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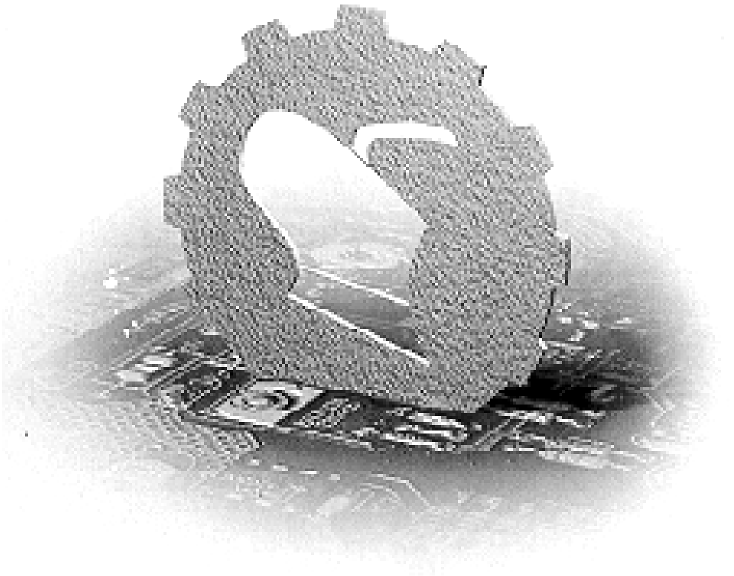

УНИВЕРЗИТЕТ У БЕОГРАДУ, ПОЉОПРИВРЕДНИ ФАКУЛТЕТ,
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STORABILITY OF WHEAT HARVESTED BY DIFFERENT METHODS

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Abstract: Wheat was harvested through combine harvester or thresher. Labor shortage and timely completion of harvesting operation attracts farmers to harvest wheat crop through combine harvester. This facilitates to make land available for next crop sowing operation. The damage loss of wheat grain is the main disadvantage of harvesting machinery utilization. The research was carried out on six months storage of wheat obtained by combine harvester and thresher considering mechanically damaged seeds; percent weight loss, moisture content, germination percent, vigor index, pest population and percent grain damage. Wheat obtained from thresher has minimum mechanical damage (1.5 to 2.7%) and moisture content (7.70 to 7.83%) at the time of harvest as well as minimum storage loss (1.13 to 2.57%), pest population (2.78 to 4.17) and damage percent due to pest infestation (10.83 to 19.94 %) after six months of storage. Threshed grain has higher germination percentage (94.10 to 95.22%) and vigor index (212.44 to 222.98) after six months of storage.

***Key words**: wheat, storage, harvesting, pest, germination, vigor*

INTRODUCTION

Wheat is an important cereal crop in India. Wheat when stored is often attacked by number of pests, viz., lesser grain borer, angoumois grain moth, khapra beetle, rice weevil etc. (Baloch, 1999)[2]. Traditionally, the wheat crop is harvested by sickle and

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prepared by thresher is a common practice. Now a day, farmers are using combine harvester for harvesting wheat crop and the use of combine harvester is increasing day by day on account of labors problem and convenience of time saving. During harvesting of wheat by combine harvester, it was observed that considerable wheat grains are damaged due to improper alignment and malfunctioning of machine parts. Moreover, the harvesting by combine harvester is generally having a slightly higher moisture content to prevent shattering losses. The mechanically damage seeds or higher moisture content encourage the infestation of pests. Very little information is available on pest incidence in storage of wheat harvested by combine harvester. Hence, it is important to find out the cause of damage of wheat crop harvested by combine harvester. Looking to the requirement, comparative study was carried out for storage of wheat obtained by thresher and combine harvester during the year 2007, 2008 and 2009.

MATERIAL AND METHODS

Wheat prepared from three different combine harvester and thresher was procured from different farmer's fields and stored in gunny bags at room temperature in laboratory. Experiment was carried out in CRD design with four replications. Bimonthly observations were recorded to find out entomological, and physical changes occurred during storage. The observations were recorded from wheat samples of 500 g.

Percent Mechanical Damage

A mechanically damage grain was sorted out and counted from 100 randomly selected grains per sample from each replication and worked out percent mechanical damage grain.

Moisture content

The moisture content was determined by an oven method, which is a direct method. The grain was weighed and dried, then weighed again according to standard procedures. The moisture content was calculated using the moisture content equations.

Grain moisture content was expressed as a percentage of moisture based on wet weight (wet basis).

$$M = \frac{w - d}{w} x100 \qquad (1)$$

Where:
w [kg] - wet weight,
d [kg] - dry weight,
M [%] - moisture content.

A representative sample was obtained to provide a useful moisture content evaluation.

Weight loss

Initial weight of wheat at storage time W_a and weight of wheat after six months d_b was noted and calculated as per following formula.

$$\%\,Weight\ loss = \frac{w_a - d_b}{w_a} x100 \tag{2}$$

Where:
w_a [kg] - initial weight of wheat,
d_b [kg] - weight of wheat after six months.

Percent Germination

One hundred grain of each stored wheat sample were placed and soaked on blotting paper in the Petri dish. Each treatment was repeated eight times. After a period of 72 hours, number of germinated seeds in each Petri dish was counted. The experiment was conducted under Completely Randomized Design (CRD). The initial germination percentage of respective sample was calculated by using the following formula.

$$Germination\ \%age = \frac{No.\ of\ germinated\ seed}{Total\ No.\ of\ seed\ soaked\ in\ each\ petridish} x100 \tag{3}$$

Same procedure was followed after a period of three months to record the final germination % age for grains of wheat.

Determination of the infestation % age

Initial and final infestation % age in each treatment was calculated by counting the number of un-germinated seeds in each replication of the respective treatment. Then from mean values, initial and final infestation % age in the respective sample was determined by using the formula: Same procedure was followed after a period of three months.

Germination percent was determined by taking randomly sample of 10 grain from each replication. The seed were kept in a 20 cm sterilized Petri dishes fitted with blotting paper soaked with distilled water and kept at room temp. Number of germinated seed were counted and recorded for germination percent.

Vigor Index

Vigor index was determined by percent germination of seed multiply root length (cm) of germinated seed after six days.

Pest population

A number of adult of pest was counted from each randomly selected sample from each replication and recorded for pest population per sample.

Percent Damage grain

A damage grain by pest was counted from 100 randomly selected grains from each samples and recorded percent grain damage.

RESULTS AND DISCUSSION

The data regarding percent mechanically damaged grains, initial moisture content and moisture content after six months storage, and percent weight loss after six months storage are given in Tab. 1. The pooled data of three years indicated that the average mechanically damaged grain was found significant in different treatments. The mechanically damaged percent of grain was found more (3.58 to 8.36 %) in wheat harvested by combine harvester treatments as compared to thresher treatments (1.59 to 2.70%).

Table 1. Percent mechanically damaged grain, moisture content and weight loss during storage

Sr. No.	Treatments	mechanically damaged grain at storage time [%]	Moisture content [%]		Weight loss of wheat after six months [%]
			at storage time	after six months	
1	(i)Combine harvester wheat I	10.91* (3.58)**	8.13	7.92	3.37
2	(ii) Combine harvester wheat II	13.93 (5.80)	7.93	7.65	4.50
3	(iii)Combine harvester wheat III	16.81 (8.36)	8.08	7.86	5.15
4	(iv) Thresher wheat I	7.24 (1.59)	7.78	7.69	1.13
5	(v) Thresher wheat II	8.61 (2.24)	7.70	7.58	2.24
6	(vi)) Thresher wheat III	9.46 (2.70)	7.83	7.77	2.57
	S.Em .for T	0.55	0.06	0.08	0.15
	CD at 5% for T	1.56	0.17	NS	0.42
	S.Em.for Y	0.37	0.04	0.04	0.09
	CD at 5%for Y	1.05	0.11	0.11	0.25
	S.Em.for TXY	0.91	0.09	0.09	0.22
	CD at 5%for TxY	NS	NS	0.026	NS
	CV%	16.32	2.32	2.35	13.97

* Arc sin transformation
** Figures in parenthesis are retransformed values

The initial moisture content at storage time was found significantly higher (7.93 to 8.13 %) in combine harvester wheat as compared to (7.70 to 7.83%) in thresher treatment. The moisture content after six months was found non significant. The percent weight loss in wheat after six months of storage was found significantly maximum in combine harvester treatment as 3.37 to 5.15% as compared to minimum in thresher treatment as 1.13 to 2.57%. This may be due to moisture content decrease and pest damage.

It was concluded that combine harvester results significantly higher mechanical damage to wheat grain as well as higher moisture content at the time of harvest.

The data regarding initial and after six months storage period, wheat germination percentage and vigor index are given Table 2. The pool data of three years showed that germination percent was found significant at storage time. The germination percent was higher (94.10 to 95.22%) in thresher wheat as compared to combine harvester wheat (92.42 to 93.22%). The germination percent was found significant after six months of storage. The germination percent was higher (73.32 to 80.00%) in thresher wheat as compared to combine harvester wheat (59.18 to 66.99%), after six months of storage. Germination percent was decreased after six months of storage, which may be due to pest infestation. Payne T.S. (2002) [8] reported the reduction in germination due to attack of pest. Results were supported by Mahmood *et al.* 2011; Manickavasagan *et al.* 2007 and Al-Yahya 2001 [5,6,7].

Table 2. Germination and vigour index of wheat

Sr. No.	*Treatments*	*Germination [%]*		*Vigor Index*	
		Initial at the storage time	*After six months storage period*	*Initial at the storage time*	*After six months storage period*
1	*Combine harvester wheat I*	*74.91* (93.22)***	*54.93* (66.99)***	*280.98*	*191.01*
2	*Combine harvester wheat II*	*74.13 (92.52)*	*52.95 (63.70)*	*278.47*	*187.19*
3	*Combine harvester wheat III*	*74.02 (92.42)*	*50.29 (59.18)*	*277.75*	*171.90*
4	*Thresher wheat I*	*77.38 (95.22)*	*63.44 (80.00)*	*290.83*	*222.98*
5	*Thresher wheat II*	*75.94 (94.10)*	*60.24 (75.36)*	*278.61*	*219.03*
6	*Thresher wheat III*	*76.67 (94.68)*	*58.90 (73.32)*	*284.95*	*212.44*
	S.Em .for T	*0.87*	*0.70*	*5.72*	*3.68*
	CD at 5% for T	*2.47*	*1.98*	*NS*	*10.43*
	S.Em.for Y	*0.56*	*0.45*	*3.93*	*2.52*
	CD at 5%for Y	*1.58*	*1.27*	*11.11*	*7.13*
	S.Em.for TXY	*1.37*	*1.11*	*9.62*	*6.16*
	CD at 5%for TxY	*NS*	*NS*	*NS*	*NS*
	CV%	*3.63*	*3.90*	*6.82*	*6.14*

* Arcsin transformation
** Figure in parenthesis are retransform value

The vigor index was found non-significant at storage time and it was significant after six months of storage. The vigor index was higher (212.44 to 222.98) in thresher wheat as compared to combine harvester wheat (171.90 to 191.01) after six months of storage.

From the results in the table, it can be seen that percentage germination decreased when mechanical grain damage increased. The percentage germination was inversely related to the moisture content. Vigor index at the harvest time is non-significant but after six months storage period it was significant with higher in threshed grain with lower moisture content.

The data regarding pest population and grain damage after four months and six months of storage period are given Table 3.The pool data of three years revealed that population buildup was found significant after four months of storage. The pest population (number of adult per sample) was found comparatively higher 2.81 to 6.16 and lower 1.32 to 2.32 in combine harvester and thresher wheat, respectively, after four months of storage. The population buildup was also found significant after six months of storage. The pest population (number of adult per sample) was found comparatively higher 5.40 to 7.62 and lower 2.78 to 4.17 in combine harvester and thresher wheat, respectively, after six months of storage.

Table. 3 Pest population (Rust red flour beetle) and grain damage of wheat

Sr. No.	Treatments	Average number of adult/sample		Grain damage [%]	
		after 4 months	after 6 months	after 4 months	after 6 months
1	Combine harvester wheat I	1.82* (2.81)**	2.43* (5.40)**	15.65# (7.28)##	31.53# (27.35)##
2	Combine harvester wheat II	2.24 (4.52)	2.59 (6.21)	20.45 (12.21)	34.65 (32.33)
3	Combine harvester wheat III	2.58 (6.16)	2.85 (7.62)	25.02 (17.89)	41.25 (43.47)
4	Thresher wheat I	1.35 (1.32)	1.81 (2.78)	9.77 (2.88)	19.21 (10.83)
5	Thresher wheat II	1.57 (1.96)	2.02 (3.58)	11.93 (4.27)	24.13 (16.71)
6	Thresher wheat III	1.68 (2.32)	2.16 (4.17)	13.21 (5.22)	26.52 (19.94)
	S.Em .for T	0.08	0.09	0.57	0.71
	CD at 5% for T	0.22	0.24	1.61	2.00
	S.Em.for Y	0.05	0.06	0.37	0.44
	CD at 5%for Y	0.14	0.17	1.04	1.24
	S.Em.for TXY	0.12	0.14	0.91	1.07
	CD at 5%for TxY	NS	NS	NS	NS
	CV%	13.29	12.37	11.32	7.24

* √X+0.5 transformation value
** figure in parenthesis are retransformed value
\# arcsin √percentage transformation value
\## figure in parenthesis are retransformed value

The data showed that damaged percent of grain due to pest infestation was found significant after four months of storage. The damage percent was found higher (7.28 to 17.89 %) and lower (2.88 to 5.22 %) in combine harvester and thresher wheat, respectively, after four months of storage.

The damaged percent of grain due to pest infestation was found significant, after six months of storage. The damage percent was found higher (27.35 to 43.47 %) and lower (10.83 to 19.94 %) in combine harvester and thresher wheat, respectively, after six months of storage.

The pest population showed highly significant but negative correlation with germination percentage at both initial and after six months of storage of experiment.

From the above mentioned results it can be concluded that wheat harvested through combine harvester results with higher mechanical damage which are responsible for higher pest population. These pests are responsible for the reduction in germination of wheat grains. These findings are in line with those of Zachavatkin (1941) [9], who reported that pest population affects the germination of the grains directly through damaging the growing tips. The present studies can be compared with those of Ashfaq *et al*. (1995) [1] who revealed 15-20 % germination loss in grains of wheat, maize and mung collected from Mansehra District due to pests after three months of storage. Similarly negative correlation between pest population and the germination was reported by Ashfaq and Wahla (1989) [2]. Bashir *et al*., (2009)[3] also revealed that with the increase in pest population the germination of the seeds reduces. Based on these results it can be concluded that pests are mainly responsible for the germination loss in the stored grains.

CONCLUSIONS

It was concluded that combine harvester results significantly higher mechanical damage to wheat grain as well as higher moisture content at the time of harvest. The percentage germination decreased when mechanical grain damage increased. The percentage germination was inversely related to the moisture content. Vigor index at the harvest time is non-significant but after six months storage period it was significant with higher in threshed grain with lower moisture content. The pest population showed highly significant but negative correlation with germination percentage at both initial and after six months of storage of experiment. The pests were mainly responsible for the germination loss in the stored grains.

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SPOSOBNOST ZA SKLADIŠTENJE PŠENICE POSLE RAZLIČITIH METODA ŽETVE

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Sažetak: Pšenica je žnjevena žitnim kombajnom ili vršalicom. Ušteda rada i vremena privlači farmere da žetvu obavljaju žitnim kombajnom. Ovim se omogućuje oslobađanje zemlje za setvu sledećeg useva. Gubitak zbog oštećenja zrna je osnovni nedostatak primene mašina za žetvu. Istraživanje je izvedeno šestomesečnim skladištenjem pšenice dobijene žetvom žitnim kombajnom i vršalicom, uz praćenje mehanički oštećenih zrna, procenta gubitka mase, sadržaja vlage, procenta klijanja, indeksa vigora, populacije štetočina i procenta oštećenja zrna. Pšenica dobijena iz vršalice, posle 6 meseci skladištenja, ima minimalna mehanička oštećenja 1.5 do 2.7%, sadržaj vlage 7.70 do 7.83% u momentu žetve, minimalni gubitak pri skladištenju 1.13 do 2.57%, populaciju štetočina 2.78 do 4.17 i oštećenja od štetočina od 10.83 do 19.94 %. Ova pšenica je posle 6 meseci skladištenja imala i veći procenat klijanja od 94.10 do 95.22% i indeks vigora 212.44 do 222.98.

Ključne reči: *pšenica, skladištenje, žetva, štetočina, klijanje, vigor*

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OPTIMIZATION OF EXTRUSION COOKING PROCESS FOR RICE-FISH EXTRUDATES WITH AN UNDERUTILIZED FISH MINCE BASED ON PHYSICAL, FUNCTIONAL AND TEXTURAL PROPERTIES

Gourikutty Kunjurayan Rajesh*, Venkatachalam Thirupathi, Vijayaram Eyarkai Nambi, Ravi Pandiselvam

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Abstract: Extrudates were prepared with Sea bass, an underutilized fish and rice flour using a twin screw extruder. Different process parameters viz. moisture content of feed (10%, 15%, 20% and 30%), fish content in feed (10%, 15%, 20% and 30%) and barrel temperatures (100°C and 110°C) were used for extrusion. The physical properties viz., bulk density, expansion ratio and moisture content of extrudates, functional properties such as water absorption index, water solubility index and textural properties of the extrudates were studied. The results shown that the expansion ratio and bulk density of the extrudates were in the range from 2.85 to 4.10 and 130 to 225 kg/m^3 respectively. The WAI and WSI of the extrudates varied from 5.2 to $6.7 g \cdot g^{-1}$ and 17% to 30% respectively. Maximum hardness was observed at 30% feed moisture, 30% fish mince content and 110°C barrel temperature. Analysis of Variance (ANOVA) revealed that all the process parameters significantly affected the physical, functional and textural properties of extrudates. The optimum process parameter to extrude rice fish extrudates were obtained at 10% feed moisture, 10% fish content and barrel temperatures of 110°C.

Key words: *Extrusion, rice-fish extrudates, extrusion cooking, underutilized fish extrudate*

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INTRODUCTION

Extrusion refers to the forming of products to the desired shape and size by forcing the material through a die opening under pressure. It also involves thermal and mechanical energy input, which triggers chemical reactions in the food being extruded [9]. During extrusion cooking, the raw materials undergo many chemical and structural transformations, such as starch gelatinization, protein denaturation, complex formation between amylose and lipids, and degradation reactions of vitamins, pigments, etc. The usage of extrusion cooking increased in the production of food ingredients and food such as breakfast cereals, baby foods, flat breads, snacks, meat and cheese analogues, and modified starches etc [1]. At present, most of the extruded snacks commercially available are prepared from grains due to their good expansion properties. But, they contain low quantities of protein and other essential nutrients. Hence, there is an increasing demand for nutritious snacks. Fish is not only excellent sources of high nutritional value protein but also excellent sources of lipid that contains ω-3 fatty acids, especially, eicosapentaenoic acid (EPA) and docosahexaenoic acids (DHA) [17]. Moreover, it contains vitamins and minerals for human nutrition. Fish oil is the richest source of vitamin A and D. It is estimated that there are 25,000 species of fish living today. Out of which 250 species are used for edible purpose. Presence of peroxidants, oxidative susceptible lipids, scales, skin, bones, connective tissue and viscera etc are the other reasons for limited utilization. Mostly these underutilized products are transferred into fish meal for animal feed or fertilizer. 30-60% of total fish catch is not utilized for human consumption and hence transformed into fish meal for animal feed. There is an obvious need to better utilize of underutilized species in light of world fishing situation and growing need for quality protein and lipids for human and animals. Some exciting developments in the science and technology of fish utilization have developed recently moves up closer to this goal. [14] Conducted study on the effects of extrusion conditions on the physical properties of soybean-fish based ready to eat snacks. The quality of extrudate depends on the selection of ingredients. The objective of the present study was to develop under-utilized fish based extruded products with rice flour and to study the effect of barrel temperature, feed moisture content and fish content on physical, functional and textural properties of extrudate.

