieved to reject pebbles and debris and three beds of size 2.5 x 10 m were prepared. The beds were filled up to 20 cm depth with soil and *FYM* mixture (6:1 soil and *FYM*). These soil beds were moistened with help of shower and kept for overnight. Next day early morning clear transparent polyethylene sheets of 25 microns thickness were used to cover the beds. All the edges were buried in soil and compacted to prevent heat and soil moisture loss. First plot was kept uncovered considered as control while second plot was covered with 25 micron transparent polyethylene sheet for 15 days and third plot was covered for 30 days during the month of May at nursery of the department of Renewable Energy & Rural Engineering, Junagadh Agricultural University, Junagadh, Gujarat, India. Based on earlier study effect of 15 days solarization duration was found at par with 30 days duration at given location hence, in this study, input data of typical day, weekly average and biweekly average (15 days) were considered for the development of models. The hourly temperatures of soil profile at 5, 10 and 15 cm depths were recorded by using the *RTD* temperature sensors attached with data logger. The temperature characteristics i.e. diurnal variation of soil profile temperature for bare soil (uncovered) and transparent polyethylene mulch conditions have been studied.

Verification of Models and Efficiency

By using the developed mathematical models, the soil profile temperatures at respective depths were predicted and plotted against the time for uncovered and solarized conditions. The theoretical results were compared with experimental results to simulate the model.The efficiency of the developed mathematical models was calculated using model efficiency coefficient as given below (Nash and Sutcliffe,1970) [7]:

$$E = 1 - \frac{\sum_{i=1}^{n}(X_i - Y_i)^2}{\sum_{i=1}^{n}(X_i - \overline{X}_i)^2} \tag{8}$$

Where:
X [-] - observed data,
$\bar{X}$ [-] - mean of observed data,
Y [-] - predicted data.

RESULTS AND DISCUSSION

Effect of Moisture Content on Physical and Thermal Properties of Soil

The average moisture content on wet basis and bulk density of soil samples from control plot before covering and after removal of plastic sheet were found to be 26.55%, 1456 kg·m^{-3} and 19.22%, 1347kg·m^{-3} respectively whereas for 15 days soil solarization treatment plot, the similar observations were observed as 24.11%, 1450 kg·m^{-3} and 21.38% 1406 kg·m^{-3} respectively.

Table: 1 Relationship of moisture content and physical and thermal properties soil

Property	Relationship			
	Control	R^2	15 days	R^2
ρ_{soil}	$14.540\theta+1070.2$	1.0	$14.457\theta+1097.3$	1.0
ε	$58.964-0.5577\theta$	1.0	$57.343-0.5626\theta$	1.0
C_{soil}	$31.694\theta+1090.5$	1.0	$31.7\theta+1093.5$	1.0
K_{soil}	$0.2243 - 0.03510\theta + 0.0057\theta^2 - 0.000009\theta^3$	0.99	$0.2298-0.0338\theta+ 0.0056\theta^2 - 0.00009\theta^3$	0.99

The particle density of the above plots soil were found to be 2608 and 2572 kg·m^{-3} respectively. The relationship between moisture content and various physical and thermal properties are given in Tab. 1.

The porosity of the respective plot soil before and after soil solarization was found as 44.15%, 43.78%, and 48.25%, 45.31% respectively. The average specific heat and thermal conductivity of the soil samples of the above plots were calculated as 1816, 1814 J·kg^{-1}°C^{-1} and, 1.32, 1.31 W·m^{-1}°C^{-1} respectively.

Soil Profile Temperature Characteristics

The temperature characteristics of control (uncovered) and 15 days solarized (covered) soils for typical day (19th May) weekly average and biweekly average are presented in Fig. 3.

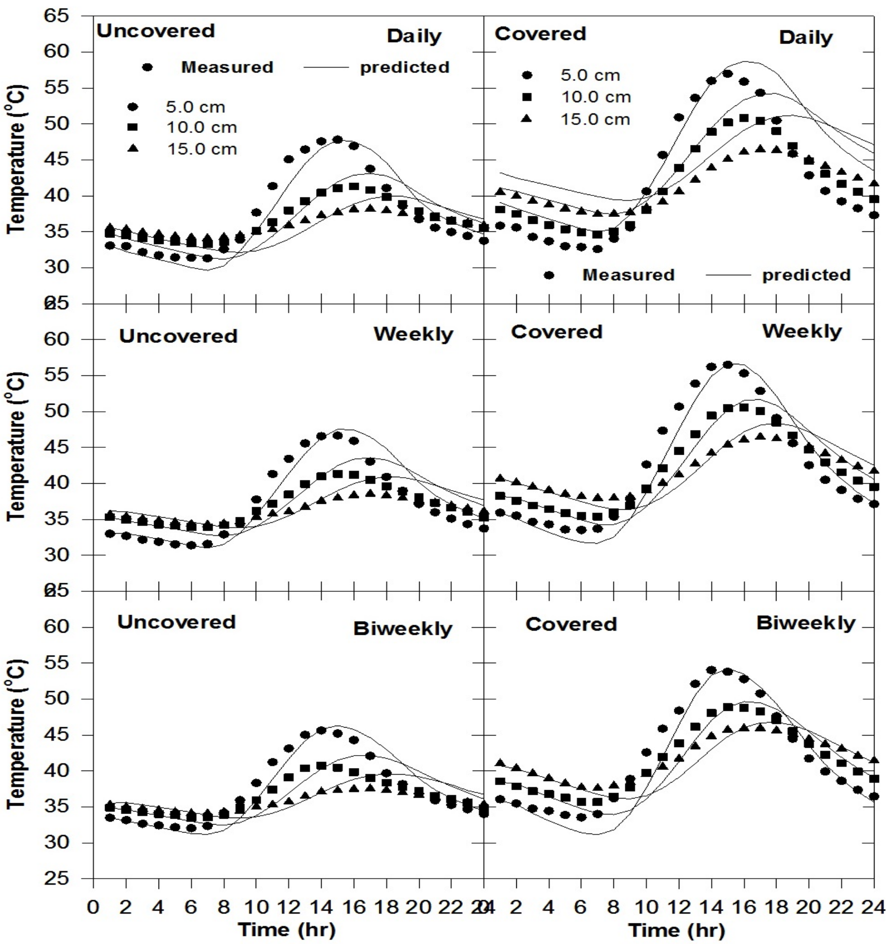


Figure 3. Measured and predicted soil profile temperature at different depths for covered and uncovered soil

The result shows that for both uncovered and covered soils, for 5 cm depth, temperatures were decreased steadily till 7.00 hour and then increased rapidly till 15.00-16.00 hours and again decreased for the remaining hours.

The similar trends were also observed for 10 and 15cm depths. However, with increase in depth, rise and fall of soil layer temperature was delayed by 1-2 hours as compared to its previous layer. The figures also show reverse trend during off-sunshine hours as that of sunshine hours. The results on temperature characteristics showed that the maximum temperatures of uncovered soil at 5.0, 10.0 and 15.0 cm depth on typical day were found to be 47.78^{o}C, 41.31^{o}C and 38.17^{o}C respectively whereas the minimum temperatures at given depths 31.29^{o}C, 33.28^{o}C and 34.10^{o}C respectively. The increment in maximum and minimum soil temperatures due to solarization (covering) at corresponding depths on typical day were found as 9.18^{o}C, 9.54^{o}C, 8.28^{o}C and 1.28^{o}C, 1.34^{o}C, 3.35^{o}C respectively. The similar trends were also observed for hourly variation in weekly and biweekly soil profile temperatures. The predicted soil profile temperature data obtained by using the mathematical model were fitted to the experimental data. A good agreement between experimental and predicted data was observed.

Verification and Efficiency of Models

The predicted data on hourly variation in soil profile temperature for typical day, weekly average and biweekly average obtained by using the mathematical models for uncovered and covered soils are plotted against experimental data (Fig. 3) to compare predicted and experimental results. From figures it can be seen that theoretical results have followed the similar pattern that of experimental results have. Thus, a good agreement with experimental data is obtained at all depths for different sets of input data. The effect of types of input data, depth of profile and solarization treatment on efficiency coefficient (*E*) for is presented in Tab. 2. From table it can be seen that for bare soil, values of E are very close to 1.0 at 5.0 cm depth followed by at 10.0 cm depth whereas at 15.0 cm depth negative values are obtained for all three types of input data.

Table 2. Model efficiency coefficient (E) for different sets of conditions

Sr. No.	*Type of input data*	*Bare field (control)*			*Solarized (mulch covered)*		
		5 cm	*10 cm*	*15 cm*	*5 cm*	*10 cm*	*15 cm*
1	*Typical day*	*0.88*	*0.59*	*-0.36*	*0.82*	*0.74*	*0.53*
2	*Weekly average*	*0.87*	*0.45*	*-0.12*	*0.92*	*0.90*	*0.78*
3	*Biweekly average*	*0.87*	*0.39*	*-0.41*	*0.90*	*0.86*	*0.75*

However, in case of solarization treatment, *E* values at 15 cm depth are found positive which indicates except for 15 cm bare soil, predicted hourly soil profile temperature data are in good match with experimental data and accuracy of the models is quite good whereas negative values indicates observed mean is a better predictor than the model. Values of *E* (except 15 cm depth) for bare soil varied between 0.87 and 0.39 whereas for soil soilarization treatment these values ranged between 0.92 and 0.53. Thus, soil temperature prediction model gave better accuracy for solarization condition as compared to bare soil. The effect of types of data on accuracy of model shows that weekly average input data has better accuracy followed by biweekly and typical day data. It can also be seen that soil profile depth has prominent effect on E values as compared to covering and types of input data.