MATERIALS AND METHODS

Preparation of Fish Mince: Sea bass (underutilized fish) procured from local market was de-scaled and beheaded using a fillet knife. Intestines were removed by open the belly and washed with ordinary water. The flesh was then deboned using a knife and ground in a laboratory mixer.

Preparation of Rice Flour -Fish Blend: Rice flour, fish mince, water and salt were used for the preparation. The ingredients were weighed and mixed properly to a desired level of fish mince content (FMC) and moisture content of feed (MCF) viz. 10%, 15%, 20%, 30% and 10%, 15%, 20%, 30% (wb) respectively. Then the blend was placed in a close vessel at room temperature for 2 hours to equilibrate before extrusion. The mixtures were then sieved using 0.5 mm mesh screen.

Extrusion Process: Extrusion was performed with a co-rotating twin-screw extruder (Model BTPL-1, Basic Technology Pvt. Ltd. India). The extruder screw and ply cutter were driven by 5 hp motor and a variable speed DC motor respectively. The barrel sections *viz.,* feed zone, compression zone and metering zone was fitted with a gasket to prevent the heat transfer from one section to another. Temperature inside the barrel was controlled with temperature controllers. The barrel temperatures considered in this study were 100°C and 110°C. The extrudate were packed in polypropylene pouches and stored for further analysis.

Physical Properties of the Extrudates

Expansion Ratio (ER): The expansion ratio was calculated as the cross sectional diameter of the extrudate divided by the diameter of the die opening [7]. The diameter of the extrudates was measured using a vernier caliper Expansion ratio was calculated from ten places randomly for each run and the average value was taken. The expansion ratio was calculated as given below.

$$ER = D^2 \cdot d^{-2} \tag{1}$$

Where:
D [m] - diameter of the extrudate,
d [m] - diameter of the extruder die.

Bulk Density (BD): Bulk density was calculated based on the method proposed by [19]. Bulk density of 10 samples was calculated for each run and the average value was taken. The weight per unit length of extrudate was measured then the bulk density was calculated based on:

$$BD = \frac{D^2 \cdot L \cdot \pi}{4} \tag{2}$$

Where:
L [mm] - total length of the extrudate,
D [mm] - average diameter of the extrudate.

Functional Properties of Extrudates: The water absorption index (WAI) and water solubility indices (WSI) of the fish-rice flour extrudates were determined according to the method prescribed by [1]. Powdered sample (2.5 g) was suspended in 30 ml of distilled water in a 50 ml pre-weighed centrifuge tube by vortexing. The tubes were placed in a 30°C water bath and intermittently stirred for 30min. The suspension was centrifuged for 10 min at 3000 × g and the supernatant was decanted into a pre-weighed 50 ml beaker. The weight of the wet sediment was used to calculate the water absorption index using the following equation.

WAI (g gel/g dry sample) = weight of the wet sediment (g)/initial weight of the dry starch (g)

The supernatant was dried at 95ºC to constant weight and the weight of the dried solids was used to determine the WSI.

WSI (%) = weight of the solids recovered by evaporating the supernatant (g) ×100/initial weight of the dry starch (g)

Textural Properties: Textural properties were evaluated using a food texture analyzer (TAHDi, Stable Microsystems, England). Cylindrical probe of 4 mm diameter was used. The detailed experiment conditions of textural analyzer are as follows:

Load cell	:	5 kg
Test Mode	:	Measure force in compression
Test option	:	Return to start
Pre test Speed	:	2 $mm \cdot s^{-1}$
Test Speed	:	0.1 $mm \cdot s^{-1}$
Post test Speed	:	2 $mm \cdot s^{-1}$
Distance	:	5 mm
Test probe	:	P 4

The area and peak force under the force-deformation curve was represented as toughness and hardness respectively.

Experimental design and data analysis: The independent process variables selected for the study were process barrel temperature (100°C, 110°C), moisture content of feed (10%, 15%, 20%, 30% (w.b) and fish content of feed (10%, 15%, 20%, 30% (wb). A full factorial design has been developed with three replications using Minitab. The observed data were analyzed using ANOVA and correlation studies were carried out.

RESULTS AND DISCUSSION

Extrudates were prepared based on the full factorial design with all possible combination of process parameters discussed in the previous chapter. All the extrudates were tested for its quality in terms of physical properties (BD, MC, ER), functional properties (WAI, WSI) and textural property (Harness). The process parameters were tested for its significance on the quality of extrudates and optimized using full factorial ANOVA. P value and r-square value obtained from ANOVA for each quality factors were consolidated and given in the Tab. 1 to estimate the level of significance of process parameters on various quality factors.

Changes in Physical Properties of Fish-Rice Flour Extrudates

The effect of process parameters on physical properties viz., bulk density, expansion ratio and moisture content of extrudates are discussed below.

Table 1. Pearson correlation coefficient between the process parameters and quality factor of extrudates (-ve shows the negative correlation)

Parameter	*Fish Content*	*Barrel temperature*	*Moisture content of feed*
Bulk Density	*0.458*	*-0.166*	*0.841*
Expansion ratio	*-0.305*	*0.236*	*-0.853*
Moisture content of extrudate	*0.748*	*-0.413*	*0.430*
WAI	*0.414*	*-0.502*	*0.650*
WSI	*-0.561*	*0.334*	*-0.677*
Hardness	*0.541*	*0.284*	*0.755*

1. Effect of Process Parameters on Bulk Density of Rice-Fish Extrudates

From the Tab. 2 it is obvious that all process parameters are affecting the bulk density of extrudate significantly (@ 1%) at individual as well as 2nd and 3rd level interaction. The r-square value was 0.998. The interaction plot for all 3 process parameters on bulk density were fitted and shown in Fig. 1.

Table 2. Consolidated ANOVA results for the quality factors of extrudates with full factorial interaction

Source	Bulk Density	Expansion Ratio	Moisture Content of the Product	WAI	WSI	Hardness
Blocks	0.965	0.828	0.135	0.490	0.438	0.066
Fish Content	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
Barrel Temperature	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
Moisture Content of the Feed	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
Fish Content x Barrel Temperature	0.000**	0.554	0.000**	0.081	0.000**	0.000**
Fish Content x Moisture Content of the Feed	0.000**	0.410	0.000**	0.355	0.000**	0.000**
Barrel Temperature x Moisture Content of the Feed	0.000**	0.000**	0.000**	0.012*	0.000**	0.000**
Fish Content x Barrel Temperature x Moisture Content of the Feed	0.000**	0.048*	0.000**	0.480	0.000**	0.000**
R^2 value	0.998	0.986	0.990	0.934	0.989	0.997

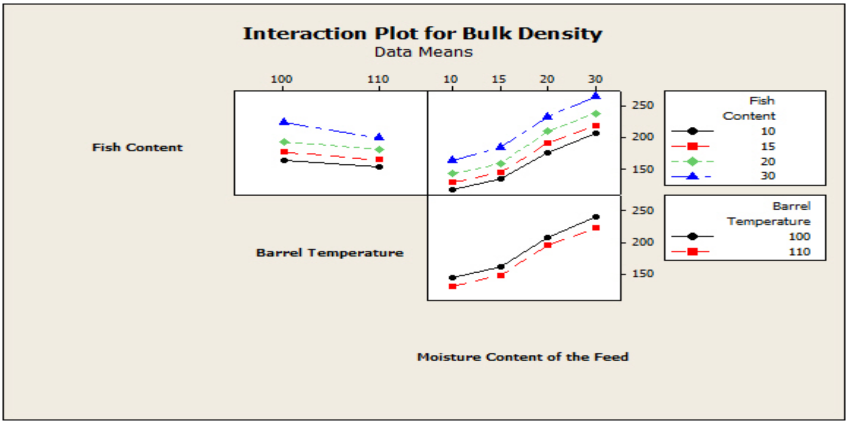

Figure.1. Interaction Plot for bulk density with the process parameters

Fig.1. shows that the bulk density increased significantly with an increase in feed moisture and fish content. However, a reverse effect was observed with barrel temperature. The bulk density increased from 135 to 225 kg·m^{-3} with increase in feed

moisture from 10 to 30% (wb). Same way, the bulk density increased from 165 to 215 kg·m^{-3} for the fish content increase from 10 to 30% respectively. The results are in agreement with [4] who have reported an increase in bulk density with an increase in feed moisture for corn, rice, and cassava flour extrudates. For higher fish content the bulk density were higher. This may be due to the high protein content may influence the expansion of extrudate thus resulting the higher bulk density. [6] Reported that low moisture content of starches may restrict flow inside the barrel, increase shear rate and residence time which could perhaps increase degree of starch gelatinization and expansion which could be linked to lower bulk density. But in case of barrel temperature, the bulk density decreased from 185 to 175 kg·m^{-3} with increase in temperature from 100 to 110°C. [11] Observed a reverse effect on bulk density with an increase in temperature on extruded foxtail millet. From Tab. 2, it can be observed that the bulk density is highly correlated with moisture content of the feed followed by fish content then barrel temperature. Both moisture content of the feed and fish content have positive correlation, but in case of barrel temperature, the bulk density is negatively correlated.

2. Effect of Process Parameters on Expansion Ratio of Extrudates

Analysis of variance (Tab.1) showed that each process parameters had a significant effect ($p \leq 0.01$) on expansion ratio of extrudates at individual level with r-square value 0.986. But some of the 2nd order interactions level between process parameters were not significant. At the same time there is a significant effect ($p \leq 0.05$) at 3rd order interaction. So the interaction effects may be considers. The interaction plot of process parameters on expansion ratio of extrudates is shown in Fig. 2.

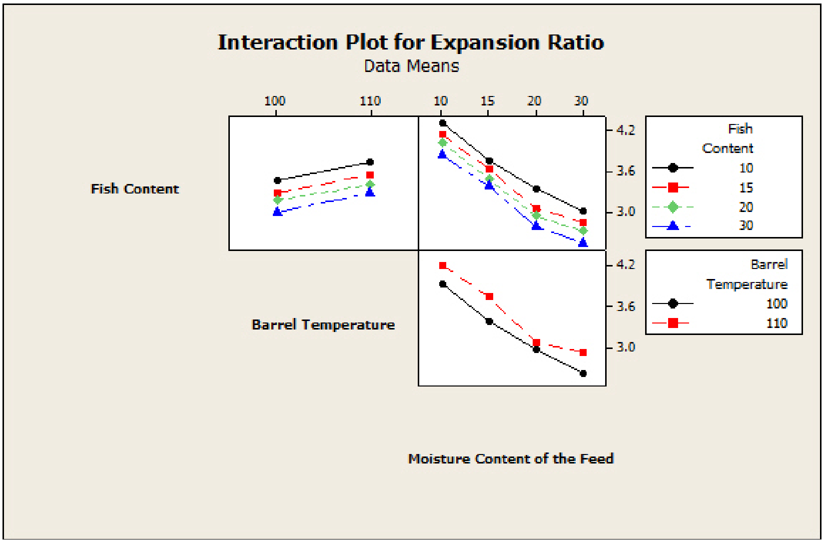

Figure.2. Interaction plot of process parameters on expansion ratio of extrudates

Expansion ratio of the extrudates ranged from 2.85 to 4.25 g gel·g^{-1} (Fig. 3). The expansion ratio of the extrudates decreased with an increase in feed moisture and fish content. Highly expanded products with very appealing color and appearance were obtained at 10% fish content with 10% feed moisture. At 10% feed moisture, the maximum expansion ratio of 4.10 was shown by the sample. It decreased to 2.8 g gel·g^{-1} with an increase in feed moisture from 10 to 30%. [5] Observed a similar trend. [5] Reported that in the arrowroot extrudates the lower moisture level showed higher expansion ratio indicating higher gelatinization. [10] Observed that decrease in moisture content from 32, 9 to 14.21%, increased the expansion ratio of corn starch from 1.36 to 2.78. Similarly, expansion ratio decreased from 3.6 to 3.2 g gel·g^{-1} with an increase in fish content from 10 to 30 %. But expansion ratio increased with barrel temperature (Figure 3). The same result given by [15] also suggested that higher protein content of the feed resulted in a lower melt viscosity and reduced extrudate expansion. In reverse to bulk density, the expansion ratio increased from 3.25 to 3.5 g gel·g^{-1}. while the barrel temperature varied from 100 to 110°C. Expansion ratio was influenced greatly by moisture content of feed followed by fish content then by barrel temperature (Tab. 3). Moisture content of feed and fish content have negative correlation with expansion ratio. High expansion ratio and low bulk density are the desired properties of the extrudates.

3. Effect of Process Parameters on Final Moisture Content of Extrudates

Analysis of variance (Tab. 2) indicates that all process parameters had a significant effect ($p \leq 0.01$) on the moisture content of rice flour-fish extrudates with r-square value 0.990. The interaction plot of process parameters on moisture content of extrudates is shown in Fig. 3. From the fig. it is obvious that the extrudate moisture content increase with increase in fish content as well as feed moisture content but decreases with increase in barrel temperature. Higher extrusion temperature resulted in lower extrudate moisture. The extrudate moisture content was in the range of 6.60 to 8.75% (Fig. 3).

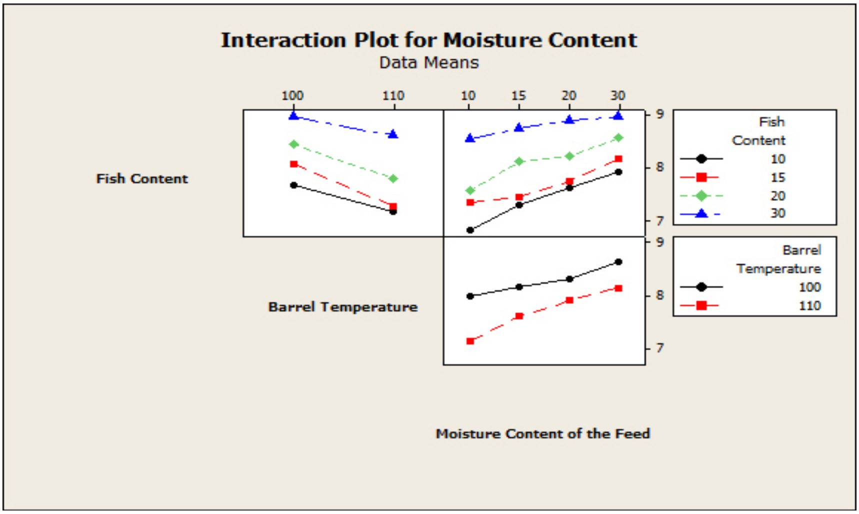

Figure.3. Interaction plot between process parameters and moisture content of extrudates

Highest extrudate moisture was obtained at the highest feed moisture of 30% and fish content of 30%. Similar results were reported by [2]. [2] Worked on cassava flour, reported that feed moisture was most significant on residual moisture content of extrudates. They also observed that the effect of increasing temperature produced lower overall extrudate moistures. According to [13], a rise in moisture feed from 17 to 20 per cent resulted an increase in extrudate moisture from 7.4 to 7.8 per cent. Also he observed a decline in product moisture from 7, 6 to 7.5 per cent with an increase in barrel temperature from 144 to 173°C. Moisture content of extrudates were highly influenced by fish content followed by moisture content of feed then by barrel temperature (Table 3).

Changes in Functional properties of Rice flour-Fish Extrudates

1. Effect of Process Parameters on Water Absorption Index of Extrudates

Water absorption index (WAI) is used to quantify the extent of starch damage during extrusion cooking. WAI has been generally attributed to the dispersion of starch in excess water, and the dispersion is increased by the degree of starch damage due to gelatinization and extrusion–induced fragmentation, that is, molecular weight reduction of amylose and amylopectin molecules [30]. ANOVA results (Tab. 2) indicated that all variables some of the interactions among process parameters had significant effect ($P \leq 0.01$) on the WAI of rice flour-fish extrudates with r-square value of 0.934. The effect of process parameters on water absorption index of rice flour-fish extrudates is presented in Fig. 4.

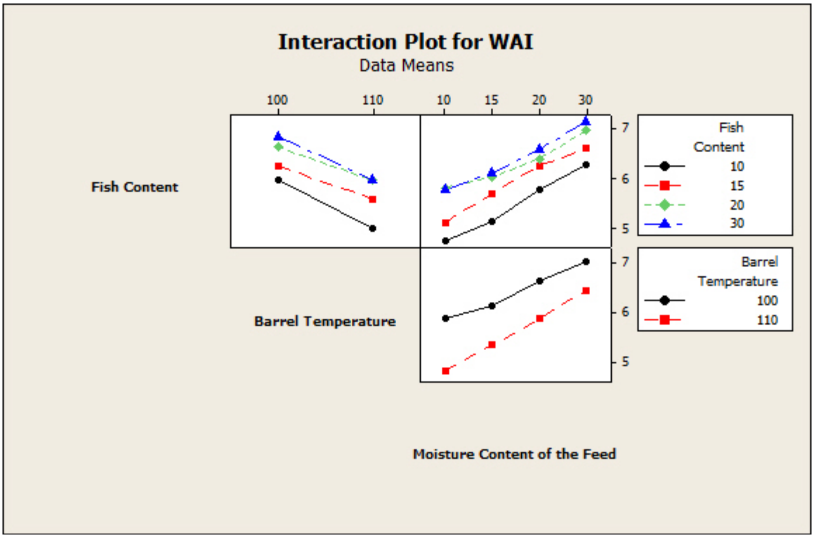

Figure.4. Interaction plot between process parameters and water absorption index of extrudates

WAI increased with increase in moisture content of feed as well as fish content. Colonna *et al.* (1989) reported same results in rice flours extruded with water absorption index increased with an increase in added moisture. According to [8], the lower WAI at low feed moisture may be related in shear resulting in structural modifications of the starch. From Fig. 5, it can be observed that the high barrel temperature resulted extrudates with low WAI. The WAI of 6.45 g·g^{-1} at 100°C reduced to 5.6g·g^{-1} at 110°C. [18] Observed a decrease in WAI with addition of pea grits in extrusion of rice. They explained that a decrease in WAI was due to the dilution of starch in rice pea blends [2] Obtained similar results. [13] Stated that this may be due to degradation of starch molecules. WAI was highly influenced by moisture content of feed followed by barrel temperature and then by fish content (Tab. 3).

2. Effect of Process Parameters on Water Solubility index of Rice Flour-Fish Extrudates

Water solubility index (WSI) is an indicator of degree of gelatinization. High WSI indicates high degree of gelatinization. WSI is often used as an indicator of degradation of molecular components, which measures the degree of starch conversion during extrusion which is the amount of soluble polysaccharide released from the starch component after extrusion process [21]. ANOVA result table indicates that all variables had significant effect (P≤0.01) level on WSI of rice flour-fish extrudates with r-square value 0.989. Also the interactions among the process variables were found to be significant at 1 per cent level.