CONCLUSIONS

From the above discussion it may be concluded that the developed SOILTEMP models can be effectively used to predict diurnal variation of soil profile temperatures at different soil profile depths for bare field (except for 15 cm depth) and solarized conditions using weather data of the location, physical, thermal and optical properties of the soil profile and mulch material. The accuracy of the models is significantly influenced by soil profile depth and mulch condition whereas types of data has little impact on accuracy of the developed models.

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Subscripts nomenclature

a ambient
g glazing
ga glazing-ambient
gs glazing-soil
(I)/i ith layer
cl clay fraction
m mineral
o organic matter

s soil/solid matter
sg soil-glazing
ss soil-soil
t transparent
(1) first layer

RAZVOJ MODELA ZA PREDVIĐANJE TEMPERATURE ZEMLJIŠNIH PROFILA U OGOLJENIM I OSUNČANIM POLJSKIM USLOVIMA

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Sažetak: Osunčanje zemljišta je jednostavna i efikasna tehnika za kontrolu problema kao što su korovi i patogeni koji nastaju u zemljištu, povećavanjem temperature vlažnog zemljišta zadržavanjem toplote tankom providnom polietilenskom folijom na nekoliko sedmica. Modeli zemljišne temperature "SOILTEMP" su razvijeni da bi se predvidele dnevne varijacije temperature zemljišnog profila na različitim dubinama za osunčano (pokriveno malčom) i ogoljeno zemljište uključivanjem različitih ulaznih podataka. Tačnost modela je ocenjivana upotrebom koeficijenta efikasnosti modela (*E*). Izuzev ogoljenog zemljišta na dubini od 15 cm, gde je dobijena negativna vrednost koeficijenta *E*, u ostalim slučajevima su dobijene pozitivne vrednosti. Najviša vrednost *E*=0.92 je postignuta na dubini od 5 cm na osunčanom zemljištu sa sedmičnim srednjim vrednostima, gde je najniža (*E*= 0.39) dobijena na dubini od 10 cm za ogoljeno zemljište i dvonedeljne podatke. Razvijeni modeli će biti korisni za predviđanje temperature zemljišnog profila i proučavanje uticaja različitih ulaznih parametara radi postizanja željenog efekta osunčanja zemljišta bez izvođenja ogleda, što smanjuje troškove i štedi vreme.

***Ključne reči**: osunčanje zemljišta, temperature zemljišnog profila, jednačine bilansa energije, matematički modeli, efikasnost modela.*

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MODELING THE MASS OF BANANA FRUIT BY GEOMETRICAL ATTRIBUTES

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Abstract: Mathematical modeling was done to predict mass of the banana fruit *var. Grand Nain* from the physical characteristics like length, width, thickness, volume, geometrical mean diameter, etc. Some physical properties of banana were statistically analyzed and their mean, standard deviation, error and coefficient of variance were presented. Models were divided into three classifications. Among the first classification model, empirical equation describing the length and width (model No. 4) predicts the mass with highest R^2 value. In the second classification, mass models of surface area (model No. 8) had a linear relationship with R^2 = 0.91. Highest R^2 value of 0.85 and 0.83 were found for mass models with true and ellipsoidal volume (models No. 9 and 10) respectively in the third classification.

Key words: *banana fruit, mass models, physical properties, dimensions, geometrical attributes*

INTRODUCTION

Physical properties of agricultural products play an important role in determining standards for designing grading, processing, conveying and packaging systems. The major physical properties of banana fruit are mass, volume, size, density, porosity, surface area etc. Of these properties like mass, projected area, volume, etc are the most important in designing grading system [22]. Surface area is important in indicating heat

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transfer rate, respiration rate, water loss, gas permeability per unit surface area, quantity of pesticide applied and ripeness index [4,10,22,23].

Mass grading of fruit becomes more essential and it is used to attain uniform weight, optimum packaging configurations, reduces packaging and transportation costs [16]. Fruits are often graded by size and it would be more economical and ease when it is graded by weight. Also the mass grading is recommended for the irregular shaped products. This makes the relationship between weight and the diameter more crucial.

In weight sorter, constant density fruits can be sorted based on their volume. Models suitable for sizing of the kiwi fruit were determined between mass, volume, projected area and length. Volume can be used to monitor yield during harvesting and to predict harvest time [6]. Measuring dimensions by a digital caliper causes human error and is not an efficient method to estimate volume. Mathematical models involving geometric mean diameter and some common methods like water and gas displacement method are used to determine volume of different fruits [14].

Many researchers formulated empirical equations and studied relationship between volume and surface area [3], mass, diameter and surface area [8,9,13] for different agricultural produces. Based on geometrical attributes, eleven models were recommended to predict mass of an apple [20]. Mass of an orange was predicted from its projected area and dimensions [21]. High correlations were obtained between mass and volume of Iranian grown potatoes [19] and all varieties of kiwi fruit [11]. Quality inspection such as citrus granulation test can be conducted based on density difference [14]. The objective of this study was to establish the models based on physical characteristics to predict mass of the banana fruit.

MATERIAL AND METHODS

Thirty matured bananas (*var.* Grand Nain) were manually harvested and conducted various experiments to determine physical characteristics. Electronic balance with an accuracy of 0.01 g was used to measure weight (M) of the banana. True volume (V) was measured by Platform scale method [5,12] and by assuming the banana fruit as ellipsoid, its ellipsoidal volume (V_{ell}) [17] and ellipsoidal ratio [23] was calculated using the Eq. (1) and (2).

$$V_{ell} = \frac{\pi}{6} * LWT \tag{1}$$

$$Ellipsoidal\ Ratio = \frac{W}{T} \tag{2}$$

Bulk density (BD) was determined by filling banana up to the neck of an empty plastic crate of known volume and then the mass of the banana contained was weighed. The mean length (L) was measured using a flexible ruler from outer (L_o) and inner length (L_i) of the banana fruit. The width (W) and thickness (T) were measured using a digital vernier caliper. Diameter at three ends (Stem, middle and apex) were measured by a digital vernier caliper with an accuracy of 0.01 mm and its mean diameter (D) was calculated. Geometric mean diameter (D_g) and arithmetic mean diameter (D_a) was calculated using Eq. (3) and (4) respectively [2,12].

$$D_g = \sqrt[3]{LWT} \tag{3}$$

$$D_a = \frac{(LWT)}{3} \tag{4}$$

Surface area (S_g, cm^2) was calculated by graphical method [12]. Estimated or apparent surface area was calculated from the Eq.(5) and (6) given by [7,15].

$$S = \frac{\pi B L^2}{2L - B};\ B = (WT)^{0.5} \tag{5}$$

$$S = \pi D_g^2 \tag{6}$$

All experiments were analyzed for mean, standard deviation (*SD*), standard error (*SE*) and coefficient of variance (*CV*) in Spreadsheet software, Microsoft EXCEL 2007. To predict mass of the banana from dimensional properties and volume, three categories of models were considered as shown below:

1. Single or multiple regressions of mass (*M*) with dimensional properties like length (*L*), width (*W*), thickness (*T*) and geometrical mean diameter (D_g).
2. Single regression of mass (*M*) of banana fruit based on surface area (S_g).
3. Single regression models to predict mass of banana fruit from true volume (*V*) and ellipsoidal volume (V_{ell}).

In the first category model, mass was predicted by the independent variables: length, width, thickness and geometrical mean diameter.

$$M = K_1 L + K_2 W + K_3 T + K \tag{7}$$

$$M = K_1 D_g + K \tag{8}$$

In the second category model, mass (*M*) was estimated as a function of surface area (S_g).

$$M = K_1 S_g + K \tag{9}$$

In the third classification, mass (*M*) of the banana fruit was modelled with actual (*V*) and ellipsoidal volume (V_{ell}).

$$M = K_1 V + K \tag{10}$$

$$M = K_1 V_{ell} + K \tag{11}$$

In all the five equations, K_1, K_2 and K_3 indicates coefficient of independent variable and *K* is the constant. Modeling was done using SPSS 12 and the suitability of the model was selected based on the highest R^2 (coefficient of determination) and lowest *RMSE* (Root Mean Square Error) value.

RESULTS AND DISCUSSION

Some selected physical characteristics of the banana such as mass, true volume, bulk density, true density, geometric mean diameter, surface area etc. were presented in Tab. 1. Ten regression models classified into three categories were presented in Tab. 2.

Table 1. Physical properties of banana var. Grand Nain

S.No	Physical properties	Mean	SD	Min	Max	SE
1	Mass (M), g	139.65	7.66	126	154.29	1.47
2	True volume (V), cm^3	136.33	9.86	118	157.00	1.90
3	Ellipsoidal volume (V_{ell}), cm^3	117.92	9.09	98.15	131.33	1.75
4	Ellipsoidal ratio	1.08	0.02	1.05	1.12	0.00
5	Fruit density (TD), $g \cdot cm^{-3}$	1.03	0.03	0.98	1.11	0.01
6	Bulk density (BD), $g \cdot cm^{-3}$	0.41	0.03	0.35	0.46	0.01
7	Length (L), cm	16.99	0.71	15.45	18.20	0.14
8	Width (W), cm	3.78	0.08	3.61	3.91	0.02
9	Thickness (T), cm	3.50	0.10	3.31	3.68	0.02
10	Mean diameter, cm	3.56	0.18	3.25	4.04	0.03
11	Geometrical mean diameter (D_g),cm	6.08	0.16	5.72	6.31	0.03
12	Arithmetic mean diameter (D_a), cm	8.09	0.28	7.48	8.54	0.05
13	Surface area by graph (S_g) , cm^2	115.84	9.31	99.17	133.28	1.79
14	Surface area by Jean & Ball, cm^2	108.77	6.06	95.25	118.16	1.17
15	Surface area by McCabe, cm^2	116.20	6.04	102.9	124.93	1.16

Table 2. Mass models of banana var. Grand Nain

S.No	Models	K_1	K_2	K_3	k	R^2	RMSE
1	$M=K_1L+C$	8.79	-	-	-9.77	0.67	4.48
2	$M=K_1W+C$	66.59	-	-	-111.95	0.53	5.35
3	$M=K_1T+C$	57.44	-	-	-61.63	0.55	5.21
4	$M=K_1L+ K_2 W +C$	6.55	40.00	-	-122.88	0.82	3.39
5	$M=K_1L+ K_2 T+C$	6.22	29.44	-	-69.27	0.76	3.90
6	$M=K_1W+ K_2 T+C$	38.29	36.07		-131.42	0.65	4.69
7	$M=K_1L+ K_2 W +K_3T+C$	5.83	32.83	12.88	-128.62	0.83	3.34
8	$M=K_1D_g +C$	43.24	-	-	-123.29	0.82	3.33
9	$M=K_1D_a +C$	24.37	-	-	-57.57	0.76	3.81
10	$M=K_1S_g +C$	0.78	-	-	48.92	0.91	2.39
11	$M=K_1V+C$	0.72	-	-	42.09	0.85	3.03
12	$M=K_1V_{ell}+C$	0.77	-	-	49.37	0.83	3.27

Among the first category model (No. 1, 2, 3, 4, 5 and 6); model number 6 had the highest R^2 value as shown in Tab. 1. In order to predict the mass of the banana fruit using this equation, it is necessary to measure all the three variables like length, width and thickness. Measuring all the three parameters makes the system more tedious [1]. Hence the model No. 4 (Eq. 12) with the R^2 value of 0.82 can be used to predict mass of the banana fruit based on two (length and width) dimensional characteristics.

$$M = K_1L + K_2W + K;\ (R^2=0.82) \tag{12}$$

Mass can also be predicted (Eq. 13) well from geometrical mean diameter using the model number 7 as shown in Table 1. Relationship between geometric and arithmetic mean diameter of banana is shown in Fig. 1. From the Eq. 14, it is clear that the relationship between the two diameters fetches the coefficient of determination 0.90 and hence either the arithmetic mean or the geometric mean method can be used to calculate the equivalent diameter of banana.

$$M = K_1D_g + K;\ (R^2=0.82) \tag{13}$$

$$D_a = 1.632 * D_g - 1.836;\ (R^2=0.90) \tag{14}$$

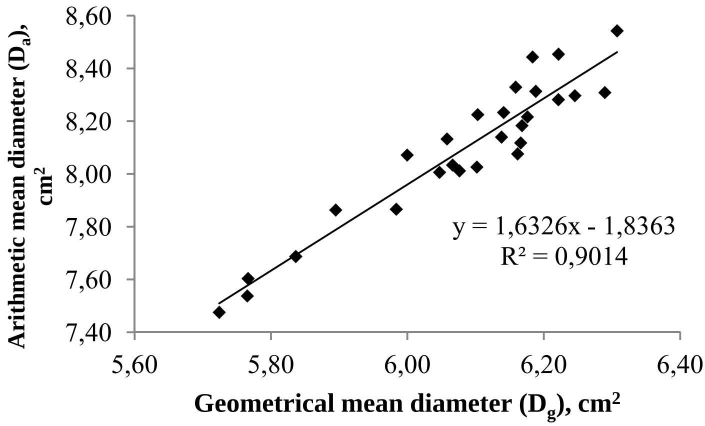


Figure 1. Relationship between geometric and arithmetic mean diameter

Model No. 8 of the second category model (Tab. 2) having the R^2 value of 0.91 shows the relationship between mass of the banana fruit and its surface area. The relationship between apparent and graphical surface area is illustrated in Fig. 2. The correlation between apparent and graphical surface area as demonstrated in Eq. 15 and 16 had the R^2 value of 0.88. This implies that there is a strong relationship between apparent and graphical surface area for the banana fruit (*var. Grand Nain*).

$$\text{McCabe method: } y = 0.598x + 46.22;\ (R^2 = 0.88) \tag{15}$$

$$\text{Jean and ball method: } y = 0.6x + 38.59;\ (R^2 = 0.88) \tag{16}$$

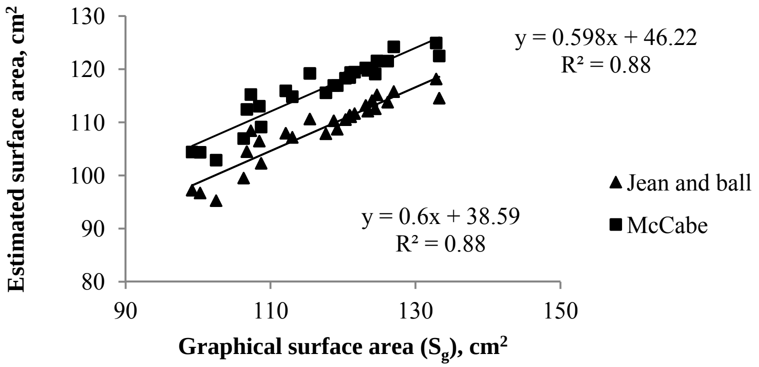
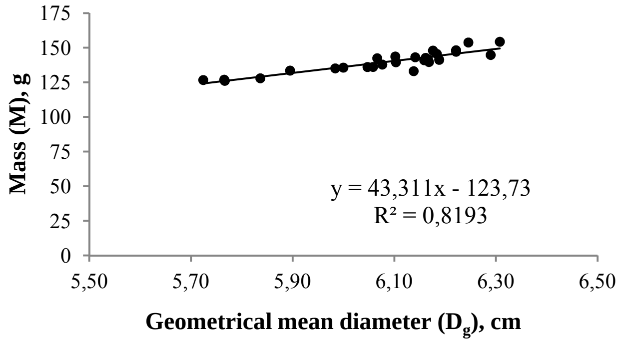
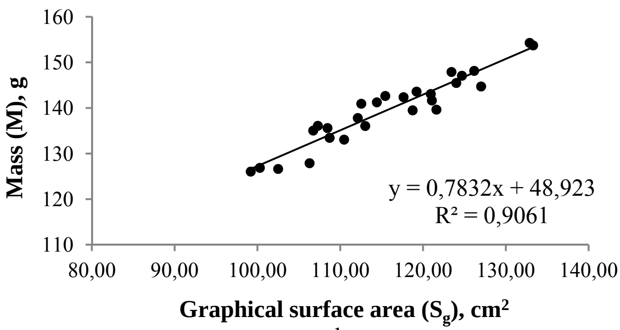


Figure 2. Relationship between graphical and estimated surface area

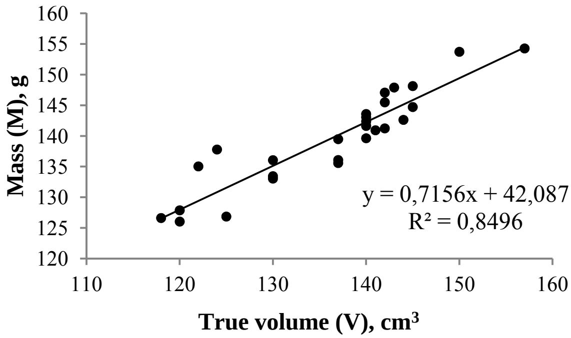
In the third model classification, model number 9 and 10 (Tab. 2) can be used to predict the mass of the banana fruit. This was clearly evident from the highest R^2 value of 0.85 and 0.83 for true and ellipsoidal volume of the banana fruit respectively. Fig. 3 depicts the relationship between mass, geometrical mean diameter, surface area by graph and true volume of the banana fruit.



a.



b.



c.

Figure 3. Relationship between mass, geometrical mean diameter (a), surface area (b) and true volume (c)

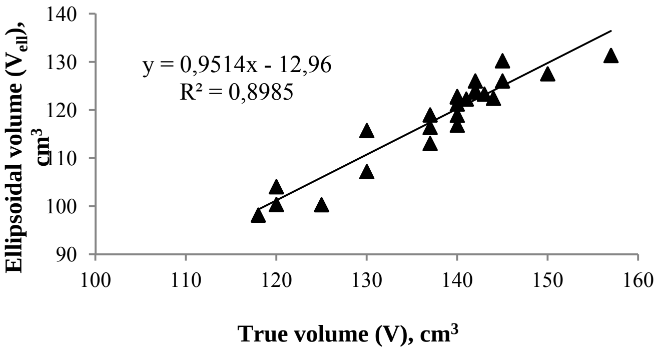


Figure 4. Relationship between true volume and ellipsoidal volume

$$V_{ell} = 0.951 \cdot V - 12.96; (R^2=0.898) \tag{17}$$

By assuming the volume of banana fruit as ellipsoid a linear relationship has been drawn as shown in Fig. 4. The high correlation coefficient (0.898) from the Eq. 17 confirms the shape of banana fruit as ellipsoid [18].