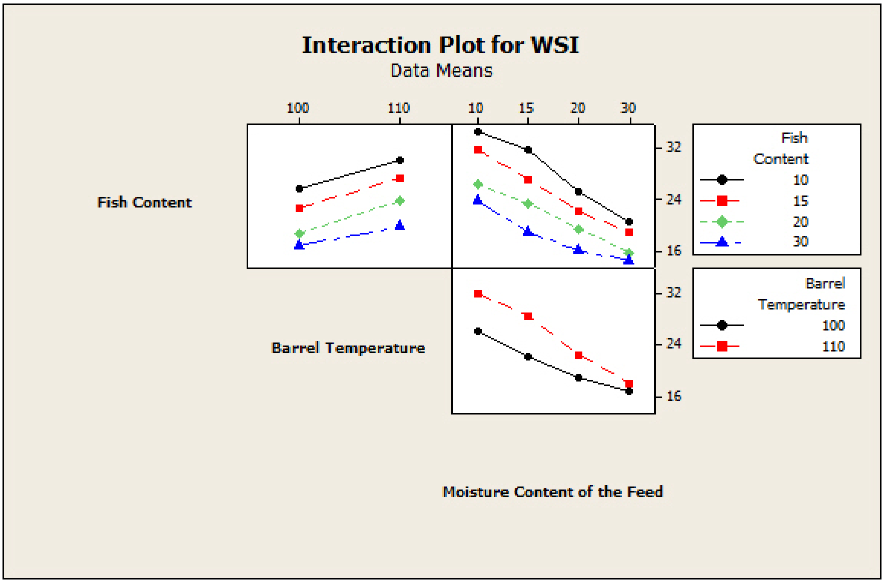

Figure.5. Interaction plot between process parameters and water solubility index of extrudates

The effect of process parameters on WSI is shown in Fig. 6. It is seen from the figure that WSI decreased with an increase in feed moisture and fish content. But increased with increase in barrel temperature. Max value of WSI (37%) was obtained at a feed moisture of 10%, having a fish content of 10% and barrel temperature of 110°C. [19] Reported that water solubility index increased from 33.1 to 45.2 per cent with an increase in barrel temperature from 144 to 172°C for corn meal. The increased solubility of extruded starches was related to stickiness of the end product. This may be due to the increase in shear degradation of starch during extrusion at high temperatures. [13] reported a reduction in WSI from 44.78% to 28.6% when moisture content of feed varies from 17% to 19.6% moisture. WSI relates to the extent of starch damage at low feed moisture levels. This may be due to low water content and exposure to high temperature. WSI was more correlated with moisture content of feed followed by fish content and then by barrel temperature (Tab. 3).

Changes in Textural Properties

Effect of Process Parameters on Hardness of Fish-Rice Flour Extrudates

Textural properties of rice flour-fish extrudates were determined by compression test and the results are given in Fig.7. ANOVA results (Tab. 2) Indicates that all variables had significant effect (P≤0.01) level on hardness of rice flour-fish extrudates with r-square value 0.997. The effect of process parameters on hardness is shown in Fig. 6.

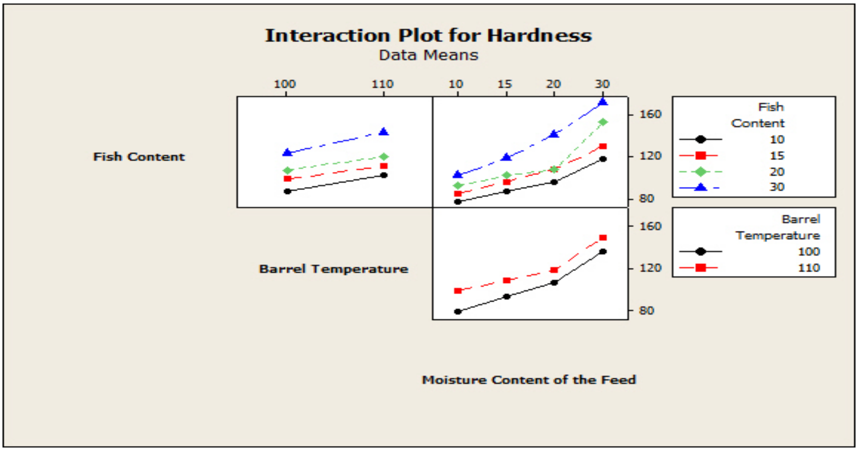

Figure.6. Interaction plot between process parameters and hardness of extrudates

Hardness of the products increased significantly with an increase in moisture content of feed (*P*<0.01), which implies that more energy is required to break the extrudates prepared at 30 % feed moisture. Also, the expansion ratio of the extrudate was lower at high moisture content of feed. An increased expansion results in a more friable product and it requires less force/energy to break. Extrusion temperature, fish content and their interactions also significantly (P<0.01) affected the hardness of the extrudates. Maximum hardness of 182 N was obtained for a feed moisture of 30%, fish content 30% and a barrel temperature of 110°C. Hardness was greatly influenced by fish content of the feed followed by and moisture content of feed and by barrel temperature. Similar report were reported by [16]. They stated the increasing protein content with increasing fish content of greater than 5% interfered the gelatinization of starch. Increasing the fish and protein content of the feed may have resulted in protein cross-linking and development of protein networks. [3] Also reported that the product hardness decreased with an increase in radial expansion. [12] Reported that the hardness of cereal-pulse based extrudates varied between 45 to 110 N, when the temperature varied between 150 and 190°C and moisture between 12 and 20 per cent. [2] Have studied the textural properties of cassava flour extrudates and they have noticed that the extrusion variables of feed moisture, feed composition and temperature significantly influenced the textural changes in extrudates. Increasing temperature would decrease melt viscosity, which favours bubble growth and produce low density less firm products. [7]. Hardness of the extrudates were influenced greatly by moisture content of feed followed by fish content then by barrel temperature (Tab. 3).

Optimization of Process Parameters

The aim of the optimization process was to get the final extrudate with lower bulk density, higher expansion ratio, lower moisture content of extrudate, higher WAI, lower WSI and lower hardness. Based on the empherical knowledge and sensory evaluation, the weightage was given to the quality factor with the following descending order viz. expansion ratio, moisture content of the extrudate, hardness, WAI, bulk density and WSI. The optimization was done in design expert package and the optimum values were 10 % feed moisture, 10% fish content and barrel temperatures of 110ºC.

CONCLUSIONS

The study revealed that the physical, functional and textural properties of fish – rice flour extrudates are affected significantly by moisture content of feed, fish content and barrel temperatures. Significant increases in expansion ratios and decreases in bulk densities were observed when feed-moisture content was decreased from 30 to 10 %. Extrudate hardness and WSI were significantly affected by feed-moisture content and fish content. At feed moisture content less than 15% and fish content of less than 15 % extrudate hardness decreased. Higher barrel temperatures results in dramatically increased expansion ratios and decreased bulk densities. Extrudates with most desirable physical properties and functional properties were obtained at 10% feed moisture, 10 % fish content and barrel temperatures of 110ºC. In case of process parameters, the moisture content of feed had high influence on the final quality of rice-fish extrudates then followed by fish content then by barrel temperature.

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OPTIMIZACIJA PROCESA EKSTRUDIRANJA PIRINAČ-RIBA EKSTRUDATA SA NEISKORIŠĆENIM DELOVIMA RIBE NA OSNOVU FIZIČKIH, FUNKCIONALNIH I TEKSTURNIH SVOJSTAVA

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Sažetak: Ekstrudati su pripremljeni od neiskorišćenih delova brancina i pirinčanog brašna pomoću dvopužnog ekstrudera. Različiti parametri procesa: sadržaj vlage u hrani (10%, 15%, 20% i 30%), procenat količine ribe u hrani (10%, 15%, 20% i 30%) i temperatura (100 °C i 110 °C) su menjani pri ekstrudiranju. Proučavane su fizičke osobine: gustina, nivo ekspanzije i sadržaj vlage ekstrudata, kao i funkcionalna svojstva kao što su: indeks apsorpcije vode, indeks rastvorljivosti u vodi i teksturna svojstva ekstrudata. Rezultati su pokazali da su odnos ekspanzije i gustina ekstrudata u opsegu od 2.85 do 4.10 i 130 do 225 $kg \cdot m^{-3}$, redom. WAI i WSI ekstrudata variraju od 5.2 do 6.7 $g \cdot g^{-1}$ i 17% do 30%, respektivno. Najveća tvrdoća je primećena na 30% vlage u hrani, 30% riba mlevenog sadržaja i temperaturi od 110°C u cevi. Analiza varijanse (ANOVA) je pokazala da su svi parametri procesa značajno uticali na fizička, funkcionalna i teksturna svojstva ekstrudata. Optimalni parametri procesa ekstruzije pirinča i ribe su iznosili: vlaga u hrani 10%, sadržaj ribe 10% i temperaturi u cevi od 110°C.

Ključne reči: *ekstruzija, ekstrudati pirinač-riba, kuvanje, neiskorišćeni ekstrudati ribe*

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COMPARATIVE PERFORMANCE OF MECHANICAL TRANSPLANTING AND DIRECT SEEDING OF RICE

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Abstract: Rice is a major crop that is grown in more than 110 countries. The total area planted under rice in India is 44.0 million hectares which is largest in the world against a total area of 156.6 million hectares. The average yield of rice in India is 3.2 3.2 $t \cdot ha^{-1}$. The reasons for low yield are limited area under irrigation, seasonal shortage of resources and delay in land preparation and transplanting. A study on economics and major constraints in rice cultivation in Kaithal district of Haryana was conducted during 2009-10. Total costs in rice production amounted to be Rs. $33778.68 \cdot ha^{-1}$. Average yield was 4.99 $t \cdot ha^{-1}$. Benefit-cost ratio worked out to be 1.27. Pests and disease incidence, lack of remunerative price and labour shortage were the major constraints in rice production.

Key words*: rice transplanter, farm economics, farm mechanization*

INTRODUCTION

The average yield of rice in India is 3.2 $t \cdot ha^{-1}$. The reasons for low yield are limited area under irrigation, seasonal shortage of resources and delay in land preparation and transplanting. With the introduction of high yielding varieties of rice and increased emphasis on inputs like fertilizers, irrigation and pesticides, yields have increased considerably. But still there is a wide gap between potential and actual yield of rice in India. This gap can be further narrowed down with the adoption and prorogation of improved cultural practices and efficient input management. Various methods of sowing

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of rice are adopted in the county. These are direct seeding of dry seeds manually or with a seed drill, broadcasting or line sowing of dry seed/pre-germinated seed and transplanting of 3-4 weeks old seedlings in puddled fields. In India, manual transplanting of 3-4 weeks old nursery seedlings after puddling is the most commonly used conventional practice of rice cultivation. Manual transplanting is pre-dominant practice in almost all the rice growing areas but scarcity of labour, high cost of transplanting and less plant population are associated with this practice [2].

About 50 % of the total irrigated area is under rice cultivation in India, and 50 % of irrigation water is used for rice crop whose water requirement is 10^7 $l \cdot ha^{-1}$ [3]. Since, rice is the lowest productive crop per unit of water consumed amongst cereals; therefore, optimum water management and cultural practices need to be followed to ensure minimum losses of water. Approximately 75 % of water applied to rice crop is lost through deep percolation during submergence of field [4]. Hence, it is cultivated under puddled condition so as to minimize the percolation losses and to enhance the water and nutrient use efficiency of plant. Mostly, in India and other developing countries of Asia, rice is transplanted manually which is labour intensive and requires 250-350 man-hr ha^{-1} that is 25 % of the total labour requirement of the crop [5].

The mechanical transplanting of rice has been considered the most promising option, as it saves labour, ensures timely transplanting and attains optimum plant density that contributes to high productivity. Hence in the present study an eight row self-propelled rice transplanter (Model 2ZT-238-8) was evaluated for its performance on field scale.

The most common method of land preparation for wetland rice in south and Southeast Asia is puddling. This method primarily helps water saving by decreasing percolation and preventing leaching losses of plant nutrients. Puddling generally refers to breaking down soil aggregates at near saturation into ultimate soil particles. The degree of puddling also depends on tillage implement and intensity of puddling. During the puddling operation, the soil is rigorously manipulated, soil structure is thoroughly disturbed and air filled pore volume is drastically reduced. Land preparation for puddling starts in summer, whenever soil moisture conditions permit ploughing. After the onset of the monsoon when there is some standing water in the bunded rice fields, the puddling operation is performed. Farmers of Chhattisgarh do not drain the ponded water from their field as a precautionary measure to save the crop from intermittent dry spells. Due to the practice of keeping extra amount of standing water in the field, percolation losses increase several folds. Soil manipulation through puddling decreases permeability, increases water retention capacity, facilitates transplanting and eradicates weeds especially in heavy textured soil with high activity clay [6].

MATERIAL AND METHODS

The experimental study of "Comparative performance evaluations of mechanical transplanting and direct seeding of rice under puddle and unpuddle conditions" was conducted at the Research Farm of CCSHAU Rice Research Station, Kaul (Kaithal) during kharif season of 2009-10. Kaul is situated 30 km away from the holy city of Kurukshetra at latitude 290 51' N, longitude 760 41' E and altitude 241 metres above mean sea level. It is located in the heart of the rice growing region, called 'Rice Bowl of Haryana (State in India).

Self-propelled rice transplanter

The machine has of two detachable parts. The front portion has engine, gear box, lever for adjusting hill spacing, PTO shaft, toothed iron wheel for field operation, steering, driver's seat and two seats for two persons feeding seedlings or nursery cake. The rear portion has floating board, nursery platform, transplanting fingers with screws for adjusting plants/hill, depth setting lever, chain for height adjustment of float board and pedal for float-lifting. For movement one place to another, toothed iron wheel is replaced with motor bike wheel, and two small wheels are fitted below the floating board. Floating board serves as a base and also helps in movement of the machine over ponded water in the field. It also serves as a platform for placement of nursery during transplanting operation. On the lower side of the board, moulded rectangular plates with round and smooth edges have been attached (front to back) 23.8 cm apart for corrugation and smooth movement of machine. Corrugation helps in firm establishment of the transplanted plants and also in the faster movement of irrigation water. It also serves the purpose of light planking/smearing which reduces percolation losses.

Table 1. Technical Specification of the Self-propelled Rice Transplanter

Sr. No.	Items	Specification
1.	Model	2ZT-238-8
2.	Dimension (L x W x H), cm	241X213.1X130
3.	Engine power, KW	2.4
4.	Fuel	Diesel
5.	Cooling system	Air cooled
6.	Weight, kg	320
7.	Number of rows	8
8.	Row to row spacing, cm	23.8
9.	Hill to hill spacing, cm	12 and 14

It is powered by a 2.4 KW diesel engine with fuel consumption of 0.5 $l \cdot ha^{-1}$ in field operation (Fig. 1). It plants 8 rows in one pass at a spacing of 23.8 cm x 12 cm and 23.8 cm x 14 cm with 35 and 30 $hills \cdot m^{-2}$, respectively. The plant to plant spacing is adjustable with the help of a lever. Similarly, number of plants per hill may be varied (2-4 plants/hill) by adjusting the position of fingers through screws vis-a-vis nursery platform. Number of plants per hill can be increased by narrowing the spacing between fingers and the platform and vice-versa. To and fro movement of nursery platform is guided by the sliding mechanism provided below it. The machine cost around Rs 1.8 lakh per unit (USD 2800) and is currently being assembled by VST Tillers and tractor Ltd, Bangalore.

Figure 1. A view of transplanting by self propelled rice transplanter

Inclined plate type zero till seed-cum-ferti drill

Sowing of paddy seed was done using inclined plate zero till seed-cum-ferti drill. The machine was operated by 45 HP tractor. The machine was made of mild steel angle iron of size 60×60×8 mm with square cross-section (Fig. 2). Spacing between two furrow openers was 20 cm having 11 furrows. The seed and fertilizer box of zero-till ferti seed–drill was made by using mild steel sheet. The 'U' shaped seed box frame is fabricated from M.S. sheet and its front side was fitted with 11 inclined plates in separate boxs (Fig 3.4). The 'U' shaped seed box size was 18×25 cm and depth of seed in the box is 18 cm. Every inclined plate was having 24 'U' shape cell constructed around its periphery at uniform distance. The drive of the inclined cell plate was given by the main drive shaft through the bevel gear set. The trapezoidal shaped fertilizer boxes with cross section (Top width 21.5 cm, bottom width 11 cm, depth 19.5 cm and length of box 240 cm) are made from 20 gauge black sheet. The fertilizer metering mechanism force feed cum gravity type was fitted in the fertilizer box. Eleven numbers of holes were provided at the bottom of fertilizer box. The agitating gears are provided on shaft just at top of holes for feeding the fertilizer towards holes given at bottom of fertilizer box.

The field performance of self-propelled rice transplanter and zero tillage seed-cum-ferti drill having inclined cell type seed metering mechanism were compared with manual method of rice transplanting. Field area of 0.014 ha for each treatment with adequate irrigation facilities was selected in RRS Kaul. Following treatments were used for the study.

Rice crop (CSR-30) was transplanted / sown in each plot at desired depth and recommended seed rate with both the machine. Recommended agronomic practices were followed in raising the crop. Field emergence in each plot was recorded after 7days, 14 days and 21 days of transplanting/sowing of the crop. Cost analysis based on labor requirement, cost of operation, breakeven point and payback period of both the machines was calculated for their economic feasibility.

Figure 2. A view of paddy sowing by inclined plate type zero till seed-cum-ferti drill

RESULTS AND DISCUSSION

Comparative field performance data of rice crop sown under different methods of establishment

Sowing of paddy seed was done using inclined plate zero till seed-cum-ferti drill. The machine was operated by 45 HP tractors. The machine was made of mild steel angle iron of size 60×60×8 mm with square cross-section. Spacing between two furrow openers was 20 cm having 11 furrows. The seed and fertilizer box of zero-till ferti seed–drill was made by using mild steel sheet. The 'U' shaped seed box frame is fabricated from M.S. sheet and its front side was fitted with 11 inclined plates in separate boxs (Fig 3.4). The 'U' shaped seed box size was 18×25 cm and depth of seed in the box is 18 cm. Every inclined plate was having 24 'U' shape cell constructed around its periphery at uniform distance. The drive of the inclined cell plate was given by the main drive shaft through the bevel gear set. The trapezoidal shaped fertilizer boxes with cross section (Top width 21.5 cm, bottom width 11 cm, depth 19.5 cm and length of box 240 cm) are made from 20 gauge black sheet. The fertilizer metering mechanism force feed cum gravity type was fitted in the fertilizer box. Eleven numbers of holes were provided at the bottom of fertilizer box. The agitating gears are provided on shaft just at top of holes for feeding the fertilizer towards holes given at bottom of fertilizer box.

The performance data of inclined plate type zero-till seed-cum-fertilizer drill is presented in Tab. 2. The machine was adjusted for a seed rate of 20 $kg \cdot ha^{-1}$. The average spacing between the seeds with inclined plate type zero-till seed-cum-fertilizer drill was 3-5 cm. Depth of sowing was recorded 4-6 cm. The average speed of operation of tractor for sowing of rice crop was 4.05 $km \cdot h^{-1}$. The effective field capacity of the drill was 0.55 $ha \cdot h^{-1}$ and field efficiency was 62.5 %. The average fuel consumption of tractor for direct sowing of rice crop was 3.2 $l \cdot h^{-1}$.

A VST rice transplanter Chinese make, model (2ZT 238-8) rice transplanter was used. The row to row spacing 23.8 cm and plant to plant spacing 12 cm. The machine was used under puddled and unpuddled conditions. The age of nursery (mat type) was used of 25 days. The puddle field was prepared with two 0peration of rotavator having 15 cm depth of water over the surface. The puddling index was 53%. The average speed of operation of self-propelled rice transplanter for sowing of rice crop was 1.28 km h^{-1}. The effective field capacity of the self-propelled rice transplanter was 0.16 $ha \cdot h^{-1}$ and corresponding field efficiency was 66.6%. The average fuel consumption of self-propelled rice transplanter was 0.46 $l \cdot h^{-1}$.