CONCLUSIONS

1. Some physical properties of banana fruit *var. Grand Nain* were presented.
2. All the three category models are in linear form.
3. The recommended equation (model No. 4) to estimate mass based on geometrical attributes (length and width) was found to be: $M = 6.55 \cdot L + 40 \cdot W - 122.88$; $R^2 = 0.82$.
4. The relationship (model No. 8) between mass and surface area was given by: $M = 0.78 \cdot S_g + 48.92$; $R^2 = 0.91$.

5. Good relationship was found between mass and measured volume of banana fruit with R^2 value of 0.85. The shape of the banana considered as ellipsoid was the most appropriate (model No. 10), since both the R^2 value of true and ellipsoidal was found to be approximately equal.

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MODELIRANJE MASE BANANA GEOMETRIJSKIM ATRIBUTIMA

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Sažetak: Matematičko modeliranje je izvedeno da bi se predvidela masa banana *var. Grand Nain* iz fizičkih karakteristika kao što su dužina, širina, debljina, zapremina, srednji geometrijski prečnik, itd. Neke fizičke osobine banana su statistički analizirane i predstavljene su njihove srednje vrednosti, standardne devijacije, greške i koeficijenti varijanse. Modeli su podeljeni u tri klase. U prvom klasifikacionom modelu empirijska jednačina opisuje dužinu i širinu (model br. 4) i predviđa masu sa najvišom R^2 vrednošću. U drugoj klasifikaciji, maseni modeli površine (model br. 8) imali su linearni odnos sa R^2 = 0.91. Najviša vrednost R^2 od 0.85 i 0.83 dobijene su u trećoj klasifikaciji za masene modele sa pravilnom i elipsoidnom zapreminom (modeli br. 9 i 10), redom.

Ključne reči*: banane, maseni modeli, fizičke osobine, dimenzije, geometrijski atributi*

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MANAGE-MANAGEMENT OF AGRICULTURAL COMPANY THROUGH MONITORING OF TOTAL COST OF MAINTENANCE TRACTOR

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Abstract: The development of enterprises should be viewed through the level built his own style of organization and management. Management has an obligation to build a system of internal control within the regular and continuous operations. This company would have a higher degree of security in their work and operated to with as little real risk. It has long been sought for the way in which management will better control the company managed. In this paper, the basic setting is to be based on research and data presented show the importance of monitoring the overall maintenance costs of the tractor (through monitoring labor costs on maintenance of tractors and spare parts *ISTIK* giving a total value of maintenance costs) and the value that is in the business records of companies, or book value. The aim of this study was to highlight the importance of showing the total cost of maintenance of the tractor as part of the functioning of the company and any future management decisions.

Keywords: *maintenance of tractors, book value, management.*

INTRODUCTION

Total business enterprise accompanied by a constant spending company resources, assets and labor of the workers. The goal of economics is to create value with rational spending. Tracking spending is a large area of the economy which must be approved by the company's management if it is to achieve positive results.

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To increase safety in their work management resorted to different methods of control. Depending on the desired level of system security, enterprise size and other criteria, a number of companies formed and internal audit, as a separate entity [1]. Internal control in most enterprises is built into the control function of the company. According to *COSO* (Committee of Sponsoring Organizations of the Tread way Commission) internal control is inherent in the way management runs the business [2]. Personnel must be trained and continuously trained, to all operations in the course of the current work processes performed in the manner prescribed in [3]. At the same time, the system of internal control system is the most important and most applied form of internal control. Solution of internal control is an integral part of risk management, and built-in management structure covering all areas of business enterprise [4].

Internal control is a process that is framed by the decisions of the Supervisory Board of the company, or management in order to obtain a reasonable belief on the achievement of objectives in the following areas: improving the efficiency of decision-making by management, increasing the reliability of financial reporting, preservation compliance with applicable laws and regulations and the protection of property [5]. New standards of internal audit control is defined as any activity undertaken by management, the Board or other persons in order to improve risk management and to increase the likelihood that the planned objectives achieved [6].

Management companies must consider and gain a true picture, especially on human resources at its disposal, which are the level of education, which are specialized and educational courses completed, they have a recognized national certification, and international certifications related to control functions in the company. After the first phase, followed by analysis of the other, and it refers to the cost of establishing internal controls, or the amount of the costs mentioned controls. In addition, must take into account and about:

- What do we want to achieve?
- How do you intend to achieve?
- What resources will except as to have available (its operating plans) and
- How successful runs in comparison with the plan [7].

Risk can be defined as the volatility of unexpected outcomes in value of assets or liabilities of interest [8]. Some authors point out that it is a known fact that inexperience and lack of qualifications of the employees have a major impact on the occurrence of errors and the same recommend revision of agricultural enterprises [9, 10]. Companies can use to engage other experts to financially reports had as large a dose of objectivity [11, 12]. At the end of the analysis elements of internal control, it should be noted that a company which does not have an effective program of successive planning probably will not have an effective development process. Professionalization of work, breaks autarchy production companies and affect the connection to the global society [13].

In addition, many authors emphasize the importance of harmonization and implementation of international accounting standards in all economic sectors, as well as the importance of establishing internal control in enterprises [14,15,16].

The above-mentioned approaches to internal control factors are the framework for the regulation of behavior within the company. A large number of agricultural enterprises should continuously monitor the costs, in order to be able to maximum profit. One way of monitoring the direct costs of the monitoring and maintenance costs. In this paper the authors present the fundamentals that are relevant to the average reader to understand the significance of the actual cost of maintenance of tractors and their continuous monitoring and analysis of the management.

MATERIAL AND METHODS

The survey was conducted in mid-2014, the specific Services Enterprise, whose name is not explicitly stated. It is a public utility company that is registered for public utility services, the second largest city in Serbia. It mainly performs tasks in the domain of agricultural activity. Essential tasks performed are related to the greening of green spaces, planting plants required by the founders, seedling plant material and other activities.

In their daily work uses a large number of working machines. There are very heterogeneous resources for the work. Uses a variety of tractors by power, age, once the word means are not uniform. This makes it difficult to monitor and enactment unique findings related to the technique with one hand.

Another important factor is that the company itself does not have a developed system of internal control functions. This clearly shows that the company does not ma procedures clear financial records of monitoring costs. This paper presents the views that refer to the actual recording and monitoring costs in a public company. Data were used to actually show the real state of public records enterprise. Shown raw data were systematized in a tabular format and show the real state primarily for monitoring maintenance costs of three different tractor by age, strength and opportunities for the use of shutters conditions. It is important to note that the company does not exist prescribed internal controls that reduce the risk to the business.

RESULTS AND DISCUSSION

The significance of this study is to show the proper way to establishing written procedures, facilitates the management of monitoring essential elements of fixed assets. In addition to technical performance, management must take into account that the production performed by the company to be monitored and analyzed continuously. But has the more methods, and this work is presented a practical application production monitoring with reporting to management. In Tab. 1 and 2, the authors gave processed real data in a tabular format the actual costs of maintaining the said tractor, giving the years of exploitation, as well as the carrying value by which a tractor every individual in the company.

In this paper clearly presents in Tab. 3, from which we can see that the total maintenance tractors in the two years of observation such that approximately 2.4 times greater than the carrying value in the accounts.

Another conclusion can management learn from those displayed tables, especially Tab. 3, which is the value maintenance youngest of the tractor, which is given in the table three in the third row higher than its carrying value in the Company.

Without going into the need for further comments value of maintenance, it can be concluded that a high amount of maintenance of the tractor. The aim of such research and the presentation was to point out that management be informed of all views and display and high costs of maintenance of the tractor. On the basis of these regular reports can make decisions such as: buying a new tractor, sale of existing entry in the repair and others. In Tab. 3 the authors present their total maintenance costs for a period of two years of observation.

Table 1. Total costs of maintaining the selected tractor in 2012th

No	Name of equipment	Total maintenance costs in 2012	First purchase and introduction of the business records	In operation of the tractor	Book value as on 31.12.2012
1	Tractor Tomo Vinkovic	222.680,62	1997.	15	0.00
2	Tractor TT 830 SA	150.609,39	2005.	7	0.00
3	Ecotraktor 21-communal	230.263,50	2012.	1	605.031,46

Table 2. Total costs of maintaining the selected tractor in 2013th

No	Name of equipment	Total maintenance costs in 2012	First purchase and introduction of the business records	In operation of the tractor	Book value as on 31.12.2012
1	Tractor Tomo Vinkovic	56.645,65	02.12.1997	16	0.00
2	Tractor TT 830 SA	250.346,98	25.07.2005	8	0.00
3	Ecotraktor 21-communal	300.757,61	24.12.2012	2	504.192,88

Table 3. Total costs of maintaining the selected tractor for the period 2012-2013

No.	Name of equipment	Total maintenance costs in 2012-213	Book value as on 31.12.2013.
1	Tractor Tomo Vinkovic	279.326,27	0.00
2	Tractor TT 830 SA	400.956,37	0.00
3	Ecotraktor 21-communal	531.021,11	504.192,88
Total		1.211.303.75	504.192,88

Management companies should introduce an internal control in the company in which performs the function of management, with the aim to increase the safety of the operation of the enterprise. The research points to the importance mainly to introduce procedures. The aim of all activities should be reducing risk and creating the conditions for which safer operations.

CONCLUSIONS

Based on the research it can be concluded that firms that do not have internal control, it is necessary to provide the conditions for the prompt implementation of the same. In particular the company does not have an internal control. Thus, there is a significant risk attached to properly track the cost of maintaining the tractor used in the operation. The study was conducted in a specific enterprise and application of research can be applied in a large number of medium and large enterprises, especially in the field of agriculture. Management after these studies, should be a familiar with the facts of the risk is primarily in the area of record keeping maintenance costs of tractors, but also with other risk to be able to take measures to eliminate risk situations.

The aim of this study was to show the importance of the introduction of control in managing the costs of maintaining tractors, primarily in terms of increased security management function of the company.

In order to realistically eliminate the risks associated with timely information management in enterprises is necessary to adopt measures that will be introduced in the shortest period of internal controls and procedures that will affect the reduction of the above risks. If that happens, the company in the short term lapses into a real problem, especially if there is a drastic increase in the cost of maintenance of the tractor. Already during the presentation clearly shows the true picture of what the costs are and how many are greater than the carrying value of the tractor that the company uses in its work. This work and the practical points to the importance of introducing control mechanisms in the management of maintenance costs, especially in the monitoring of maintenance costs on older equipment in service.

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UPRAVJANJE MENADŽMENTA POLJOPRIVREDNOG PREDUZEĆA PREKO PRAĆENJA UKUPNIH TROŠKOVA ODRŽAVANJA TRAKTORA

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Sažetak: Razvoj preduzeća treba posmatrati preko stepena izgrađenog sopstvenog stila organizacije i upravljanja. Menadžment ima obavezu da izgradi sistem internih kontrola u okviru redovnog i kontinuiranog poslovanja. Time bi preduzeće imalo veći stepen sigurnosti u svom radu, odnosno poslovalo bi uz što manje realnog rizika. Dugo se tragalo za načinom na koji će menadžment bolje kontrolisati preduzeće kojim upravlja. U ovom radu osnovna postavka je da se na osnovu istraživanja i prezentovanih podataka prikaže značaj praćenja ukupnih troškova održavanja traktora (preko praćenja troškova rada radnika na održavanju traktora i rezervnih delova istih koji daju ukupnu vrednost troškova održavanja) i vrednosti koja je u poslovnim knjigama preduzeća, odnosno knjigovodstvene vrednosti. Cilj ovog rada je bio da ukaže na značaj prikazivanja ukupnih troškova održavanja traktora u sklopu funkcionisanja preduzeća i eventualnih budućih odluka menadžmenta.

Ključne reči: *troškovi održavanja traktora, knjigovodstvena vrednost, upravljanje*

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VISUAL PARAMETERS OF SOYBEAN (*GLYCINE MAX* L.) AS INFLUENCES BY MOLE DRAIN SPACING AND DEPTH IN VERTISOLS OF MADHYA PRADESH

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Abstract: Field experiments were conducted at farmer's fields in Hoshangabad district of Madhya Pradesh during 2010 to 2011 to assess visual parameters and profitability of soybean as influences by mole drain spacing and depth in temporary waterlogged vertisols of Madhya Pradesh. The mole drain spacing selected includes 2, 4, 6 and 8 m and these drains were formed at an average depth of 0.4, 0.5 and 0.6 m from ground surface. The average length of each lateral was 50 m and a 75 hp tractor was operated at a speed of 0.80 km·h^{-1} during the mole drain formation. Observation on physiological parameters like days to germination, days to 50% flowering, days to 75 % maturity were recorded visually for continuous two seasons, analyzed statistically. On the basis of the results obtained from the experiment, it can be concluded that mole drains at a spacing of 2 meter and at a depth of 0.4 meter was found optimal for better soybean profitability.

Key words: *drainage, drain spacing, drain depth, mole drains, soybean, vertisols*

INTRODUCTION

Mole drains are the pipe less drains formed with a mole plough exclusively in soils dominated with clay content. The spacing of mole drains are generally varies from 2 to 10 m. Although the spacing is related to soil texture in some countries in Eastern Europe, it is largely determined based on local experience in most countries [1]. However, it

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depends on the soil permeability and the necessity of drainage also. If the spacing is less than 2 m, there is a danger of damage of the previously constructed drain, where as if the spacing is greater than 5 m, the fissuring effect may not cover the intervening space. Local experience rather than the adopting a particular value determines the spacing of the mole drain. The length of mole channels depends on the grade of the mole drains formed, soil type, shape, size and topography of the field. Flat slopes require shorter drain. A balance has to be found between risk of scouring with high water velocities on deep grades and risk of pond and channel collapse at low grades in order to decide the length and grade of mole channel. In order to protect the outlet of mole drain, a small piece of approximately 1 m length PVC pipe is inserted at the outlet side of the drain. For longer life of mole drains, the timing of the installation is very critical. At the time of moling the soil at moling depth should be plastic and soil above this depth should be friable so that there is adequate traction and the soil will crack well from the leg slot to the soil surface. The ideal time for moling after one to two months after withdrawal of monsoon. Immediately after mole drains installation it would be better irrigate the field with sprinklers otherwise do not irrigate at all at least for a month, allowing the soil to ripen before the mole carries water. The useful life of mole channels varies from 2 to 10 years depending upon many factors. Success of moling depends on working with the correct soil type and installing the mole drainage at the right depth and spacing at a optimum moisture content i.e., near the lower limit of the ‘plastic’ range. The speed of operation of mole plough for mole drain formation is very important. Better mole drains are formed when the tractor speed is slow and steady. The generally recommended speed is less than 1.0 $km \cdot h^{-1}$.

Several researchers have studied the influence of mole drainage on crop production. [2] reported that the effects of different types of mole drains on some clay soil properties and wheat yield were tested in the study in heavy clay soil. Moles were composed of 3 different materials; compost, sand and mixture of compost with sand (1:1). Two depths of moles (0.3 and 0.5 m) and three distances among moles (10, 15 and 20 m) were investigated in this work. The results indicated that: The Piezometric head increases as the distance among moles increases and vice versa. At each mole spacing, the Piezometric head decreases as the time advances after irrigations. However, the 10 m mole spacing achieved the best significant results over the 15 and 20 m spacing. The highest yield (2737 $kg \cdot fed^{-1}$) was obtained by using compost, 10 m distance among moles and 0.5 m moles' depth. Decreasing distance among moles, increases yield penetration resistance (PR), hydraulic conductivity (Kh) and infiltration rate. Increasing mole depth, increases yield (Kh) and infiltration rate while decreases (PR).

[3] conducted the study in salt affected soils of Godavari western delta and concluded that sub-surface drainage technology has been very instrumental in achieving sustainable agricultural productivity levels in the saline-sodic soils of Godavari Western Delta that were badly affected by salinity and waterlogged situations and ECe of soils were reduced by 20.15% in surface soil and 28.58- 41.24% in sub surface soil indicating that desalinization of soil profile was taken place. They also concluded that the productivity levels of paddy were increased by 46% in kharif season and 50% in rabi seasons and sub-surface drainage technology is financially feasible, economically viable and cost effective with payback period of 2.18 years.

[4] reported that a system of subsurface drainage was implemented (simple drainage) and part of the site was equipped with mole drains (combined drainage) and

data from the two situations were used to calibrate the HYDRUS2D model and the dynamics of salt movement in the two situations were modeled. It was shown that high precipitation and low evapo-transpiration are important in controlling soil salinity. At the end of winter, both treatments presented Na+ concentrations of less than 1 $mg \cdot ml^{-1}$, but this value was close to 2 $mg \cdot ml^{-1}$ at the end of the irrigation period.

[5] examined the impact of pipeless drainage on soil properties and on soybean growth in Bangkok soils. The effects of pipeless drainage on soil physical and chemical properties were found to be very significant : basic infiltration rate increased by about 2.7 fold, porosity increased by 14% at 25 cm depth and by 19% at 40 cm depth, soil aeration improved markedly, saturated hydraulic conductivity increased by 34 fold at 25 cm depth and by 61 fold at 40 cm depth, and pipeless drains with liming showed along-lasting improvement in soil pH and EC in the lower soil profile. Because of these improvements in the soil properties it was found that the soybean crop responded very well to pipe less drainage. There was about 46% increase in grain yield and 118% increase in the dry matter per plant.

Four year (2004-2009) field experiment was carried out at Central Institute of Agricultural Engineering (CIAE), Bhopal feasibility of mole drainage for draining excess rain water in Vertisols and concluded that crop yields increased by about 50% in the mole drained plots as compared to the control, while the cost per ha for construction of mole drains at 2,4 and 6 m drain spacing were *Rs* 3200, *Rs* 1800 and *Rs* 1200 respectively [6]. [7, 8, 9] also reported an increase in crop yield due to pipeless drainage in Vertisol.

MATERIAL AND METHODS

The study area is located in the farmer's fields in the village Bamuriya in Hoshangabad district of Madhya Pradesh. The study area is situated between 22°37'30'' to 22°38'10'' N latitude and 77°39'30" to 77°40'59" E longitude with an altitude of 307 meters from mean sea level (*MSL*).