Number of seedling per hill: The number of seedling per hill varied from 2.3 to 2.8 under mechanical transplanting whereas in DSR method it was recorded 1.4 to 2 and in manual method it was found 2.1.

Number of plants/hills per square meter: The number of plants per square meter under DSR techniques was observed in the range of 120 to 150 whereas number of hills per square meter varied from 27 to 32 under mechanical transplanting and in manual it was observed 33. Transplanting was done with manual method as per recommended row to row and plant to plant spacing (20×15 cm)

Number of missing hills per square meter: Results recorded revealed that the number of missing hills per square meter varied from 1 to 2 whereas no such observations was recorded as neither required under DSR and manual method.

Number of floating hills per square meter: The number of floating hills per square meter varied from 1 to 5 when the crop was transplanted with self-propelled rice transplanter.

Missing index: The missing index varied from 3.1 to 7.4% when the crop was transplanted with self-propelled rice transplanter.

The grain yield was similar among all the treatments when compared with manual PTR, except Zero-till mechanical transplanting having lower grain yield than all other methods. Maximum grain yield was recorded under zero-till DSR with residue and puddled manual transplanting. These results are in line with the findings of Thakur (1993) [7].

Yield and yield attributes under different methods of rice establishment

Plant height of crop was similar under all the establishment methods. However, Puddled mechanical transplanting and Puddled manual transplanting had larger plant height. Days of crop maturity were similar in all establishment methods.

Maximum effective tillers were recorded under manual transplanted rice under puddle conditions and also in unpuddled mechanical transplanting but these were non-significant in all other establishments' method.

Panicle length in all the treatments was found to be non-significant. Among the treatments the panicle length was shorter in T_4 treatment than other treatments. Numbers of grains per panicle non-significantly differ in all the crop establishment method (Tab. 2). 1000-grains weight was influenced by enhanced growth during grain development period. There was no-significant difference in 1000-grain weight among all the treatments.

Table 2. Comparative field performance data of rice crop shown different methods

S.No.	Parameters	T_1	T_2	T_3	T_4	T_5	T_6	Manual (T_7)
1.	Area covered (m^2)	140.2	140.2	140.2	140.2	140.2	140.2	140.2
2.	Speed of operation($km \cdot h^{-1}$)	4.05	4.05	4.05	1.3	1.28	1.28	-
3.	Row to row spacing (cm)	20	20	20	23.8	23.8	23.8	20
4.	Hill to hill distance (cm)	3.3	3.5	4.4	12	12	12	15
5.	No. of seedling/ hill	1.4	2	1.5	2.3	2.5	2.8	2.1
6.	No. of plants m^{-2}	150	142	120	27	32	32	33
7.	No. of missing hills m^{-2}	-	-	-	2	1	1	-
8.	No. of floating hills m^{-2}	-	-	-	5	1	1	-
9.	Missing index (%)	-	-	-	7.4	3.1	3.1	-
10.	Fuel consumption ($l \cdot h^{-1}$)	3.21	3.21	3.21	0.46	0.46	0.46	-
11.	Actual field capacity ($ha \cdot h^{-1}$)	0.55	0.55	0.55	0.18	0.16	0.16	-
12.	Field efficiency (%)	62.5	62.5	62.5	75	66.66	66.66	-
13.	Puddling index (%)	-	-	-	-	-	52.3	52.7

Economic analysis

The lowest yield of (29.75 $q \cdot ha^{-1}$) was obtained in T_4 and the maximum yield (32.67 $q \cdot ha^{-1}$) was obtained in T_5. Economic of rice cultivation under different crop establishment techniques is presented in the Tab. 3.

Table 3. Yield and yield attributes under different methods of rice establishment

Treatments	Days to crop maturity	Panicle length [cm]	No. of effective Tillers/m^2 at harvest	No. of grains/panicle	Test weight [g]	Grain yield [$kg \cdot ha^{-1}$]
T_1	144	23.26	220	76.66	23.43	31780
T_2	144	23.26	220	73.52	23.40	31290
T_3	144	23.77	221	78.33	24.04	32.19
T_4	145	22.56	218	73.30	23.11	29750
T_5	145	23.55	220	76.61	23.85	31940
T_6	145	23.98	220	78.77	24.06	32670
T_7	145	24.34	221	79.55	23.69	32020
SEm	0.39	0.62	0.63	4.75	0.65	0.75
CD 5%	NS	NS	NS	NS	NS	NS

The rental value of the land is assumed to remain the same offset the price fluctuation. The gross returns of T_4 and T_2 were found less as compared to other treatments. The lowest and highest net returns were found to be Rs.5314 (T_7) and Rs.16090 (T_3) per hectare, respectively.

The highest benefit cost ratio was obtained as 1.27 and 1.30 for T_2 and T_3, respectively. The lowest benefit cost ratio was obtained as 1.08 and 1.16 for T_7 and T_4, respectively.

CONCLUSIONS

1. The break-even point of the inclined plate type zero-till seed cum ferti-drill in terms of annual area of coverage was determined as 19.53 ha. Payback period of the inclined plate type zero-till seed-cum-ferti-drill decreased with the increase in annual area covered and found to be 0.09 year.
2. The field capacity, field efficiency and fuel consumption of transplanter were found as 0.18 $ha \cdot h^{-1}$, 65.33% and 0.46 $l \cdot h^{-1}$ respectively. Nursery feeding to the transplanter consumed approximately 18.75% total time of operation.
3. The field capacity and field efficiency of tractor operated inclined plate type zero-till seed cum ferti-drill were found as 0.55 $ha \cdot h^{-1}$ and 62.5%, respectively.
4. The cost of transplanting by self-propelled rice transplanter was estimated to be Rs 1372 per ha (if 250 hours run) as compared to Rs 2500 per ha with custom hiring cost of transplanting.
5. The cost of sowing by tractor operated inclined plate type zero-till seed cum ferti drill was Rs. 629 per ha (if 300 hours run) as compared to Rs 1250 per ha with custom hiring cost of sowing . The labour requirement with tractor operated inclined plate type zero-till seed cum ferti drill was 4 man-$h \cdot ha^{-1}$.
6. Alternate methods of rice establishment like zero-till DSR with or without residue, zero-till MTR, unpuddle MTR and puddle MTR produced grain yields similar to conventional PTR.
7. The break-even point of the self-propelled rice transplanter in terms of annual area of coverage was determined as 45 ha. Payback period of the transplanter decreased with the increase in annual area covered and found to be 0.98 years.

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UPOREDNE KARAKTERISTIKE MEHANIČKOG PRESAĐIVANJA I DIREKTNE SETVE PIRINČA

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Sažetak: Pirinač je osnovna kultura koja se gaji u više od 110 zemalja. Ukupna površina posejana pirinčem u Indiji je 44 miliona hektara, što je najviše u svetu, u poređenju sa ukupnom površinom od 156.6 miliona hektara. Prosečan prinos pirinča u Indiji iznosi samo 3.2 $t \cdot ha^{-1}$. Razlog za ovako nizak prinos su ograničene oblasti koje se navodnjavaju, sezonski nedostatk resursa i kašnjenje sa pripremom zemljišta i presađivanjem. Proučavanje ekonomskih parametara i najznačajnijih ograničenja u uzgoju pirinča u oblasti Kaithal u Haryana izvedeno je tokom 2009-10. Ukupni troškovi u proizvodnji pirinča iznosili su Rs. 33778.68$\cdot ha^{-1}$. Prosečni prinos bio je 4.99 $t \cdot ha^{-1}$. Odnos prihoda i troškova iznosio je 1.27. Pojava štetočina i bolesti, slaba cena i nedostatak radne snage predstavljali su glavna ograničenja u proizvodnji pirinča.

Ključne reči: *presađivač pirinča, poljoprivredna ekonomija, poljoprivredna mehanizacija*

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EFFECT OF MOISTURE CONTENT ON GRAVIMETRIC AND FRICTIONAL PROPERTIES OF RIDGE GOURD SEED (*Luffa Actangula Roxb*)

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Abstract: The present study was undertaken with five moisture levels (8%, 12%, 16%, 20% and 24%), whose effect was studied on gravimetric and frictional properties of ridge gourde seed. The gravimetric properties such as thousand grain weight, single grain weight and porosity increased linearly with increase in moisture content from 8 to 24% except bulk density and kernel density showed a decreasing trend. The frictional properties such as angle of repose and coefficient of static friction also increased linearly with increase in moisture content. The thousand grain weight, volume of single grain, bulk density, kernel density and porosity of ridge gourd were found to be 137.65 gm, 0.145 cc, 0.666 gm·cc^{-1}, 1.124 gm·cc^{-1} and 40.75% respectively. The angle of repose was 24.16^0 and coefficient of static friction varied between 0.40 to 0.47 (due to various surfaces). The relationship between moisture content and various gravimetric and frictional properties was also established.

Key words: *Thousands grain weight, bulk density, kernel density, porosity, angle of repose and coefficient of static friction, moisture content*

INTRODUCTION

Ridge gourd (*Luffa Actangula Roxb*) is one of the vegetable cultivated, in the tropics. It is commonly grown all over India but it is more popular in the south and the east. It is also called angled gourd, angle loofah. Ridge gourd fruits are cooked as a vegetable and their seeds are rich in protein and oil. It contains 95.2 gm moisture, 0.1 gm

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fat, 0.5 gm fiber and 0.5 gm protein. Ridge gourd originated in India the production of gourd, pumpkin and squash in India is 33.50 lakh metric tons on an area of 3.50 lakh ha [6]. Gravimetric and frictional properties are the engineering properties of ridge gourd seed. Engineering properties of ridge gourd seed are important in the design of storage structure and processing equipments. The information regarding gravimetric properties of ridge gourd seed is useful for design and analysis of separation and drying equipments. Frictional properties such as angle of repose and coefficient of static friction are used in the design of storage structure.

MATERIAL AND METHODS

The ridge gourd seed var. Phule Sucheta were cleaned and graded with top screen size 9.50 mm and bottom screen size of 6.40 mm round hole with cleaner cum grader (make OSAW Agro. Industries, Hariyana, Capacity 50 to 100 $kg \cdot hr^{-1}$) in the month of Mar 2003 in Agricultural Process Engineering laboratory, at M.P.K.V, Rahuri The initial moisture content of the ridge gourd seed was determined. The samples were further prepared of different moisture contents by conditioning grains. The prediction equations for the effect of moisture content on the engineering properties were developed. Statistical analysis was done using completely randomized design (C.R.D) to test the significance of moisture content on different properties.

Different levels of moisture content (wb) considered in this study were 8, 12, 16, 20 and 24. Half kg of cleaned and graded ridge gourd seeds were used as test material and five replications were taken. The cleaned seeds were conditioned for desired level of moisture content. The test material was then allowed to equilibrate in the airtight stored in a refrigerator for 72 hrs. The actual moisture content of sample was then determined after conditioning.

Gravimetric Properties

Volume of single grain:

Volume of single grain was determined using tolune displacement method by Mohsenin (1970) [7].

$$Volume\ single\ grain = \frac{Volume\ of\ displaced\ tolune}{Number\ of\ grains} \qquad (1)$$

Thousand grain weight:

Five samples of 1000 seeds were taken and weighed on precision balance.

Bulk density:

Bulk density of ridge gourd seed was determined by using a 500cc conical glass graduated cylinder used for measuring volume of the sample. The seeds were slowly poured into a measuring cylinder up to its full capacity. Then weight of grain sample was taken using an electronic balance. Then bulk density of sample was calculated by:

$$Bulk\ density = \frac{Weight\ of\ Sample}{Volume\ of\ Sample} \tag{2}$$

Kernal Density:

Kernal density was determined by using tolune displacement method (Mohsenin 1970) [7]. Five gram of sample was taken into relative density (RD) bottle. About 20 cc of tolune was poured in RD bottle such that sample was fully submerged. Four such RD bottles were kept in vacuum desiccators. One Hp vacuum pump was used to extract the entrapped air in between sample particles. A suction part of pump was connected with the help of plastic pipe of 10 mm in diameter. The vacuum pump was run to extract air by suction. After 15 min settled particles were gently stirred and again air was sucked out. When there was no bubble coming out, the pump was stopped.

Relative density bottles were further filled up to their capacities. The weight of the RD bottles along with sample and tolune was taken. Then RD bottles were emptied and carefully washed. The RD bottles were again filled with water up to full capacity weighed. The weight of empty RD bottle was takes. The kernel density was calculated by:

$$Specific\ gravity\ of\ tolune = \frac{(W_3 - W_2)}{(W_5 - W_2)} \tag{3}$$

$$Kernel\ density\ of\ seeds = \frac{Specific\ gravity\ of\ tolune\ \ X\ \ W_1}{(W_1 - (W_4 - W_3))} \tag{4}$$

Where:
W_1 [gm] - weight of sample,
W_2 [gm] - weight of RD bottle,
W_3 [gm] - weight of RD bottle + weight of tolune,
W_4 [gm] - weight of RD bottle + weight of tolune + weight of sample,
W_5 [gm] - weight of RD bottle + weight of water.

Porosity:

Porosity of unconsolidated mass of material was determined by:

$$Porosity = 1 - \frac{B.D}{K.D} x 100 \tag{5}$$

Where:
B.D. [g·cc^{-1}] - bulk density,
K.D. [g·cc^{-1}] - kernel density.

Frictional Properties

Angle of Repose:

Angle of repose of seeds was calculated by the formula:

$$\Theta_R = \frac{tan^{-1} 2(H_c - H_p)}{D_p} \tag{6}$$

Where:
Θ_R [deg] - angle of repose,
H_c [cm] - height of pile,
H_p [cm] - height of platform,
D_p [cm] - diameter of circular platform.

Coefficient of static friction:

Coefficient of static friction was determined for various surfaces viz. glass, steel and asbestos using the method given by. Surfaces were attached to tilting table one at a time then the sample was placed on the surface. The table was then slowly tilted until the sample started to slide. The angle of tilting table was measured. The coefficient of static friction was calculated as tangent of angle measured.

Data was analyzed using completely randomized design (C.R.D) and the graphs were plotted. The linear mathematical models were developed to correlate the moisture content with the properties on the basis of the correlation coefficient. The best-fit equation with maximum regression coefficient was selected for prediction.

RESULTS AND DISCUSSION

The effect of moisture content on gravimetric and frictional properties of ridge gourd seed (Var. *Phule Sucheta*) was studied and is tabulated in Tab. 1 and Tab. 2, which gives the data on the effect of moisture content on the gravimetric and frictional properties of ridge gourd seed.

Gravimetric Properties

Volume of single grain:

Fig. 1 shows the effect of moisture content on the volume single grain. Volume of single grain weight increased from 0.145 to 0.223 cc for moisture content variation from 8 to 24%. The swelling of grain due to absorption of moisture resulted in increase in volume. The increase in volume with increase in moisture content was reported for niger seed by Bhanuwanshe *et al.,* (1997) [1] and Munde (2000) [4]. The effect was significant at all levels. The mathematical model developed was of form as given below (R^2 = 0.98849).

$$V_s = 0.0948 = 0.0057\ M \tag{7}$$

Thousand grain weight:

Fig. 2 shows the effect of moisture content on the thousand grain weight. Thousand grain weight increased from 137.65 to 171.27 gm with increase in moisture content from 8 to 24 %. This was due to absorption of moisture by grains. The variation of thousand-grain weight was significant for all moisture levels. The increase in moisture content increased thousand grain weight was also reported for gram, horse-gram, niger seed by

Datta *et al.* (1988) [2], Munde (2000) [4] and Banuwanshe *et al.* (1997) [1] respectively. Thousand grain weight at different moisture levels can be predicted by (R^2 = 0.9356).

$$W_{1000} = 124.85 = 1.861M \tag{8}$$

Table 1. Effect of moisture content on gravimetric properties

Moisture content [% w. b.]	1000 grain weight [gm]	Volume of single grain [cc]	Bulk density [g·cc^{-1}]	True density [g·cc^{-1}]	Porosity [%]
8	137.65	0.145	0.666	1.124	40.75
12	148.00	0.160	0.590	0.998	40.88
16	155.66	0.187	0.540	0.935	42.24
20	161.00	0.212	0.513	0.900	43.00
24	171.27	0.233	0.485	0.880	44.87
S.E. ±	3.164155	5.5785E-03	4.0917E-03	1.7794E-03	0.4462518
C. V. (%)	2.045058	2.976784	0.7322766	0.1838508	1.05136

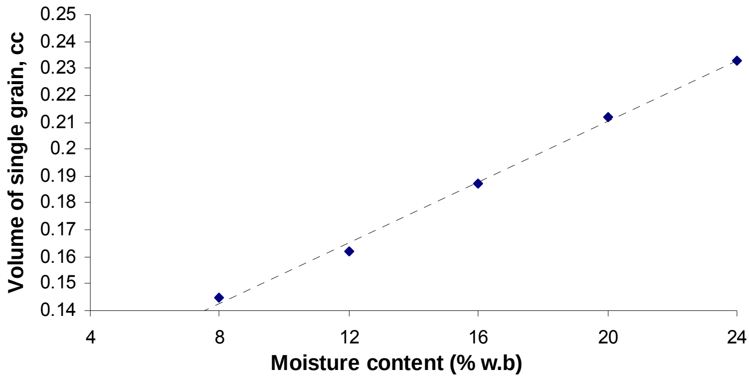

Figure 1. Effect of moisture content on volume of single grain

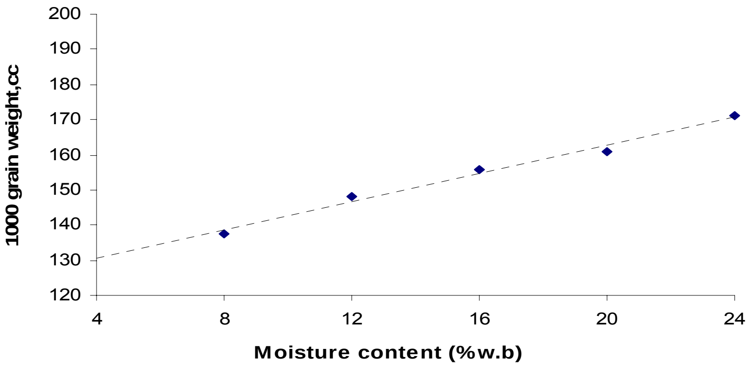

Figure 2. Effect of moisture content on 1000 grain weight

Thousand grain weight:

Fig. 2 shows the effect of moisture content on the thousand grain weight. Thousand grain weight increased from 137.65 to 171.27 gm with increase in moisture content from 8 to 24 %. This was due to absorption of moisture by grains. The variation of thousand-grain weight was significant for all moisture levels. The increase in moisture content increased thousand grain weight was also reported for gram, horse-gram, niger seed by Datta *et al.* (1988) [2], Munde (2000) [4] and Banuwanshe *et al*. (1997) [1] respectively. Thousand grain weight at different moisture levels can be predicted by (R^2 = 0.9356)

$$W_{1000} = 124.85 = 1.861M \tag{9}$$

Bulk density and Kernel density:

Fig. 3 shows the relationship between bulk density and kernel density verses moisture content. It was observed that the bulk density decreased from 0.666 to 0.485 gm·cc^{-1} and kernel density decreased from 10124 to 0.880 gm·cc^{-1}, due to increase in moisture. Mass and bulk volumes both are increased due to absorption of moisture by the seed. However, increase in bulk volume is more pronounced and hence there is decrease in bulk density. In addition in case of kernel density, rate of increase in volume is more and hence there is effective decrease in kernel density. Similar results were reported for pigeon pea and gram by Shephard and Bharadwaj (1986) [5] and Dutta *et al.* (1988) [2].