Table 1. Details of treatment combination for mole drains spacing and depths

Symbol	*Treatments detail for Soybean crop*	*Symbol*	*Treatments detail for Soybean crop*
T0	*S_0D_0 - Control*		
T1	*S_1D_1 (spacing 2 m + depth 0.4 m)*	*T7*	*S_3D_1 (Mole spacing 6 m + depth 0.4 m)*
T2	*S_1D_2 (spacing 2 m + depth 0.5 m)*	*T8*	*S_3D_2 (Mole spacing 6 m + depth 0.5 m)*
T3	*S_1D_3 (spacing 2 m + depth 0.6 m)*	*T9*	*S_3D_3 (Mole spacing 6 m + depth 0.6 m)*
T4	*S_2D_1 (spacing 4 m + depth 0.4 m)*	*T10*	*S_4D_1 (Mole spacing 8 m + depth 0.4 m)*
T5	*S_2D_2 spacing 4 m + depth 0.5 m)*	*T11*	*S_4D_2 (Mole spacing 8 m + depth 0.5 m)*
T6	*S_2D_3 (spacing 4 m + depth 0.6 m)*	*T12*	*S_4D_3 (Mole spacing 8 m + depth 0.6 m)*

The slope of the area is less than 1% with good drainage outlets. The dimensions of the mole plough designed and developed at *CIAE* include a leg with 1250 × 250 × 25 mm and a foot of 63 mm with 75 mm bullet or expander diameter. With a 3 point linkage the plough can be mounted on a wheeled tractor. The total weight of the plough was 75 kg. The treatments consisted of 13 combinations of mole drain spacing (4 levels) and mole drain depth (3 levels). The details of treatment combinations are given in Tab.

1. The mole drains installed 4 spacing (2,4,6 and 8 m spacing) at 3 depths (0.4,0.5 and 0.6 m depth) under a split plot designed experiment with 3 replications.

Following visual parameters were also recorded during soybean crop period:

Days to germination. Days to initiation of germination was recorded in each plot.

Days to 50% flowering. When flowering started the numbers of flowers plant/plot were counted in alternate days. At the time of 50% flowering stage the dates were recorded. Whenever to 50% plants of the total plants population of each plot reached flowering, the total number of days from sowing were counted and recorded.

Days to 75 % maturity. When pods started to mature the number of plants reaching maturity per plot were counted in alternate days. At the time of 75% pod mature plants, the dates were recorded.

Dry matter accumulation per plant. Dry matter accumulation per plant at 30, 45, 60 days after sowing and at harvest stage was recorded in each plots. Five randomly selected plants were uprooted and they were kept in oven at 65^0 C for 48 hours and then weighed. The data is converted on plant basis and analyzed.

Net monetary returns. Net monetary returns were obtained by subtracting cost of cultivation from gross monetary returns. Net monetary returns are considered to be a good indicator of suitability of a particular cropping system as this represents the accrued net income to the farmer.

Net monetary returns ($R_s \cdot ha^{-1}$) = Gross monetary return ($R_s \cdot ha^{-1}$) – Cost of cultivation ($R_s \cdot ha^{-1}$)

RESULTS AND DISCUSSION

Observation on physiological parameters like days to germination, days to 50% flowering, days to 75 % maturity content were recorded visually, analyzed statistically and presented in Tab. 2 and 3.

Non-significant differences were observed on days to germination, days to 50 % flowering and days to 75 % maturity due to different treatments of spacing and depth of mole drains and interaction of these two. Maximum values of all the parameters were observed under mole drain depth D_1: 0.4 m in most of the cases. As far as depth is concerned, maximum values of all the characters were recorded in almost under mole drain depth D_1: 0.4 m. No clear trends were observed in all the cases as spacing and depth of mole drains practices are concern.

Dry matter accumulation per plant (g). The data on dry matter accumulation per plant were recorded periodically at an interval of 15 days beginning from 30 DAS and analyzed statistically. The analysis of variance is given in Appendix VI. The mean dry matter accumulation per plant at different stages under different treatments is presented in Tab. 4, 5 and 6.

It can be seen from Tab. 4 and 5 that the dry matter accumulation per plant gradually increased with advancement of age of the crop. The maximum rate of increase was recorded between 30 and 60 DAS in almost all the treatments. Later on rate of increase in dry weight accumulation reduced. Among various mole drains spacing, the maximum dry matter on all the stages were recorded under mole drain spacing S_1: 2 m in both the years and in pooled data analysis. Minimum values of dry matter accumulation were observed in case of control followed by mole drain spacing S_4: 8 m. Influence on dry matter content when observed, it was recorded highest under mole drain depth of 0.4 m and lowest under mole drain depth D_3: 0.6 m in all the crop growth stages during the years 2010-11, 2011-12 and pooled data analysis.

Table 2. Effect of spacing (S) and depth (D) of mole drains on visual character of soybean at different growth and at harvest stages

Treatme-nts	Visual characters								
	Days to germination			Days to 50 % flowering			Days to 75 % maturity		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
Spacing of mole drains									
S_0: 0 m	4.67	4.33	4.50	41.73	39.27	40.50	96.67	98.33	97.50
S_1: 2 m	3.89	4.22	4.06	39.19	36.52	37.85	91.22	91.89	91.56
S_2: 4 m	4.33	4.11	4.22	38.99	37.56	38.27	92.11	91.89	92.00
S_3: 6 m	4.33	4.22	4.28	39.38	38.15	38.76	92.22	92.22	92.22
S_4: 8 m	4.22	4.44	4.33	39.36	37.91	38.63	93.44	93.11	93.28
SEm±	0.14	0.12	0.05	0.62	0.42	0.33	0.45	0.59	0.21
$CD_{5\%}$	NS	NS	0.16	NS	NS	NS	NS	NS	0.74
Depth of mole drains									
D_0: 0 m	4.67	4.33	4.50	41.73	39.27	40.50	96.67	98.33	97.50
D_1: 0.4 m	4.08	4.17	4.13	39.06	37.29	38.17	92.25	91.83	92.04
D_2: 0.5 m	4.25	4.25	4.25	39.23	37.47	38.35	92.25	92.42	92.33
D_3: 0.6 m	4.25	4.33	4.29	39.40	37.84	38.62	92.25	92.58	92.42
SEm±	0.23	0.12	0.16	0.48	0.31	0.32	0.42	0.33	0.25
CD5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3. Effect of interaction S X D on visual character of soybean at different growth and at harvest stages

Treatme-nts	Days to germination			Days to 50 % flowering			Days to 75 % maturity		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
S_0D_0	4.67	4.33	4.50	41.73	39.27	40.50	96.67	98.33	97.50
S_1D_1	3.67	4.00	3.83	38.93	36.30	37.62	90.00	91.67	90.83
S_1D_2	4.00	4.33	4.17	39.10	36.30	37.70	92.00	91.67	91.83
S_1D_3	4.00	4.33	4.17	39.53	36.96	38.25	91.67	92.33	92.00
S_2D_1	4.33	4.00	4.17	39.57	37.29	38.43	92.67	91.67	92.17
S_2D_2	4.33	4.00	4.17	38.53	37.82	38.18	92.00	92.00	92.00
S_2D_3	4.33	4.33	4.33	38.87	37.56	38.21	91.67	92.00	91.83
S_3D_1	4.33	4.33	4.33	38.87	38.94	38.90	92.33	91.67	92.00
S_3D_2	4.33	4.33	4.33	39.67	37.49	38.58	92.00	92.67	92.33
S_3D_3	4.33	4.00	4.17	39.60	38.02	38.81	92.33	92.33	92.33
S_4D_1	4.00	4.33	4.17	38.87	36.63	37.75	94.00	92.33	93.17
S_4D_2	4.33	4.33	4.33	39.60	38.28	38.94	93.00	93.33	93.17
S_4D_3	4.33	4.67	4.50	39.60	38.81	39.21	93.33	93.67	93.50
SEm=	0.22	0.32	0.17	1.10	1.10	0.80	0.71	0.88	0.53
$CD_{(5\%)}$	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4. Effect of spacing (S) and depth (D) of mole drains on dry matter accumulation of soybean at different growth and at harvest stages

Treatments	Dry matter accumulation (g)					
	30 DAS			45 DAS		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
Spacing of mole drains						
S_0: 0 m	2.11	2.02	2.06	6.54	6.61	6.58
S_1: 2 m	3.74	3.83	3.79	12.37	13.09	12.73
S_2: 4 m	3.58	3.63	3.61	11.73	12.50	12.11
S_3: 6 m	2.84	3.00	2.92	9.04	9.84	9.44
S_4: 8 m	2.47	2.54	2.50	7.60	7.85	7.73
SEm±	0.02	0.15	0.07	0.22	0.69	0.40
$CD_{5\%}$	0.07	0.52	0.25	0.76	2.40	1.39
Depth of mole drains						
D_0: 0 m	2.11	2.02	2.06	6.54	6.61	6.58
D_1: 0.4 m	3.30	3.41	3.36	10.55	11.41	10.98
D_2: 0.5 m	3.16	3.11	3.13	10.35	11.03	10.69
D_3: 0.6 m	3.02	3.22	3.12	9.65	10.02	9.84
SEm±	0.08	0.12	0.10	0.24	0.27	0.22
$CD_{5\%}$	NS	NS	NS	NS	1.07	0.85

Table 5 Effect of spacing (S) and depth (D) of mole drains on dry matter accumulation of soybean at different growth and at harvest stages

Treatments	Dry matter accumulation (g)					
	60 DAS			At harvest		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
Spacing of mole drains						
S_0: 0 m	9.41	9.07	9.24	13.98	14.72	14.35
S_1: 2 m	20.90	21.85	21.37	28.02	28.31	28.17
S_2: 4 m	19.20	18.54	18.87	25.94	26.61	26.28
S_3: 6 m	16.05	16.38	16.22	21.49	21.89	21.69
S_4: 8 m	12.62	12.61	12.61	18.78	19.11	18.95
SEm±	0.51	0.60	0.39	0.26	0.36	0.16
$CD_{5\%}$	1.76	2.08	1.35	0.90	1.26	0.55
Depth of mole drains						
D_0: 0 m	9.41	9.07	9.24	13.98	14.72	14.35
D_1: 0.4 m	18.16	18.99	18.58	24.59	24.77	24.68
D_2: 0.5 m	17.43	17.97	17.70	23.48	24.18	23.83
D_3: 0.6 m	15.98	15.06	15.52	22.60	23.00	22.80
SEm±	0.28	0.29	0.02	0.34	0.29	0.21
$CD_{5\%}$	1.11	1.13	0.09	1.32	1.13	0.84

A close of the data in Tab. 6 further reveals that at 30 DAS and 45 DAS the influence of spacing and depth of mole drains on dry matter was non-significant, but at later growth stages, the dry matter was affected significantly due to different spacing and depth of mole drains. It is also observed that maximum dry matter accumulation at 60 DAS and at harvest of crop was recorded highest with S_1D_1 (mole drains at the spacing of 2 m on the depth of 0.4 m), which was significantly superior to control. The differences in dry matter accumulation between S_1D_1 with S_1D_2 (mole drains at the spacing of 2 m on the depth of 0.5 m) and S_1D_3 (mole drains at the spacing of 2 m on the depth of 0.6 m) were found non-significant. Dry matter content per plant at both stages was found lowest in case of Treatment S_4D_3 (mole drains at the spacing of 8 m on the depth of 0.6 m) in both the years.