The mathematical models for bulk density were as under (R^2 = 0.9464, 0.8875)

$$B.D. = 0.7344 - 0.011M \tag{10}$$

$$K.\ D. = 1.2018 - 0.0014M \tag{11}$$

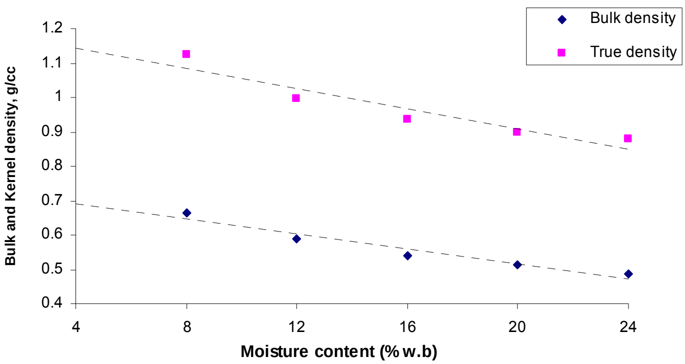

Figure 3. Effect of moisture content on bulk and kernel density

Porosity:

Fig. 4 shows the variation of porosity with moisture content. The data is statistically significant for all moisture levels. The porosity increased from 40.75 to 44.87% with increase in moisture content. Similar results were reported by Dutta *et al.* (1988), Shephard and Bharadwaj (1986) [5] and Kanawade and Dhingra (1982) [3]. The mathematical model for porosity was as under (R^2 = 0.9356)

$$P_0 = 38.214 = 0.2585M \tag{12}$$

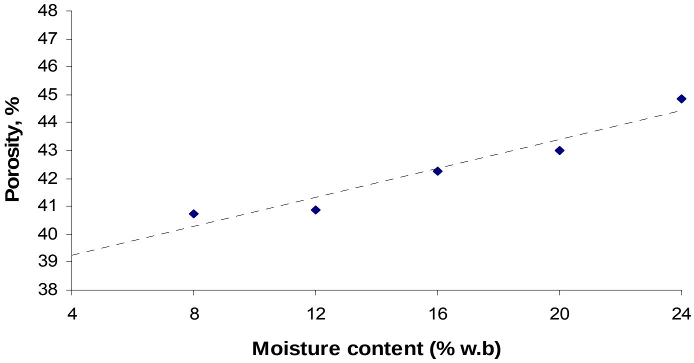

Figure 4. Effect of moisture content on porosity

Frictional properties:

The data on variation in angle of repose and coefficient of static friction with moisture content are presented in Tab. 2.

Table 2. Effect of moisture content on frictional properties

Moisture content [% w. b.]	*Angle of repose [deg]*	*Coefficient of static friction*		
		Glass	*Steel*	*Asbestos*
8	*24.16*	*0.40*	*0.43*	*0.47*
12	*32.08*	*0.41*	*0.46*	*0.50*
16	*36.90*	*0.43*	*0.48*	*0.53*
20	*39.89*	*0.45*	*0.52*	*0.55*
24	*40.38*	*0.47*	*0.55*	*0.59*
S.E. ± *C. V. (%)*	*0.613822* *1.773*	*5.05931E-03* *1.171137*	*3.68709E-02* *0.7567916*	*6.06688E-03* *1.1534*

Angle of repose:

Fig. 5 represents the variation in angle of repose with moisture content. It was observed that the angle of repose increased with increase in moisture content from 24.16^0 to 40.38^0. The variation of angle of repose with moisture content was due to layer of moisture that surrounds each grain and the surface tension effect becomes predominant in holding the aggregates of solids together. Similar results were reported for gram, niger seed, fababean and pigeon pea by Dutta *et al.* (1988) [2], Bhanuwanshe *et al.* (1997) [1] and Munde (2000) [4]. The angle of repose is predicted by equation (R^2 = 0.8924).

$$R = 1.8662 + 0.9983M \tag{13}$$

Coefficient of Static friction:

Fig. 6 represents the graphical representation of variation of coefficient of static friction with moisture content. It was observed that coefficient of static friction was 0.40, 0.43 and 0.47 at 8% moisture content and 0.47, 0.55 and 0.57 at 24 % moisture content for glass, steel and asbestos respectively. The presence of moisture on rubbing surface caused an increase in friction due to increase in adhesion, resulting in increase in coefficient of static friction. The effect of the moisture content on coefficient of static friction was found to be statistically significant at 5% level of significance. Similar results were reported for niger seed, fababean and pigeon pea by Bhanuwanshe *et al.* (1997) [1] and Shephard and Bharadwaj (1986) [5]. The mathematical models for coefficient of static friction are as under (R^2 = 0.8463, 0.9787, 0.9648 for glass, steel and asbestos respectively).

Glass:

$$K_G = 0.3136 + 0.0085M \tag{14}$$

Steel:

$$K_S = 0.3288 + 0.0106M \tag{15}$$

Asbestos:

$$K_A = 0.43 + 0.0050M \tag{16}$$

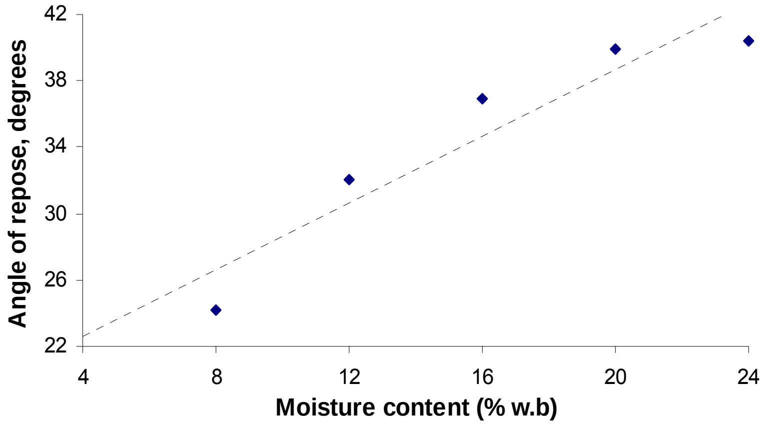

Figure 5. Effect of moisture content on angle of repose

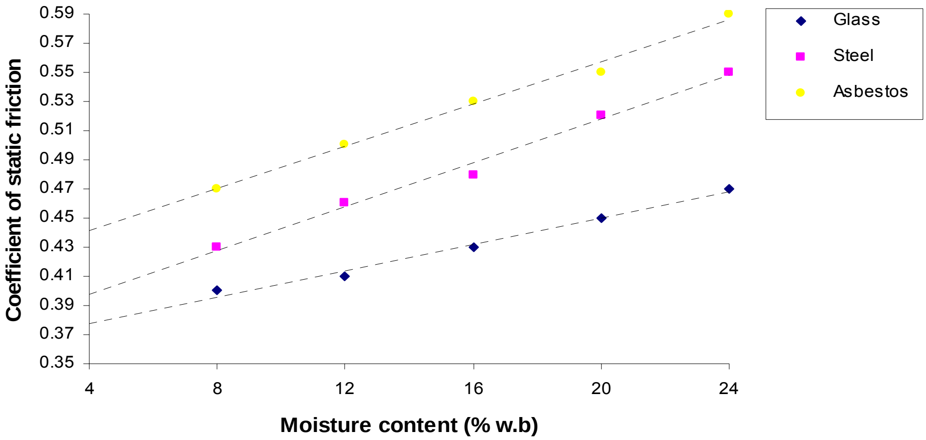

Figure 6. Effect of moisture content on coefficient of static friction

It was revealed that effect of moisture content on gravimetric and frictional properties was found statistically significant at all moisture contents.

CONCLUSIONS

Gravimetric and Frictional properties are the Engineering properties of ridge gourd seed, which are important in the design of storage structures and processing equipments. The gravimetric properties of ridge gourd seed are useful for design and analysis of separation and drying equipments. Frictional properties such as angle of repose and coefficient of static friction are used in the design of storage structure.

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UTICAJ SADRŽAJA VLAGE NA GRAVIMETRIJSKE I FRIKCIONE KARAKTERISTIKE SEMENA TIKVICE (*Luffa Actangula Roxb*)

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Sažetak: Ova studija je izvedena sa pet nivoa vlažnosti (8%, 12%, 16%, 20% i 24%), a proučavani su njihovi uticaji na gravimetrijske i frikcione karakteristike semena tikvice. Gravimetrijska svojstva kao što su masa hiljadu zrna, masa jednog zrna i poroznost linearno su se povećavala sa porastom vlažnosti od 8 do 24 %, izuzev gustine koja je imala trend opadanja. Frikcione osobine, kao što su ugao stabilnosti i koeficijent statičkog trenja takođe su se linearno povećavali sa povećanjem vlažnosti. Masa hiljadu zrna, zapremina jednog zrna grain, gustina i poroznost iznosili su 137.65gm, 0.145cc, 0.666gm·cc^{-1}, 1.124gm·cc^{-1} i 40.75%, redom. Ugao stabilnosti iznosio je 24.16°, a koeficijent statičkog trenja je varirao od 0.40 do 0.47 (zbog različitih površina). Odnos između sadržaja vlage i različitih gravimetrijskih i frikcionih karakteristika takođe je ustanovljen.

Ključne reči*: masa hiljadu zrna, gustina mase, gustina zrna, poroznost, ugao stabilnosti, koeficijent statičkog trenja, sadržaj vlage*

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PERFORMANCE ASSESMENT OF VARIABLE RATE SPINNER DISC FERTILIZER SPREADER – "PreFer"

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Abstract: The objective of this study was to verify systems performance of developed variable rate spinner disc fertilizer applicator (PreFer) which allows applying of granular fertilizer at variable rates in field conditions. Distribution uniformity and accuracy were assessed using a matrix of collection pans and following test procedures outlined in ASAE Standard S341.2. Spread patterns were produced in triangular shape which is favorable in overlapping process. But it was seen that, triangular shapes are differed due to fertilizer types. The performance of system as found by overlapping transverse spread patterns resulted in a CV of 11% with a 10 m working width in calcium ammonium fertilizer application while the CV and working width for composite fertilizer were 20% and 9 m, respectively. It is clear that working width, and so cell width, was limited by spread width of machine and the CV value while applying different types of fertilizer.

Key words: *Precision agriculture, spinner disc fertilizer spreader, variable rate fertilizer application, performance assessment*

INTRODUCTION

In order to increase the productivity and profitability, agriculture-related researches have been focused on introduction of new high–yield and pest-resistant varieties as well

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as finding the best ways to use agricultural inputs more effectively due to the recent focus on environmental concerns since 1990 [8].

Modern agricultural systems, along with preserving the quality of world's environmental sources, must increase the productivity and profitability for farmers. Variability that exists in growing conditions (soil, crop, disease etc.) has to be considered while managing through a new approach called "Precision Agriculture" and its related technologies (GIS, GPS, VRT). Precision Agriculture is an approach for producing food and fiber in a sustainable way by assigning information technologies. Precision agriculture approach has made a deep impact on the world's agriculture, and although the principals of this trend are the same, the tools and machines should be modified, based on the country and also each farm's conditions.

Many studies in the past were conducted to develop prototype variable rate applicators. Some of them focused on applying fertilizer (spinner disc type or pneumatic type). Sensor based or map based variable rate technologies have been under consideration. In sensor based technology, sensors are employed in order to determine the amount of fertilizer requirement for a particular location and then actuators vary the input rate based on the fertilizer need. Map based technology uses digital maps with location data. The map is generated by analyzing the data obtained by soil sampling, yield mapping etc [15].

Spinner disc type spreaders are very popular, due to the fact that they are simple in design; and also that they are require little maintenance while field work capacities are high [5, 12, 14, 7, 9]. Earlier studies on variable rate granular fertilizer application were carried out by Fulton et al. (2001), who modified a granular spreader truck equipped with a commercially available controller and a GPS system.

Fulton *et al.* (2001) tested the performance of the applicator by modifying ASAE S 341.2 standard. Besides this one, they conducted many studies concerning the performance assessment and modeling of variable rate fertilizer applicators.

Cerri *et al.* (2002) designed and built a system for variable rate lime application. The system included a computer to obtain the coordinate information from GPS and to look up prescription map in order to find the exact rate to instant location, and then send signals to step motor to control the fertilizer flow.

Recently, some researchers have focused on electromechanical control system. There are also commercial products in the world market that have such a system. But, there is no similar system on the spreaders produced by national companies. Tekin (2005) completed his PhD. degree with an output of VRT double spinner disc prototype (PreFer). The system (considering country specific conditions) applies granular fertilizer at variable rate by employing rollers. In order to build the VRT spreader they used main components of commercially manufactured spinner disc granular fertilizer spreader. Tekin and Sindir (2013) reported the system with indoor test results.

Akdemir *et al.* (2007) developed a variable rate controller for centrifugal fertilizer spreader. They employed step-motors to control the fertilizer application rate by varying the outlet area of windows at the bottom of the spreader hopper. Step motors were connected to the rate control levers of spreader.

The objective of this study was to verify the field performance of the developed VRT spinner disc fertilizer spreader (PreFer) while applying granular fertilizer at variable rate in field condition.

MATERIAL AND METHODS

In this study, double spinner disc fertilizer spreader equipped with prototyped variable rate control system (PreFer) was tested while applying granular fertilizer in field condition (Fig. 1).

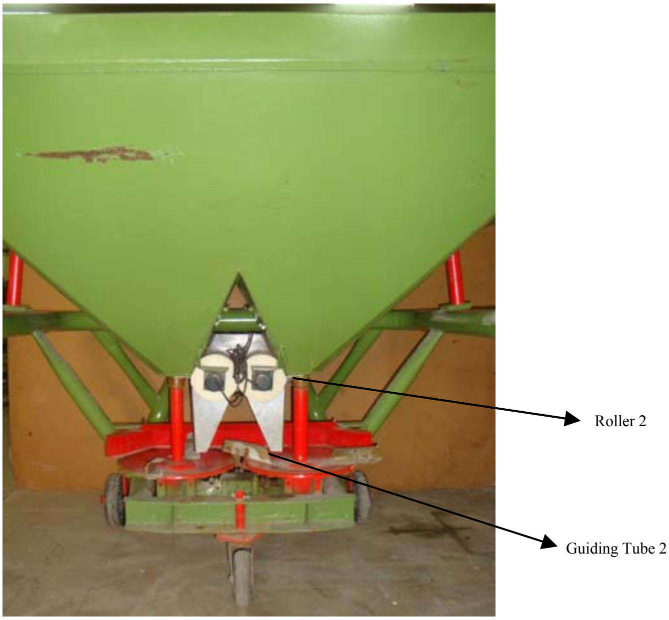

Figure 1. Rollers on spinner disc fertilizer applicator

Transverse distribution uniformity is one of the important indicators for reporting the machine performance. Therefore, in order to quantify the machine spread uniformity, outdoor tests were conducted. Calcium Ammonium Nitrate (26% CAN) and composite 20.20.20 fertilizer were used as test materials.

According to provided collection device dimension, plastic boxes were built (ASAE S341.3). The pans used were 472 mm long, 312 mm wide and 110 mm tall. A carton divider with a 102 mm by 102 mm (50 mm height) grid was also fabricated in order to be placed inside each tray to reduce material from ricocheting out of the pan. Plastic boxes were placed in a line (perpendicular to travel direction) side by side, covering the whole spreading width. In order to allow the tractor to drive over the lines of plastic boxes, the boxes on the wheel track lines were taken. For replication purposes, boxes were placed as three parallel lines (Fig. 2). After each test, the fertilizer collected in each box was bagged, sealed and labelled. Samples were taken to laboratory and weighed. By using the data, transverse distribution uniformities were calculated and the coefficient of variation (CV) was found as an indicator of spread uniformity and was used for evaluating the spread uniformity.

Figure 2. Transverse distribution test site layout

Two different guiding tubes were used to change the fertilizer drop location onto the disc (Fig. 3). During the test process, two different fertilizers were used and the application rates were 250 kg ha^{-1}. All of the tests were conducted when the sustained wind speeds were less than 8.0 km h^{-1} at the height of 1.5 m, and the test side slope was less than 2%. Hopper was filled to approximately 40–50% of the whole capacity when the tests were run. Tests were conducted at 540 rpm (PTO).

(1) (2)

Figure 3. Guiding tubes

During the performance tests of designed variable rate control system, electronic balances (Sartorius BL610, with a range of 610 g and 0.01g precision; Tamtest TTS 2010 with a range of 50 kg, and 20 g precision) were used in weight measurement.

RESULTS AND DISCUSSION

Spreading uniformity of the prototype was examined with different fertilizers and guiding tubes. Initial tests were conducted to reveal the affects of guiding tube on the spreading uniformity. Although the analysis of transverse spread patterns showed that the effect of guiding tube 1 is similar to that of guiding tube 2, spreading uniformity of guiding tube 1 was less than that of guiding tube 2 (Fig. 4, 5, 6 and 7). Transverse spread patterns of guiding tube 1 was less skewed in shape than that of guiding tube 2. In addition, guiding tube 1 caused fertilizer granules to be collected predominantly in the centre, in contrast to tube 2. Therefore, latter tests were conducted by attaching guiding tube 2 to collect data during transverse spread uniformity tests.

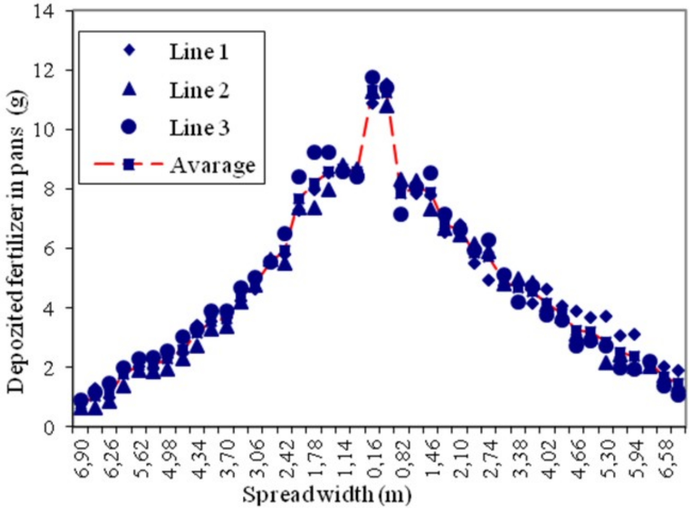

Figure 4. Transverse spread pattern
(Calcium ammonium nitrate- Guiding Tube 1)

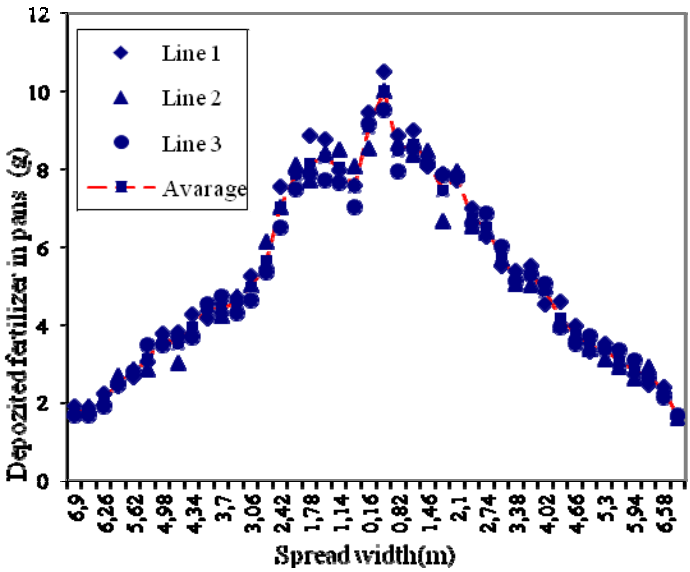

Figure 5. Transverse spread pattern
(Calcium ammonium nitrate- Guiding Tube 2)

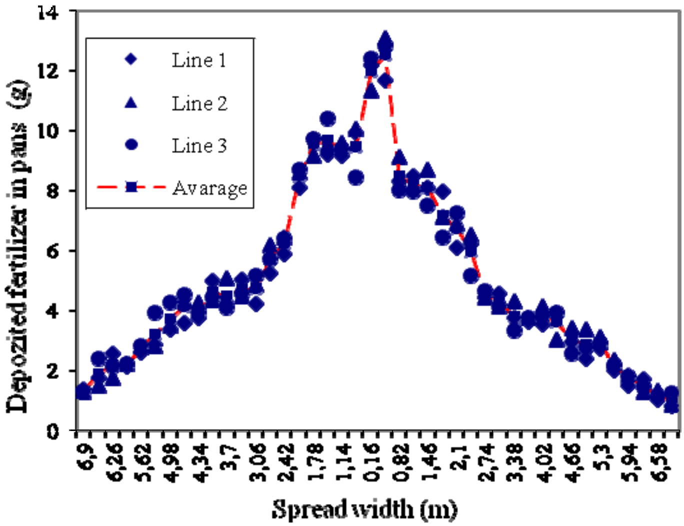

Figure 6. Transverse spread pattern
(Compose Fertilizer- Guiding Tube 1)

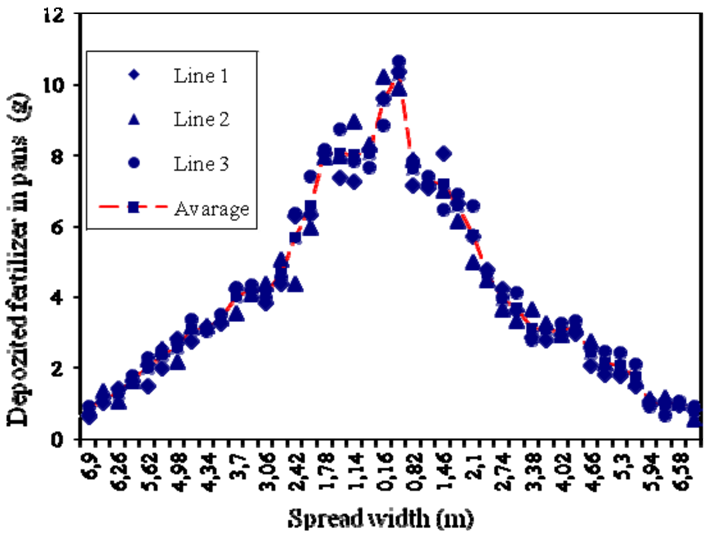

Figure 7. Transverse spread pattern
(Compose Fertilizer- Guiding Tube 2)

Left/right ratio of applied fertilizer was given in Tab. 5. Although the spread patterns of composite fertilizer have some typical irregularities as compared to ammonium, surprisingly, left/right ratios showed that compose fertilizers were applied to both sides of tramline equally.

Table 5. Left/right ratio of applied fertilizer due to guiding tube and type of fertilizer

Left / right ratio (%)	*Calcium ammonium nitrate*	*Compose*
Guiding Tube 1	*0.77*	*0.94*
Guiding Tube 2	*0.79*	*0.91*

Coefficient of variation was used in analyzing of spinner disc spreader performance by scientists [10]. Therefore, the data set also was used in order to determine the relation between the coefficient of variation and the working width (Fig. 8 and 9). Analysis showed that 9 % CV was reached, which corresponds to 9.32 m working width in calcium ammonium nitrate application, whereas CV is relatively higher in compose application with a value of 16% in 8 m working width.

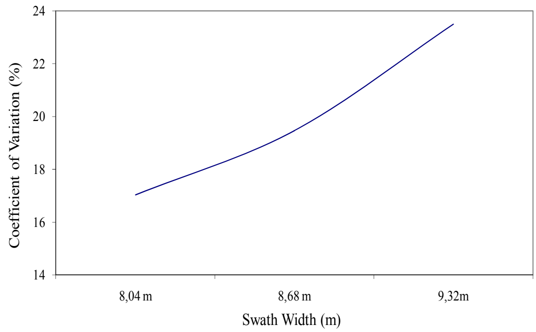

Figure 8. Working width vs CV in calcium ammonium nitrate fertilizer application

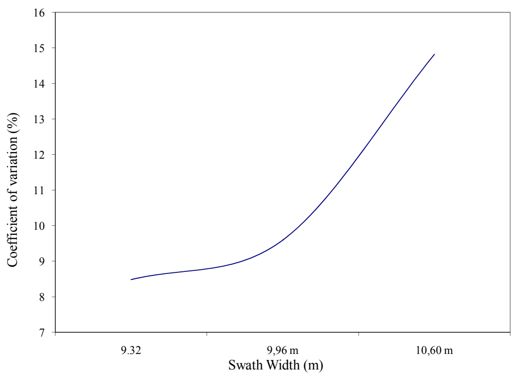

Figure 9. Working width vs CV in compose fertilizer application

Depending on the results concluded from CV versus working width analysis, transverse spread patterns were overlapped by considering basic A–B parallel swathing and in Back-Forth mode since it represents the worst-case scenario and is most popular [12]. The left/right ratio value reached to 0.88 from 0.79 in ammonium application. The ratio also was changed to 1.06 in composite application (Fig. 10 and 11).

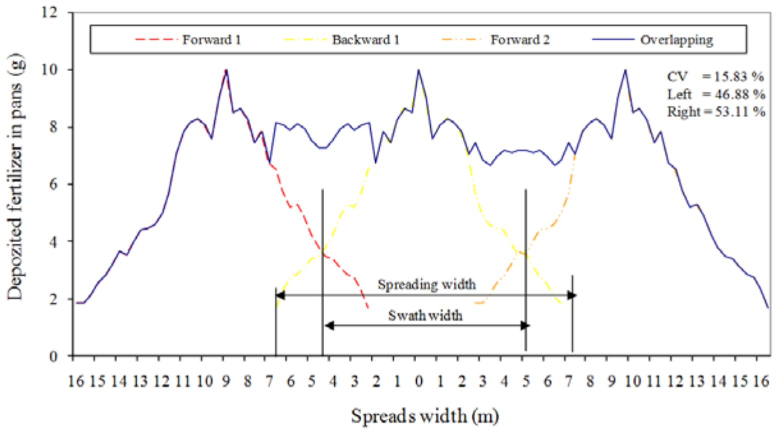

Figure 10. Overlapping in calcium ammonium nitrate (250 kg ha^{-1}) application

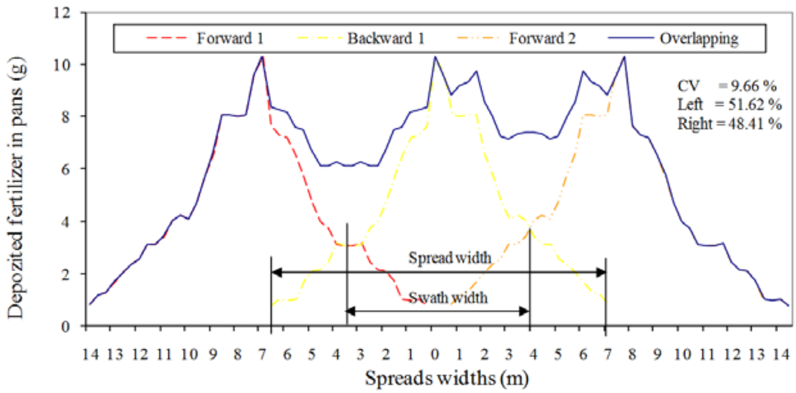

Figure 11. Overlapping in compose fertilizer (250 kg ha-1) application

CONCLUSIONS

A prototype of variable rate fertilizer spreader using a frame of commercially available spinner disc fertilizer spreader was developed considering the country-specific conditions in this study. The machine was mechanically modified and equipped with metering rollers, an electronic control unit, a speed control unit, and a DGPS module.

Initial tests revealed that, dropping point of fertilizer onto disc is affecting spreading uniformity which is coinciding with the results of previous researches. Spreading uniformity tests also made visible the affect of fertilizer type as reported from researches. Experimental tests are required in field conditions to investigate the performance of the system, optimize settings, and to verify if any modifications are required before the system can be used in farm conditions.

Beside this, variation of fertilizer volume realising onto disc is another critical issue since uniformity tests is conducted at fixed rate based on the ASAE S341.3. However, variable rate application brings variation at flow rate which will probably cause distortion on spreading uniformity. Due to the fact that, online adjustments of several parameters such as vane angle, disc speed are needed to overcome the negative effect of flow rate variation. Therefore, further tests and development on the system will be conduct for improving the performance.

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PROCENA PERFORMANSI RASIPAČKOG DISKA PROMENLJIVE NORME RASIPANJA NA RASIPAČU ĐUBRIVA – "PreFer"

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Sažetak: Cilj ove studije bio je da proveri performance sistema razvijenog rasipačkog diska rasipača đubriva sa promenljivom normom aplikacije (PreFer), koji omogućuje primenu granuliranog đubriva u promenljivim normama u poljskim uslovima. Ujednačenost distribucije i tačnost su procenjivane upotrebom matrice sabirnih sudova i po procedurama testiranja koje su istaknute u ASAE standardu S341.2. Modeli rasipanja su izvedeni u trouglastim oblicima što je zastupljeno pri preklapanju. Ali bilo je uočeno da se trouglasti oblici razlikuju zbog tipova đubriva. Performanse sistema koje su uočene preklapanjem podužnih modela rasipanja dao je koeficijent varijacije od 11% na 10 m radnog zahvata sa kalcijum amonijačnim đubrivom dok je su koeficijent varijacije i radni zahvat za kompozitno đubrivo bili 20% i 9 m, redom. Jasno je da je radni zahvat, kao i širina ćelije, bio ograničen radnim zahvatom mašine i vrednošću koeficijenta varijacije pri primeni različitih tipova đubriva.

Ključne reči*: Precizna poljoprivreda, rasipački disk, promenljive norme aplikacije đubriva, procena performansi*

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FLAME WEEDING METHOD TO CONTROL WEEDS IN FABA BEAN IN RIVER NILE STATE IN SUDAN

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Abstract: A flame apparatus was designed and its performance in terms of weeding efficiency and economic feasibility was compared with hand weeding and herbicides application. Weeding was carried out at 4 and 4 plus 6 weeks after sowing for flaming and hand weeding. A pre-emergence herbicide Pursuit plus Stomp, was mixed in a tank and applied before one day of first irrigation at the recommended rate. The mean number of weeds over two seasons revealed that flaming at 4 weeks after sowing reduced weed density by 77.3% and 71.3% respectively, whereas for hand weeding at the same period was 80.8% and 70.3% respectively. Grain yield of the plots subjected to flame weeding was comparable to that from pre-emergence herbicides and hand weeding treated plots for both growing seasons. However, economic analysis showed that flame weeding at 4 weeks after sowing gave the highest value of marginal rate of return for both seasons.

Key words: *weeding, faba bean, flame, River Nile State, Sudan.*

INTRODUCTION

Faba bean (*Vicia faba*) is one of the main cash and food crops in northern Sudan where 98% of the crop is produced. One of the major factors limiting the production of faba bean in the Sudan is the high weed infestation. Sudan is classified as a class C country (least developed), in which losses of yield in the large-acreage food crops

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attributed to weeds are estimated at 25% [1]. For faba bean Kukula *et al*. [2] found that without weed control practice, a crop loss of up to 54% was recorded. Hand weeding is common around the world, and an estimate up to 50-70% of the world's farmers control weeds by this methods [3,4]. In the River Nile State, it is the most common method adopted by the farmers and represents 85% of weed control [5], however other practices such as the use of herbicides are also used.

Faba bean crop is very sensitive to competition with both broad-leaved and grassy weeds [6, 7, 8, 9]. Intensive studies were carried out to determine most prevalent weeds, weed competition critical period and chemical weed control methods in faba bean crop in the River Nile State [10, 11]. From these studies, the critical period has been found to be between 2 and 6 weeks from sowing and a mixture of pre-emergence herbicides are recommended for legume crops, and hand weeding which is tedious and time consuming is usually performed after 6 weeks to use weeds as animal fodder.

There has been a dramatic increase in cases of herbicide-resistant weeds worldwide. For the ALS herbicide group (Glean, Accent, Pursuit) 95 species are now resistant, and for Dinitroanilines herbicide group (Treflan, Prowl, Stomp) 10 species [12]. Developing countries contribute 22 percent of the herbicide resistance incidences worldwide [13], thus emphasis continues on all possible alternatives of cultural and biological weeds control. This study analyzes the flaming technique for weed control to alleviate the tedious human power use and to improve efficacy of weeding, as also flame can suppress any weeds.

MATERIAL AND METHODS

A flame apparatus using liquefied petroleum gas (LPG) was designed, the apparatus consisting of a LPG cylinder with 10.5 liter capacity, equipped with a valve, a pressure regulator, a high pressure hose, a round burner with valve, shield, ground wheel and a frame with handle (Photo 1). Its performance in terms of weeding efficiency; work rate and economic feasibility was compared with hand-weeding using a hand-held tool (toryia) and the recommended pre-emergence herbicides, namely, Pursuit and Stomp (in tank mixture) as sprayed at the rate of 0.05 and 1.2 kg a.i./ha respectively. Flaming and hand weeding were carried out at four and 4+6 weeks after sowing.

Herbicide efficiency has been based on the average weeds/m^2 four weeks after sowing in herbicides treated plots. Weeding efficiency for flaming and hand weeding was assessed from a specific area, as a percentage of total weeds before weeding to the eradicated weeds from the same area, with labels fixed till weeds counted 3 days after weeding operation for complete desiccation, with the purpose to study the effect of flaming on already emerged weeds before treatment rather than weeds emerging after treatment. The mean weeding efficiency was calculated as the average of weeding efficiency to control grasses and broad-leaved weeds. For the work rate calculation, as the different weeding treatments depended on one man power, and herbicides and flaming were applied at a man walking speed and pre-emergence herbicides sprayed with a 1.2 m boom width, hand weeding and flaming carried out within 0.6m width, therefore time to cover a unit of area was taken.

A test carried out for evaluating the effect of flaming soil surface on micro flora content, one gram of 3 soil samples from the field dissolved in 10 mℓ of sterile distilled water.

Figure 1. Flame emission apparatus

Nutrient agar and Malt extract agar media for the isolation of bacteria, fungi respectively were prepared and poured into Petri dishes under sterile conditions, and they inoculated with 1mℓ of soil samples dissolve, plates were incubated at 35^{o}C for 24 hours for bacteria and at 27^{o}C for 28 hours for fungi, then counted under microscope. Data on weeds/m^2; yield; application time; herbicides and LPG consumed and their cost for each plot were collected. The experiment was executed in randomized block design with four replications, for two consecutive seasons 2006/07 and 2007/08. The results were analyzed statistically using Mstat C computer software.

RESULTS AND DISCUSSION

The flame weeding shows a promising efficiency to control grasses and broad-leaved weeds (Tab. 1), analysis shows that there was significant difference in mean weeding efficiency, and efficiencies to control grasses and broad-leaved weeds in both seasons. Comparison of means of flaming and hand weeding efficiency at four weeks after sowing show no differences except on grasses in the last season. The means of flaming efficiency to control weeds at four weeks after sowing were 77.3% and 71.3% respectively at the two seasons, whereas for hand weeding at the same period they were 80.8% and 70.3% respectively, and the efficiencies of a mixture of Pursuit + Stomp as a pre-emergence herbicides were 89.3% and 88.1% respectively. As shown in Fig. 1, with the means of the two seasons, which shows that flaming at four weeks after sowing was comparable to hand weeding at the same period.

Table 1. Efficiency of flaming compare to hand weeding and pre-emergence herbicides application in faba bean in RNS

Season 2005-06					
	Number of weeds		Weeding efficiency (%)		
Treatments	Grass/m^2	Brd*/m^2	on grass	on Brd.	Mean
4WAS† flaming	42	99	74.6	80.0	77.3
4WAS HW$^♦$	63	87	85.5	76.2	80.8
4+6WAS HW	68	73	89.4	76.1	82.7
4+6WAS flaming	67	65	68.5	87.0	77.8
Pre-em.herbicides	80	61	86.8	91.8	89.3
SE	10.1^{ns}	12.2^{ns}	4.5*	3.4*	2.9^{ns}
C.V. (%)	31.6	31.7	11.2	8.2	7
LSD (5%)			13.9	10.4	
Weedy	63	77			
Season 2006-07					
4WAS† flaming	85	38	69.2	73.3	71.3
4WAS HW$^♦$	97	37	76.7	63.8	70.3
4+6WAS HW	89	34	77.1	72.9	75.0
4+6WAS flaming	99	39	68.2	73.9	71.0
Pre-em.herbicides	96	41	98.2	77.9	88.1
SE	13.6^{ns}	4^{ns}	1.9**	3.8^{ns}	2.2**
C.V. (%)	29.3	21.4	4.9	10.6	5.9
LSD (5%)			5.9	6.9	
Weedy	95	40			

WAS†= weeks after sowing HW$^♦$= hand weeding Brd.*= broad leaved

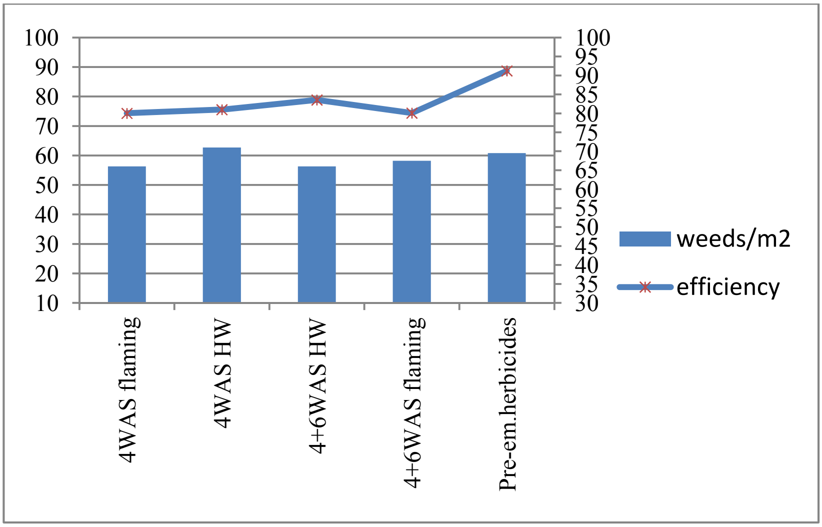

Figure 1. Means of weeding efficiencies for the two seasons

As shown in Tab. 2. there was no significant difference in the yield of faba bean of the different weeding treatments tested in both seasons of the experiment, but there was a significant difference in faba bean yield between treated plots and weedy control plot.

Table 2. Effect of the three weeds control methods in faba bean yield in River Nile State

Season	2005-06			2006-07		
Treatment	Plants /m^2	Weeds /m^2	Yield (t/ha)	Plants /m^2	Weeds /m^2	Yield (t/ha)
4WAS† flaming	31	141	1.5	27	123	5.8
4WAS HW	30	150	1.5	28	135	5.0
4+6WAS HW	28	141	1.8	26	123	6.0
4+6WAS flaming	24	132	1.6	33	138	5.3
Pre-eme. Herbicides	28	141	1.9	20	137	6.1
SE ±	3.7^{ns}	15.2^{ns}	0.14^{ns}	3.3^{ns}	15.1^{ns}	0.39^{ns}
C.V. (%)	26.5	21.6	17.2	24.5	23	13.8
Weedy	22	140	1.04	27	135	4.3

The bacteria and fungi in the soil in 0-5 mm depth were decreased by 9% and 13.6% respectively, when the soil was flamed using a flaming dose of 55.5 kg·ha^{-1} in this study at walking speed (Tab. 3). As the soil is a very good insulator with little increase in temperature at the crops roots zone.