Table 6. Effect of interaction S X D on dry matter accumulation of soybean at different growth and at harvest stages

Trea-tment	30 DAS			45 DAS			60 DAS			At harvest		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
S_0D_0	2.11	2.02	2.06	6.54	6.61	6.58	9.41	9.07	9.24	13.98	14.72	14.35
S_1D_1	3.80	3.93	3.87	12.68	13.25	12.97	21.43	22.35	21.89	28.57	29.53	29.05
S_1D_2	3.51	3.57	3.54	12.49	13.33	12.91	21.19	21.97	21.58	27.80	27.97	27.88
S_1D_3	3.91	3.99	3.95	11.93	12.70	12.31	20.09	21.22	20.65	27.70	27.43	27.56
S_2D_1	3.75	3.54	3.65	11.97	13.06	12.52	20.27	21.00	20.63	26.80	26.43	26.62
S_2D_2	3.63	3.59	3.61	12.19	13.23	12.71	19.60	21.84	20.72	25.62	26.16	25.89
S_2D_3	3.36	3.76	3.56	11.02	11.21	11.12	17.73	12.77	15.25	25.40	27.25	26.32
S_3D_1	2.94	3.46	3.20	9.55	10.53	10.04	15.69	16.94	16.31	21.49	22.01	21.75
S_3D_2	3.07	2.87	2.97	9.29	10.15	9.72	15.95	17.06	16.50	21.68	22.91	22.30
S_3D_3	2.49	2.66	2.58	8.28	8.84	8.56	16.52	15.15	15.83	21.31	20.75	21.03
S_4D_1	2.70	2.72	2.71	8.01	8.82	8.41	15.27	15.69	15.48	21.51	21.11	21.31
S_4D_2	2.42	2.40	2.41	7.41	7.40	7.41	12.97	11.02	11.99	18.84	19.67	19.25
S_4D_3	2.30	2.48	2.39	7.37	7.34	7.36	9.61	11.12	10.36	15.99	16.57	16.28
SEm=	0.27	0.20	0.19	0.64	0.81	0.60	0.64	0.98	0.54	0.68	0.73	0.46
$CD_{(5\%)}$	NS	NS	NS	NS	NS	NS	1.98	3.03	1.65	2.10	2.26	1.41

The Tab. 7 reveals that the highest net return of Rs 36561, 46100 and 41330 per ha was recorded with S_1D_1, while it was found lowest of Rs 19723, 22332 and 21027 per ha under S_0D_0 in the years 2010-11, 2011-12 and pooled data respectively. The other treatments were found in decreasing order of S_1D_2, S_2D_1, S_2D_3 in both the years and in pooled data analysis.

Table 7. Effect of interaction S x D on net return (Rs·ha^{-1}) soybean under different treatments of mole drains

Treatment	Net return (Rs·ha^{-1})			Treatment	Net return (Rs·ha^{-1})		
	2010-11	2011-12	Pooled		2010-11	2011-12	Pooled
S_0D_0	700	2437	1568	S_3D_1	12544	20925	16735
S_1D_1	12538	26204	19371	S_3D_2	12279	20001	16140
S_1D_2	12120	26113	19116	S_3D_3	10001	15932	12966
S_1D_3	10578	23050	16814	S_4D_1	3716	10117	6916
S_2D_1	13257	21984	17621	S_4D_2	2940	8926	5933
S_2D_2	12694	19918	16306	S_4D_3	2223	8443	5333
S_2D_3	11314	21496	16405	SEm=	325.3	644.7	337.1
				$CD_{(5\%)}$	NS	1986.6	1038.8

The net return is the best index of profitability of soybean crop production .The lowest net return of Rs 700, 2437 and 1568 per ha was recorded under the control. Under various mole drain formation, the highest net return was recorded under S2D1 (Rs 13257 per ha) followed by S_3D_1 (Rs 13478 per ha), while the lowest net return was recorded under S_4D_3 (Rs 2223 per ha) in the year 2010-11. While, it was recorded higher under S_1D_1 followed by S_1D_2 (Rs 26204 and 19371 per ha) in 2011-12 and in pooled data analysis respectively. Similar trends from various field studies conducted in Vertisols on mole drainage in soybean crop [6,9].

CONCLUSIONS

Days to germination, days to 50 % flowering and days to 75 % maturity showed non-significant differences due to different treatments (spacing of mole drain, depth of mole drain and interaction of these two). Maximum values of all the parameters were observed under mole drain spacing S_1 (2 m) and mole drain depth D_1 (0.4 m) in most of the cases. No clear trends were observed in all the cases as spacing and depth of mole drains practices are concern. The net return under various mole drain spacing treatments, the higher net return was recorded under mole drain spacing S_1 (2 m) in case of 2011-12 and pooled data, while in the year 2010-11, it was highest with mole drain spacing S_2 (4 m). In case of mole drain depth, D_1 (0.4 m) gave highest net return as compared to other treatments in both the years as well as in pooled data analysis. Mole drain with S_1D_1 (spacing of 2 m at the depth 0.4 m) was found better in comparison with other spacing and depth as well as the control.

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VIZUELNI PARAMETRI SOJE (*GLYCINE MAX* L.) POD UTICAJEM RASTOJANJA I DUBINE KRTIČNE DRENAŽE U SMONICAMA OBLASTI MADHYA PRADESH

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Sažetak: Poljski ogledi su izvođeni na farmama u oblasti Hoshangabad u Madhya Pradesh tokom 2010 i 2011 da bi se procenili vizuelni parametri i profitabilnost proizvodnje soje pod uticajem različitog rastojanja i dubine krtične drenaže u povremeno plavljenim smonicama. Izabrane krtične drenaže imale su rastojanja od 2, 4, 6 i 8 m, a drenovi su formirani na srednjim dubinama od 0.4, 0.5 i 0.6 m ispod površine parcele. Srednja dužina svake laterale bila je 50 m, a za formiranje drena korišćen je traktor snage 75 KS koji se kretao random brzinom od 0.80 $km \cdot h^{-1}$. Tokom dve sezone su posmatrani, beleženi i statistički analizirani fiziološki parametri kao što su broj dana do: nicanja, pojave 50% cvetova i pojave 75% zrelosti. Na osnovu rezultata dobijenih iz ogleda se može zaključiti da su krtični drenovi na rastojanju od 2 mi na dubini od 0.4 m bili optimalni za poboljšanje proizvodnje soje.

Ključne reči: *drenaža, rastojanje drenova, dubina drenaže, krtični drenovi, soja, smonica*

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Tempus CaSA

TEMPUS PROJECT PRESENTATION

Project title:
BUILDING CAPACITY OF SERBIAN AGRICULTURAL EDUCATION TO LINK WITH SOCIETY
Acronym: “CaSA”

Part 1. PROJECT SUMMARY

544072-TEMPUS-1-2013-1-RS-TEMPUS-SMHES
(2013 – 4604 / 001 - 001)
Sub programme:
Structural Measures, Action Higher Education and Society

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INTRODUCTION

This is a presentation of the CaSA project and the role it plays in linking research and innovation with knowledge improvement in agriculture. CaSA is a national project, coordinated by The University of Belgrade, Faculty of Agriculture.

It belongs to the TEMPUS sub-program Structural measures and the Action Higher education and society. These two benchmarks point out what are the main objectives of the project: to improve quality and availability of vocational agricultural education; to strengthen competences of educators; to create a National Repository for Agricultural Education (NaRA) [3].

Basic course is strengthening links between higher education (HE) and society by building capacity of Serbian:

- University teachers from Faculties of Agriculture (FA)
- Agricultural secondary school (AMS) teachers
- experts in Extension services (ES)

to improve teachers' competences in pedagogic skills and provide in-service vocational training courses.

Specific objectives of the project are:

- SO1 - Improvement of quality and availability of vocational agricultural education
- SO2 - Strengthening of professional and pedagogical competences of educators
- SO3 - Creation of the "open source" repository for educators in the area of agricultural education

Creation of a National Repository for Agricultural Education (NaRA) - a repository for online courses and teaching resources to ensure project sustainability and networking of all stakeholders in agricultural education.