Table 3. Effect of flaming on soil micro flora biomass

Season	Sample	Number of bacteria/mℓ			Number of fungi/mℓ		
		Before flaming	After flaming	Reduction (%)	Before flaming	After flaming	Reduction (%)
2005-06	1	75	70				
	2	70	68				
	3	50	39				
Mean		65	59	9.2			
2006-07	1	24	22		15	14	
	2	30	29		21	19	
	3	34	29		30	24	
Mean		29.3	26.7	8.8	22	19	13.6

As there were different treatments widths of application, and at pre-emergence application of herbicides no faba bean plants were grown on soil surface, where flaming and hand weeding were carried out when the ridges were covered with faba bean plants, therefore a variation on work rate was obtained as presented in Tab. 5. Flame weeding reduced work rate by 46% compared to hand weeding, which means enhancing of using human power.

For economic analysis as presented in Tab. 5. the marginal rate of return of flaming at 4 weeks after sowing and pre-emergence herbicides in both seasons, they exceeded targeted rate of return. The flaming at 4 weeks after sowing had the highest value of marginal rate of return, which indicates that farmer can gain 5.62 and 10.94 Sudanese Pound for each 1SP invested as compared to 0.9 and 3.14 for using herbicides in the two seasons. In spite of the low yield of faba bean in season 2005-06, due to unsuitable weather compared to yield of the next season, marginal rate of return from flaming at 4 weeks after sowing gave better values.

Table 4. Work-rate of different weeding treatments

Season	*2005-06*		*2006-07*	
Treatment	*Weeds/m²*	*Work rate (m-hr/ha)*	*Weeds/m²*	*Work rate (m-hr/ha)*
4WAS flaming	*141*	*41.3*	*123*	*36*
4WAS HW	*150*	*85.5*	*135*	*62*
4+6WAS HW	*142*	*118.6*	*123*	*139.2*
4+6WAS flaming	*132*	*67.2*	*138*	*62.7*
Pre-em.herbicides	*141*	*5.1*	*137*	*3.7*

Table 5. Marginal analysis for the flame weeding compare to prevailing weeds control treatments

Treatment	*Value of output (SP/ha)*	*Weeding cost (SP/ha)*	*Threshing cost (SP/ha)*	*Net benefit (SP/ha)*	*MNB⌖ (SP/ha)*	*MVC! (SP/ha)*	*MRRψ (%)*	*IOV♦ (%)*
2005-06								
Herbicides	*2182.8*	*204.7*	54.6	1923.5	109.15	121.25	90*	7.2
4+6 HW	2139.6	296.5	53.5	1789.6				
4 WASF	1952.4	89.25	48.8	1814.3	*601.05*	*106.95*	562*	5.3
4 WASHW	1917.0	209.15	47.9	1659.9				
4+6 F	1944.0	125.7	48.6	1769.7				
Weedy	*1244.4*	0	31.1	1213.3	0.0	0.0	0.0	
2006-07								
Herbicides	*7338.6*	*204.7*	183.5	6950.4	455.3	144.67	314.7*	1.1
4+6 HW	7209.6	348.0	180.2	6681.4				
4 WASF	*6738.6*	75.03	168.5	6495.0	*1171.5*	107.03	*1094**	4.6
4 WASHW	*6671.4*	172.5	166.8	6332.1				
4+6 F	6160.0	117.2	159.0	5883.8				
Weedy	5460.0	0	136.5	5323.5	0.0	0.0	0.0	

⌖ marginal net benefit ! marginal variable cost ψ marginal rate of return
*♦index of variability * meet or exceed target rate of re*

CONCLUSIONS

Regards to the low work rate of hand weeding linked to the critical period of weeds competition, and considering the recommended herbicides to control weeds in faba bean in River Nile state is pre-emergence herbicides, the flaming apparatus shows promising results in terms of weeding efficiency and economic feasibility.

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UKLANJANJE KOROVA PLAMENOM KAO METOD ZA SUZBIJANJE KOROVA U BOBU U OBLASTI REKE NIL U SUDANU

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Sažetak: Plamenik je bio konstruisan i ispitivan tako da su njegove karakteristike efikasnosti uništavanja korova i ekonomske isplativosti poređene sa suzbijanjem korova primenom herbicida. Tretman je izvođen 4 i 4 plus 6 nedelja posle setve, paljenjem i ručnim plevljenjem. Herbicid Pursuit plus Stomp je mešan u rezervoaru i primenjen u preporučenoj dozi jedan dan pre prvog navodnjavanja. Prosečan broj korova tokom dve sezone pokazao je da je paljenje na 4 nedelje posle setve smanjilo gustinu korova za 77.3% i 71.3% redom, dok je ručnim plevljenjem u istim periodima postignuto 80.8% i 70.3%, redom. Prinos zrna sa parcela tretiranih plamenom bio je uporediv sa prinosom sa parcela tretiranih herbicidom i ručnim plevljenjem, u obe sezone. Ipak, ekonomska analiza je pokazala da je tretiranje plamenom 4 medelje posle setve u obe sezone dalo najveću vrednost jedinične stope prinosa.

Ključne reči: *suzbijanje korova, bob, plamen, oblast reke Nil, Sudan*

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SOME PHYSICAL PROPERTIES OF *Telfaria Occidentalis* SEEDS AS INFLUENCED BY MOISTURE CONTENT

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Abstract: The effect of moisture content on some physical properties of *Telfaria Occidentalis* seed was investigated at 31%, 34%, 36% and 41% moisture content (wet basis). The mean values of the physical properties of the seeds were determined as length 36.09 – 38.32 mm,width 30.22 – 32.82 mm, thickness 14.22 – 16.42 mm, geometric mean diameter 24.94 – 27.44 mm, sphericity 0.69 – 0.73 mm, thousand seed mass 8.50 – 10.81 kg, bulk density 0.77 – 0.80 $g \cdot cm^{-3}$, true density 0.86 – 1.17 $g \cdot cm^{-3}$, porosity 17.09 - 26.74 %, surface area 1953.46 – 2364.00 cm^2. The coefficient of friction as measured on glass was 0.37 – 0.58%, sheet metal 0.49 – 0.58%, plywood 0.53 – 0.65%. All the physical properties of the seeds evaluated increased with increase in moisture content but however the porosity, decreased with the increase in moisture content. This information will provide engineers and designer the relevant data for efficient equipment design and process handling of *Telfaria Occidentalis* seed thereby increasing its utilization in Nigeria.

Keywords: *Telfairia Occidentalis, moisture content, physical properties, porosity*

INTRODUCTION

Telfairia Occidentalis commonly called fluted pumpkin grows in the forest zone of West and Central Africa, most frequently in Benin, Nigeria and Cameroon. It is known as *Ugwu* in Yoruba, *Ubong* in Efik, *umee* in Urhobo and *umeke* in Edo [1], [2]. The plant is drought resistant and is usually grown for its young leaves and shoots use for various forms of soups in Nigeria [3]. *Telfairia Occidentalis* produces fruits of different sizes

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which contains highly nutritious seeds. The highly nutritious seed of *Telfairia Occidentalis* can be left intact in the pod until when required [4]. The *Telfaria Occidentalis* seeds can be roasted or boiled and eaten like the seeds of breadfruit (*Treculia*) and sometimes used as soup thickeners.

The levels of crude protein (3.47%), crude fat (31.38%), moisture (10.93), ash (2.02%), carbohydrate (50.08%), fibre (2.12%), calcium (280 μg g^{-1}), phosphorus (2100 μg g^{-1}), iron (69 μg g^{-1}), sodium (10.80 μg g^{-1}), potassium (1280 μg g^{-1}), vitamin A (890 IU) and vitamin C (0.7 μg g^{-1}) detected in *Telfaria Occidentalis* seeds are comparable with the nutritional composition of some plant foods in Nigeria [5]. *Telfaria Occidentalis* seeds are for agricultural and domestic purposes, traditional and modern medicines, water purification and other industrial uses such as in biodiesel production [6] [7] [8]. The high oil content makes it a potential source of raw material for the vegetable oil industries in Nigeria. The use of the oil extracted from *Telfaria Occidentalis* seed for the production of bio-diesel has also been reported [9]. In order to design material handling equipment for the proper handling, drying, storing and processing of *Telfaria Occidentalis* seeds, it is imperative to determine their physical properties.

The problems associated with local processing method, the shortage of processing equipment, and inadequate storage of *Telfaria Occidentalis* seed may be due to the fact that the basic necessary data on the physical properties are limited or not available. Furthermore, most agricultural products are visco-elastic, hence the determination of the engineering properties of biomaterials are difficult and complicated since they are apparently affected by comparative moisture content and the rate of loading [10]. The knowledge of the physical properties of *Telfaria occidentalis* seed will be useful for engineers, food scientists as well as plant and animal breeders, who are involved in the design of machine necessary for processing, handling and preservation of *Telfaria occidentalis* seeds. The main objective of this work is to evaluate some physical properties of *Telfaria Occidentalis* seed at four different moisture content levels with the view of creating a database for basic information necessary for the design of processing and handling equipment for *Telfaria Occidentalis* seeds.

MATERIALS AND METHODS

Telfaria Occidentalis fruit was obtained from the Kure central market in Minna, Niger State Nigeria. The fruit was broken with a knife and the seeds removed. The initial weight and moisture content of the seed were determined using standard method as described by Mosehnin [11]. The seed samples were divided into four parts; A, B, C, D and the moisture content was varied to 31% (wb), 34% (wb), 36% (wb) and 42% (wb) respectively. These moisture contents were attained by heating samples A, B, C in an oven at 105^0C for 90 minutes, 60 minutes and 30 minutes respectively, while sample D was not heated. The moisture content of the samples were then determined by oven drying at a temperature of 105^0C and the moisture content wet basis was calculated using the expression given by Mosehenin [11]. The moisture content, length, width, thickness, thousand seed mass, geometric mean, sphericity, volume and true density, as well as the porosity were determined as described by Mosehin [11] and ASAE, [13]. The static coefficient of friction, angle of repose, static coefficient of friction and specific gravity were determined as described Mosehin [11], Olaofe [16], Adejumo [17] and Olaoye [18].

RESULTS AND DISCUSSION

The results of the effect of moisture content on some physical properties of *Telfaria Occidentalis* seeds are as presented in Table 1. The physical properties were determined at 31%, 34%, 36%, 41% for sample A, B, C and D respectively.

Table 1. Effect of moisture content on some physical properties of Telfaria Occidentalis seeds

Parameters	*Sample A*	*Sample B*	*Sample C*	*Sample D*
Length (mm)	*36.09*	*36.27*	*36.28*	*38.32*
Width (mm)	*30.22*	*32.40*	*32.64*	*32.82*
Thickness (mm)	*14.22*	*14.52*	*15.65*	*16.42*
Geometric Mean Diameter (mm)	*24.94*	*25.74*	*26.46*	*27.44*
Surface Area (mm^2)	*1953.46*	*2081.78*	*2199.70*	*2364.61*
Sphericity (mm)	*0.70*	*0.71*	*0.72*	*0.73*
Thousand Seed Mass (kg)	*8.50*	*9.43*	*9.56*	*10.81*
Bulk Density ($g \cdot cm^{-3}$)	*0.77*	*0.79*	*0.80*	*0.80*
True Density ($g \cdot cm^{-3}$)	*0.86*	*0.96*	*1.09*	*1.17*
Porosity (%)	*26.74*	*21.88*	*18.35*	*17.09*
Angle of Repose (degree)	*38.66*	*41.35*	*50.19*	*60.02*
Coefficient of Friction				
Glass Surface	*0.36*	*0.45*	*0.53*	*0.58*
Sheet Metal Surface	*0.49*	*0.55*	*0.58*	*0.58*
Wood Surface	*0.53*	*0.58*	*0.62*	*0.65*
Specific Gravity	*0.30*	*0.31*	*0.33*	*0.37*
Moisture Content (%)	*31.00*	*34.00*	*36.00*	*41.00*

The result shows that the three linear dimensions (length, width and thickness) increase with the increase in the moisture content because of the increase in microscopic structure of the seed as it absorbs moisture. The length, width and thickness increased from 36.09 to 38.32 mm, 39.22 to 32.82 mm and 14.22 to 16.42 respectively for moisture content increase from 31 to 41 % w.b. This result is similar to that reported on the increase in linear dimensions with increase in moisture content of Desma seed, two varieties of Lablab seed (Rongai seed and Highworth seed) and Tef seed [19], [20], [21].

The geometric mean diameter, sphericity and surface mass area also increase with increase in moisture content. These properties are dependent on the three linear dimensions, which were observed to increase within increase in moisture content. This occurs probably due to the fact that these properties are directly dependent on moisture content. The geometric mean diameter which increased from 24.94 mm to 27.44 mm is similar to that of different varieties of watermelon seed (Sarakhsi, Kolaleh and Red) which increased with an increase in moisture content [22]. The sphericity of *Telfaria Occidentalis* seeds which ranged from 0.691 mm to 0.729 mm is similar to that of the different varieties of barley kernels (Sahra and Valfarjr) [23].

The thousand seed mass of the seed varies from 8.50 kg to 10.81 kg with respect to the increase in moisture content. The knowledge of thousand seed mass is applicable in design of storage structure for seeds. The true density varied from 0.86 to 1.17 $g \cdot cm^{-3}$ and the bulk density also varied from 0.77 $g \cdot cm^{-3}$ to 0.80 $g \cdot cm^{-3}$ with the increase in moisture content from 31 to 42 % w.b. This indicates the significant importance of the mass of biomaterials on their bulk and true densities. The direct proportionality in the increase in true density with increase in moisture content is similar to that reported for sunflower seed and karinda seed respectively [24]. The increase in bulk density of the seed with increase in moisture content indicates that the increase in mass owing to moisture gain in the sample is more than the accompanying volumetric expansion of the bulk. The bulk density of agricultural products have been reported to be important in the design of silos and storage bins, maturity and quality evaluation of products which are essential in grain marketing. It also has practical application in the calculation of thermal properties in heat transfer problems, in determining Reynolds's number in pneumatic and hydraulic handling of materials and in predicting physical structure and chemical composition [25]. Similar results has been were reported for soybean grains and rubber seeds, respectively [26] [27].

The porosity calculated from relevant experimental data decreased from 26.74 % to 17.09 %. This trend was observed in some other seeds like pumpkin seed and pigeon pea [28] [29]. The decrease in porosity occurred due to the fact that increase in moisture content results in more significant increase of linear dimensions, thereby leading to reduction in pore spaces and giving a more compact arrangement of the seeds, thus reducing the porosity.

The angle of repose increased with increase in moisture content. This may be due to the fact that an increase in moisture content increased the cohesion between the seeds, thus increasing the friction the seed experiences during its movement on the selected surface. The angle of repose is paramount in the design of hopper openings, storage-bin side wall and chutes for bulk transport [25].

Coefficient of friction for all the samples at all moisture content followed a similar pattern; it increased with increase in moisture content on all the surfaces used. It was observed that coefficient of friction was highest on wood surface as reported for Karinda seeds [24], while the minimum friction occurred from the samples tested on the glass surface which is also similar to that reported for lentils seeds [15]. This difference in coefficient of friction is due to the roughness of the various surfaces. This is because the effect of moisture content is more significant with decrease in roughness of the selected surface since the smoother the surface, the less the friction. The knowledge of the coefficient angle of friction is important in the design of an arch free hopper, silo and storage structures. The coefficient of mobility, which represents the freedom of motion of a substance, is inversely related to the angle of friction. The higher the angle of friction the larger the opening and side wall slope of the hopper. Therefore, optimum design will avoid immature flow (where some depth of granular particles remains stationary) and the arching phenomena to ensure a fully developed sliding flow in the hopper [25]. The coefficient of friction of the seeds on the three different surfaces is similar to that reported for *Moringa Oliefera* seeds [30].

The specific gravity of the seed increased from 0.30 to 0.37 g. The specific gravity of the seed increased with increase in moisture content as a result of increase in weight. Specific gravity is an important quality criterion for processing of biomaterials. It is used as an estimate of solid or dry matter content of biomaterials. The higher the dry matter content, the lower the water content and the higher the specific gravity.

CONCLUSIONS

The length, width, thickness, sphericity, geometric mean diameter, thousand seed mass, angle of repose, surface area, true density, and coefficient of friction, showed an ascending linear relationship except, the porosity which has a descending linear relationship with moisture gain. These properties will provide important and essential data for efficient process and equipment design.

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NEKE FIZIČKE OSOBINE SEMENA OŽLJEBLJENE TIKVE – TIKVE TELFARIJE (*Telfaria Occidentalis)* IZLOŽENOG UTICAJU VLAGE

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Sažetak: Uticaj sadržaja vlage na neke fizičke osobine semena *Telfaria Occidentalis* bio je ispitivan pri vlažnostima od 31%, 34%, 36% i 41%. Srednje vrednosti fizičkih osobina semena koje su određene su: dužina 36.09 – 38.32 mm, širina 30.22 – 32.82 mm, debljina 14.22 – 16.42 mm, geometrijski srednji prečnik 24.94 – 27.44 mm, sveričnost 0.69 – 0.73 mm, masa hiljadu zrna 8.50 – 10.81 kg, gustina gomile 0.77 – 0.80 $g \cdot cm^{-3}$, stvarna gustina 0.86 – 1.17 $g \cdot cm^{-3}$, poroznost 17.09 - 26.74 %, spoljna površina 1953.46 – 2364.00 cm^2. Koeficijent trenja meren na staklu iznosio je 0.37 – 0.58 %, na metalnoj ploči 0.49 – 0.58 % i šperploči 0.53 – 0.65%. Sve vrednosti fizičkih osobina ocenjivanog semena povećale su se sa povećanjem sadržaja vlage, izuzev poroznosti koja je opadala sa porastom sadržaja vlage. Ove informacije će inženjerima i konstruktorima obezbediti relevantne podatke za efikasno konstruisanje uređaja i opreme za tretman semena *Telfaria Occidentalis* čime će se povećati njegova upotreba u Nigeriji.

Ključne reči: *Telfairia Occidentalis, sadržaj vlage, fizičke osobine, poroznost*

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EFFECT OF DESIGN PARAMETERS ON MECHANICAL HARVESTING OF CARROTS

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Abstract: The effect of design parameters on mechanical harvesting of carrot were studied by conducting experiments on a test set-up having provision to vary design variables. The test set-up consists of digging unit and soil separation unit. Design parameters - Rake angle, soil separator length and angle of soil separator were evaluated at an optimum soil moisture content of 12%. Performance parameters like percentage of carrots harvested, carrots damaged, soil separation index and power requirement were measured at different levels of design parameters and design values of different components were determined. The maximum percentage of carrots harvesting of 97.4% at 60 cm length of soil separator, rake angle of 25° and 20° angle of soil separator. Minimum percentage of carrots damage of 4.87% was obtained at 40 cm length of soil separator and 20° soil separator angle. Carrots damaged obtained in the range of 4.63 to 4.97% between 25° and 35° rake angle. The soil separation index was most affected by length and angle of soil separator. A minimum soil separation index of 0.23 can be obtained at 80 cm and 20° of length and angle of soil separator, respectively. An average power requirement for the operation of carrot harvester at a speed of 2.3 km·h^{-1} was 4.44, 5.3 and 5.75 kW at 15°, 25° and 35° of rake angle.