There are 13 partners contributing to the project, 10 Serbian and 3 EU partner institutions. Serbian partners are 5 agricultural faculties from Belgrade, Novi Sad, Kragujevac, Novi Pazar and Sremska Kamenica, as well as Association of Agricultural Middle School in the area of agriculture, food processing and food production, Institute for Science Application in Agriculture responsible for in-service training of agricultural advisors, 2 NGO training organization (Education Forum and Balkan Security Network) and the Ministry of Education, Science and Technological Development of the Republic of Serbia. EU partners are universities from Timisoara (Romania), Maribor (Slovenia) and Foggia (Italy)

All project activities are grouped into 11 work packages.

The project lasts for 3 years (01/12/2013 - 30/11/2016) and aims to build the capacity of main holders of Serbian agricultural education: university teachers, teachers in agricultural middle schools and agricultural advisors working in extension services.

The CaSA project's main achievement will be the creation of a NaRA, available as an electronic platform that should enable the sustainability of the project and connection of stakeholders involved in all levels of agricultural education and training in Serbia. This repository will include: information necessary for teaching traditional courses as well as online courses for professional development of Agricultural Middle Schools and experts in extension services; databases of results obtained by research; selected and recorded classes of interactive teaching; selected parts of courses realized and/or developed within the project, prepared in the form of online video tutorials and posted together with additional teaching contents; and other relevant contents added to the repository based on authorized decisions of the NaRA Advisory Board.

All project participants have agreed and signed the Constituent agreement on project implementation and NaRA management.

PROJECT SUMMARY

The project, coordinated by Faculty of Agriculture, Belgrade, will build capacity of Serbian faculties of agriculture to improve teacher's competences in pedagogic skills as well as in their ability to provide distance learning in-service teacher training vocational courses for teachers in agricultural middle/secondary schools (AMSs) [1] and for experts in extension services. Networking of all relevant stakeholders in agricultural education as well as project sustainability will be enabled by creation of the National Repository for Agricultural Education (NaRA) [3].

At all Serbian Faculties of Agriculture and State University of Novi Pazar, courses in active teaching/learning (ATL) including e-learning for young university teachers and teachers from AMSs will be held during project lifetime. ATL courses, given by experts from NGO Education Forum, are important for both groups of teachers (University and AMS) since they did not have any pedagogical training during their graduate courses in agronomy.

University teachers, that have improved teaching competences and other academic skills, will develop and implement classical and web-based vocational courses targeting recent advances in agriculture for AMS teachers [2] and agronomists in the extension services as beneficiaries. It will be done in collaboration with University from Maribor and with University of Foggia, Italy. Implementation of these courses will be done in year 3 at AMSs under the supervision of EU partners. During the project lifetime NaRA will be formed with the help of EU partner from Agricultural University, Timisoara, Romania, to provide relevant information, to serve as stakeholder data-base and to be used as repository for e-learning courses developed in the project, as well as for various teaching materials developed during ATL trainings of both university and AMS teachers. NaRA will then become a platform for improving teaching skills of both, university and AMS teachers as well as for improving professional skills for AMS teachers and agronomists in the extension services. Since the agronomists working in the extension services lack: modern techniques of communication to work with farmers, as well as skills needed for preparation of project proposals, this project will provide training given by experts from NGO Balkan Security Network (BSN) for agronomists how to communicate with farmers and how to prepare a project proposal. Academic and communication skill courses, given by experts, will be recorded and stored together with accompanying teaching material as a live stream courses, available at NaRA for all university and AMS teachers and agronomists in extension services to be used after the project lifetime. Creation of NaRA will, therefore, provide sustainability of the project since all project deliverables (all types of e learning courses and teaching materials) developed during project lifetime will be stored and available for future users. NaRA will also provide networking and active communication of all relevant stakeholders (Universities, AMSs, extension services, governmental and non governmental bodies).

Sustainability of NaRA will be ensured after the project life-time by the support and recognition of the Ministries of Education, Science and Technological Development and of Ministry of Agriculture of the Republic of Serbia, as well as with some courses commercialization, while some databases, professional forums, and relevant information will remain open access. Management of the NaRA will be regulated by the Agreement between universities and other project partners.

Project partners

P1 University of Belgrade Faculty of Agriculture UB – coordinating institution
P2 University of Novi Sad Faculty of Agriculture UNS
P3 University of Kragujevac Faculty of Agronomy Cacak UNIKG
P4 University EDUCONS Faculty of Ecological Agriculture
P5 State University Novi Pazar SUNP
P6 Association of Middle Agricultural Schools AMS
P7 Institute for Science Application in Agriculture IPN
P8 Educational Forum (NGO) EF
P9 Balkan Security network, (NGO) BSN
P10 Ministry of Education, Science and Technological Development ME
P11 Banat University of Agricultural Sciences and Veterinary Medicine USAMVBT
P12 University of Maribor UM
P13 University of Foggia UNIFG

WORK PACKAGES AND PROJECT ACTIVITIES

WP 1 - Creation of the Repository
WP leader: *Cosmin Salasan*, USAMVBT, Timisoara, Romania
- A1.1. Organizing workshop in Belgrade with all relevant stakeholders to define structure and content of NaRA
- A1.2. Creating and maintenance NaRA

WP 2 - Infrastructural support for NaRA functioning / Development of resources
WP leader, project secretary: *Goran Topisirović*, UB, Belgrade, Serbia
- A2.1. Purchase of the equipment for improving/creating faculty e learning platform at every faculty /university and for NaRA at P1
- A2.2. Training of IT administrators at every faculty/university for maintenance of the platform
- A2.3. Engaging an IT expert for programming and software support 2.4. Engaging one cameraman and film editor from University of Arts

WP 3 - Improvement of competences of university teachers
WP leader: *Ana Pešikan*, EF, Belgrade, Serbia
- A3.1. Training of university teachers in ATL
- A3.2. Training of university teachers in academic skills
- A3.3. Training of university teachers in methodology of creating vocational courses in elearning format

WP 4 - Modernization of teaching contents
WP leader: *Snežana Tanasković*, UNIKG, Čačak, Serbia
- A4.1. Need analysis for knowledge refreshment
- A4.2. Workshop in Cacak with EU partners to compare experiences and good practices
- A4.3. Development of classical (f2f) vocational courses for AMS teachers and agronomists in extension service
- A4.4. Development of web based vocational courses

WP 5 - Improvement of competences of AMS teachers
WP leader: *Vidoje Vukašinović*, AMS, Požarevac, Serbia
- A5.1. Training of AMS teachers in ATL
- A5.2. Training of AMS teachers in e-learning

WP 6 - Improvement of competences of experts in extension services
WP leader: *Snežana Janković*, IPN, Belgrade, Serbia
- A6.1. Training of agronomists in extension services in using e-learning platform
- A6.2. Training of agronomists in extension services in communication and project proposals preparation skills

WP 7 - Pilot implementation of vocational courses
WP leader: *Ljubinko Jovanovic*, EDUCONS, Sremska Kamenica, Serbia
- A7.1. Implementation of classical pilot vocational courses
- A7.2. Implementation of pilot web based vocational courses

WP 8 - Quality assurance control of project activities
WP leader: *Sofija Pekić Quarrie*, SUNP, Novi Pazar, Serbia
- A8.1. Creation of the body for project quality control
- A8.2. Development of questionnaires for training courses evaluation
- A8.3. Analysis of training courses feedback questionnaires
- A8.4. QA of vocational courses – peer review by EU Partners
- A8.5. Development of questionnaires for vocational course evaluation
- A8.6. Analysis of course feedback questionnaires from pilot implementation of vocational courses

WP 9 - Dissemination of project results
WP Leader: *Dušan Petrić*, UNS, Novi Sad, Serbia
- A9.1. Adopting a dissemination plan and identify target groups for dissemination
- A9.2. Designing and maintenance of the project web-site
- A9.3. Organizing other dissemination and visibility activities: briefings, presentations, press conferences and other events
- A9.4. Publishing and dissemination of training manuals and guidelines
- A9.5. Dissemination at Final conference in NS

WP 10 - Exploitation of project results
WP Leader: *Predrag Pudja*, UB, Belgrade, Serbia
- A10.1. Reaching agreement between faculties' managements on: maintenance of NaRA, recognition of teachers work in courses preparation, availability of NaRA content, and courses commercialization
- A10.2. Defining procedures for intellectual property rights of courses creators
- A10.3. Preparation for accreditation of vocational courses for AMS teachers
- A10.4. Preparation for certification of vocational courses for ES experts

WP 11 - Project Management
WP Leader, project coordinator: *Vesna Poleksić*, UB, Belgrade, Serbia

A11.1. Organizing kick off meeting in Belgrade and SC meetings in: Belgrade, Čačak and N. Pazar
A11.2. Establishment of SC and defining procedures of cooperation between partners
A11.3. Daily project coordination and administration
A11.4. Meetings of the local project teams
A11.5. Regular reporting to EACEA
A11.6. Organizing final conference in Novi Sad
A11.7. Organizing final SC meeting in Novi Sad
A11.8. Financial Audit

CONCLUSION

In conclusion of this first article presenting the CaSA project, it is important to emphasis that the whole project management and participants are working together to improve agricultural HE in Serbia and that the project Specific objectives are: Improvement of quality and availability of vocational agricultural education; Strengthening of professional and pedagogical competences of educators; and Creation of the repository for educators in the area of agricultural education will be reached.

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PREDSTAVLJENJE TEMPUS PROJEKTA

Naslov projekta:

IZGRADNJA KAPACITETA SRPSKOG OBRAZOVANJA U OBLASTI POLJOPRIVREDE RADI POVEZIVANJA SA DRUŠTVOM

Koordinator:
Univerzitet u Beogradu, Poljoprivredni fakultet

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