Key words*: carrot harvester, design parameters, rake angle, soil separation.*

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INTRODUCTION

India has achieved annual growth rate of 2.6% in total vegetable production has been recorded during the last 10 years, the average yield of vegetables in India is still lower than many Asian countries. In addition to the demand for local consumption, there is an increased demand of vegetables as one of the most potential commodities for exports [1]. Vegetables are highly perishable and need harvesting within a narrow time span, along with careful handling and proper storage before consumption or processing. In developing countries conventional method is still followed for carrot harvesting. The sequence practiced for conventional method are pulling of carrot from the bed, picking of dugout carrots, separation of green top from carrot, cleaning/washing of carrot and transportation to market (cold storage) [2]. For carrots, on an average, about 350 – 400 man-hours are required for digging and pulling out in one hectare area. Besides the quantum of labor, manual harvesting involves considerable drudgery and human discomfort. The labor has to stoop forward while digging/pulling carrot from the bed and also during picking up. Stooping posture results in a lot of bio-mechanical stresses in the back and has higher energy consumption as compared to other working positions [3]. Continuous use of bare hands for pulling out carrots may cause bruises on hands leading to infection. Both stooping and squatting working positions are not ergonomic and therefore carrot harvesting operation involves considerable human drudgery. In traditional method of harvesting, the yields are low, cost of cultivation is high and there were huge loses ranging between 30-40% of the total produce due to damage caused during harvesting, handling, storage, transport and processing [4]. By adopting mechanical harvesting manpower requirement was found 60% lower as compared to manual digging, whereas crop damage was less than 2% [5]. So there is a need for mechanization in root crop harvesting to reduce human drudgery and to reduce the cost of cultivation by 30 – 50% with better harvesting efficiency compared to manual harvesting [6]. Hence, successful harvest mechanization requires a systematic approach and involves the integrated efforts of engineers, plant breeders, plant physiologists, food scientists and others to develop technology for quality output and higher profits. Mechanical harvesting of carrots is a real challenge and truly an inter disciplinary problem.

The design parameters of any root or tuber crop harvester effects the performance of the machine. Generally the root harvester consists of digging blade and a soil separator. The tool geometry of the blade effects the digging efficiency of the harvester and draft required. The tool geometry governs by rake angle of the blade and friction angle of the soil [7]. This allows the design of simple tools on the basis of their draft force requirements and their soil cutting efficiency. The specific draft force per unit soil area and degree of soil loosening were observed to increase with relative narrowness of the tillage blades and with rake angle [8,9]. The draft increases with width, depth and rake angle of the tool. The cross-sectional area of the soil disturbed did not change appreciably with rake angle, but significant increase in draft with angle resulted in markedly diminished soil cutting efficiency [10]. The best implement design for low draft, high cutting efficiency and superior soil loosening should have rake angle of about 30° and should be fairly narrow with depth to width ratio of 2 or more [11]. The convex type blades with 20° rake angle performed better than the concave with the total recovery of 87.6 to 93.44% while it was only 77.47 to 82.14% for concave type blade and the depth of operation of potato digger should be 200 mm in order to avoid damage and loss of potatoes [12]. After digging of the roots crops, the crops had to be separated from soil mass and leave on the soil surface. This soil separation process will depend upon the length and degree of inclination of soil separator with ground surface. In case of gravity separator for separating clods from peanuts in the field, showed that with slope of 16° of the mesh belt, conveyor velocity of 0.44 meters per second, the separation effectiveness obtained was 98.6% and peanut recovery was 99.1 percent [13]. The width and pitch of conveyor, inclined at 18°, were 58 cm and 30 mm, respectively in case of potato digger showed, at slow forward speed or at higher conveyor speed there is better soil separation [14]. Very fewer efforts have been made to develop indigenous mechanized systems for carrot harvesting. Use of self propelled and tractor drawn equipment in vegetable crops, in India, is very dismal except in potato cultivation [15]. Mechanical harvesters were developed only for underground crops like potato [6,16,17], onion [18], groundnut [19,20] and cassava[21]. No information is available on mechanical harvesting of carrots on design and operational parameters and power consumption. The objective of this paper is to determine design values of carrot harvester by conducting experiments on a test set-up specially made for this purpose.

MATERIAL AND METHODS

The desired functions of carrot harvester are to dig and lift the carrots and soil mass; separate soil mass from carrots, leaving them over soil surface for collection with minimum damage to crop. There are two basic components in carrot harvester, digging blade and soil separation unit. The different variables which affect the carrot harvester were rake angle, length and angle of the soil separator. The digger was designed for harvesting carrot crop by lifting the soil and carrot without tops from the field with the help of digging unit and subsequently transferring the same onto a separating unit where carrots are separated from the soil through soil separator. After harvesting, the clean carrots are collected manually.

The functional requirements for the design of harvester were: a) The machine should dig carrots from the field. b) It should be operated by common size of tractor available in Indian farm. c) The carrots should be left uncovered over the soil surface to the rear of the tractor and they are picked up manually with minimum manual requirement. d) The carrot damage in terms of cut, crush, sliced and bruised should be as low as possible. e) The carrot should be dug up from the field in such a way that the minimum volume of soil with carrots. f) It should be simple in design and construction and efficient in digging carrots.

The experiments are conducted directly in the field where the carrots are grown. Before conducting the experiments the haulms or tops of the carrots are destroyed 3 – 6 days before harvesting by mechanical means. The experimental setup with above components was used to determine the optimum machine parameters for better performance of the harvester at optimized moisture content. The experiments were conducted as per plan, Table 1. The tests were conducted on the experimental farm in Division of Agricultural Engineering, I.A.R.I, New Delhi taking cultivar 'Nantes'. An area of 75 x 30 m^2 the test was conducted by varying different machine parameters like rake angle, length of soil separator and angle of soil separator at different levels and replicated thrice. The observations were recorded for number of carrot harvested, number of carrots damaged, weight of soil collected with carrots and power requirement. The data on performance parameters were analyzed using factorial randomized block design and statistical parameters were evaluated using Design Experts and SPSS version 16.0 software.

Table 1. Plan of experiments on test setup

Machine Variables	*Levels*	*Performance parameters*
Rake angle (degree)	$R_1 = 15$ $R_2 = 25$ $R_3 = 35$	*i. Percentage of carrot harvested* *ii. Percentage of carrots damaged* *iii. Soil separation index* *iv. Power requirement (kW)*
Length of Soil Separator (cm)	$L_1 = 40$ $L_2 = 60$ $L_3 = 80$	
Angle of Soil Separator (degree)	$A_1 = 0$ $A_2 = 10$ $A_3 = 20$	

RESULTS AND DISCUSSION

The performance parameters of the test set up of carrot harvester was evaluated at a fixed soil moisture content of 12% for three different rake angles of 15°, 25° and 35°; at three soil separator lengths of 40, 60 and 80 cm and at three angle of soil separator with horizontal surface of 0°, 10° and 20°.

Percentage of carrot harvested

All three lengths of soil separator gave comparable performance at given rake angle and angle of soil separator Fig 1. The percentage of carrot harvested increased initially with increase in rake angle and later decreased marginally. The average maximum carrot harvesting percentage of 97.79% was obtained with 60 cm length of soil separator followed by 97.66 and 97.27% with 80 and 40 cm length, respectively. In comparative terms, mean values of length of soil separators are almost same for 60 and 80 cm, whereas in case of 40 cm length of soil separator a marginally lower harvesting percentage was obtained. The other variables remaining same, carrot harvesting percentage increased with increase in rake angle; at 60 cm length of soil separator, it increased from 96.53 to 97.46% as the rake angle increased from 15° to 25°. But it remains comparatively same i.e. 97.3% when rake angle changes from 25° to 35°. For same soil separator length and angle of soil separator there is increase in the carrot harvested percentage, when rake angle increased from 15° to 25° and a very small decrease in the harvested value with increase in the rake angle from 25° to 35°. The rake angle of 25° yielded the best percentage of carrot harvested. The average percentage of carrot harvested for the length of soil separator with 60 cm at rake angle of 15° was 96.4, 96.54 and 96.56%, when angle of separator was 0°, 10° and 20°, respectively. This shows a comparatively small increase in carrot harvested percentage with increase in angle of soil separator.

The influence of soil separator angle was less pronounced in all combinations of rake angle and length of soil separator. Rake angle influenced carrot harvesting significantly at 1% level of significance (Tab. 2.). Hence, it could be inferred that in the given range of the variables, highest percentage of carrots harvested was observed at 25° rake angle, 60 cm length of soil separator and 20° of soil separator angle. The pair wise comparison of influence of length of soil separator and rake angle on carrot harvesting percentage indicated that the 60 cm gave higher harvesting percentage in comparison to other two lengths and 25° rake angle was observed higher harvesting percentage than other two levels of rake angles as the mean difference was found positive for both variables in pair wise comparison at 5% level of significance. Hence, it could be inferred that in the given range of the variables, highest percentage of carrots harvested was observed at 25° rake angle, 60 cm length of soil separator and 20° of soil separator angle.

Table 2. Descriptive statistics of percentage of carrot harvested for different level of variables

Levels of variables	*Percentage of carrot harvested (%)*		*CV (%)*	*F – Value*
	Range	*Mean*		
Length of soil separator (cm)				
40	96.40–97.66	97.07	0.47	0.76
60	96.53–97.79	97.18	0.46	
80	96.95–97.72	97.11	0.12	
Rake angle (degree)				
15	96.40–96.98	96.69	0.23	11.3**
25	97.18–97.79	97.4	0.22	
35	97.18–97.14	97.29	0.08	
Angle of soil separator (degree)				
0	96.40–97.46	97.03	0.36	0.18
10	96.54–97.51	97.12	0.34	
20	96.86–97.79	97.21	0.43	

*** significant at 1% level of significance*

The percentage of carrot damaged increased with increase in length of soil separator and decreased with increase in rake angle and soil separator angle (Fig 1). The average percentage of carrots damaged with 40, 60 and 80 cm length of soil separator was observed as 4.87, 5.44 and 5.51% with corresponding coefficient of variation of 16.83, 14.7 and 12.5%, respectively (Tab. 3). The damage percentage in case of 40 cm soil separator length was found lower due to less travel time of carrots with soil, which reduces the damages of carrots due to friction with soil mass. Carrots damage percentage decreased with increase in rake angle; at 80 cm length and 0° angle of soil separator, it decreased from 6.57 to 5.41% as the rake angle increased from 15° to 25°. But it remains comparatively same i.e. 5.11% when rake angle changes from 25° to 35°. The rake angle of 35° yielded the best percentage of carrot harvested but there is no large difference when compared to 25°. The average percentage of carrot damaged for the length of soil separator with 60 cm at rake angle of 15° was 6.86, 6.48 and 5.89%, when angle of separator was 0°, 10° and 20°, respectively. This shows a comparatively decrease in carrot damage percentage with increase in angle of soil separator.

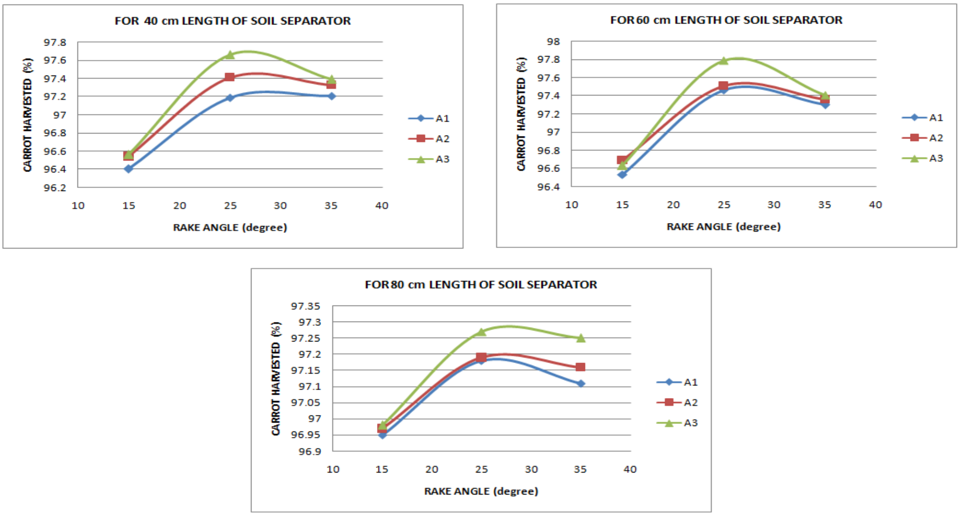

Figure 1. Effect of different variables on carrots harvested

Percentage of carrots damaged

The pair wise comparison of influence of soil separator length and rake angle on percentage of carrots damaged indicated that lower damage percentage was observed at 40 cm in comparison to damage percentage obtained at other two levels of soil separator lengths and 35° of rake angle was observed lower damage percentage than other two levels of rake angles, pair wise comparison was significant at 5% level of significance. There is no much difference in the carrot damage percentage between 25° and 35° of rake angle.

Table 3. Descriptive statistics of percentage of carrot damaged for different level of variables

Levels of variables	*Percentage of carrot damaged (%)*		*CV (%)*	*F – Value*
	Range	*Mean*		
Length of soil separator (cm)				
40	3.09 – 6.26	4.87	16.83	2.18
60	4.45 – 6.86	5.44	14.7	
80	4.86 – 6.57	5.51	12.5	
Rake angle (degree)				
15	5.54 – 6.86	6.86	6.25	42.74**
25	4.35 – 5.45	4.94	7.48	
35	3.99 – 5.11	4.63	8.42	
Angle of soil separator (degree)				
0	4.23 – 6.86	97.03	0.36	0.98
10	4.31 – 6.48	97.12	0.34	
20	3.99 – 6.31	97.21	0.43	

*** significant at 1% level of significance*

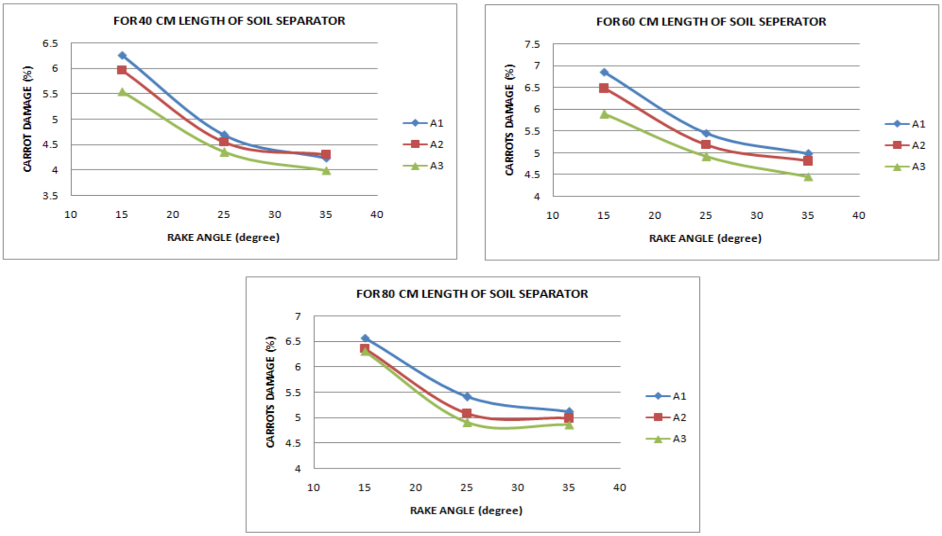

Figure 2. Effect of different variables on carrots damage

Soil separation index

After digging of carrots the soil was to be separated from carrots with the help of soil separating unit. To measure the efficiency of the carrot harvester to separate the soil, soil separation index was defined. For better separation of soil from carrots the value of soil separation index should be minimum. Soil separation index is a function of moisture content and travel time of soil over soil separator. Travel time of soil is further depends upon length of soil separator and angle of soil separator with horizontal surface.

Table 4. Descriptive statistics of soil separation index for different level of variables

Levels of variables	*Soil separation index*		*CV*	*F – Value*
	Range	*Mean*	*(%)*	
Length of soil separator (cm)				
40	0.26 – 0.33	0.29	9.3	234.74**
60	0.21 – 0.26	0.23	6.08	
80	0.21 – 0.26	0.23	6.52	
Rake angle (degree)				
15	0.21 – 0.32	0.24	14.63	1.52
25	0.21 – 0.32	0.24	14.11	
35	0.22 – 0.33	0.26	12.6	
Angle of soil separator (degree)				
0	0.23 – 0.33	0.27	14.8	134.04**
10	0.22 – 0.30	0.25	12.4	
20	0.21 – 0.26	0.23	29.8	

*** significant at 1% level of significance*

The soil separation index increased initially with increase in length of soil separator and later remained almost same (Fig 3). The average minimum soil separation index of 0.21 was obtained with 60 cm length of soil separator followed by 0.22 and 0.26 with 80 and 40 cm length, respectively. The average soil separation index were very closely distributed for two levels of soil separators length, the mean values of separation index were 0.22 and 0.23 for 60 and 80 cm length of soil separators, respectively. Therefore, it could be inferred that, 60 and 80 cm lengths of soil separator can be used for effective soil separation. Soil separation index increased from 0.23 to 0.26 as the rake angle increased from 25° to 35°. But it remains same i.e.0.23 when rake angle changes from 15° to 25°. However, in case of other two lengths of soil separators i.e. 40 and 80 cm, same pattern was observed. Based on mean values, the soil separation index at 15° and 25° did not vary much for both rake angles. But there is increase in separation index at 35° rake angle i.e.0.26 compared to other two levels. The soil separation index decreased with increase in soil separator angle, it decreased from 0.32 to 0.26 as the soil separation index increased from 0° to 20° at 40 cm length of soil separator. The average soil separation index for the length of soil separator with 60 cm at rake angle of 15° was 0.24, 0.23 and 0.22%, when angle of separator was 0°, 10° and 20°, respectively. The influence of soil separator angle was more pronounced in all combinations of rake angle and length of soil separator.

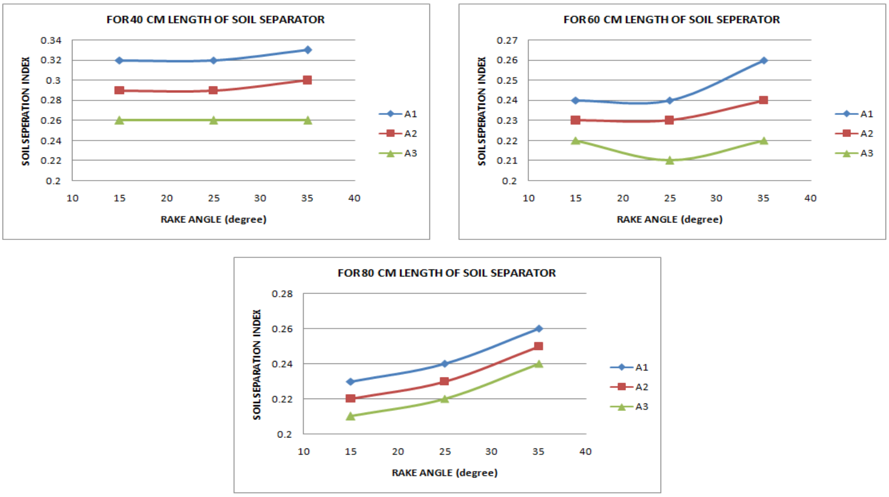

Figure 3. Effect of different variables on soil separation index

The length of soil separator and angle of soil separator was effecting soil separation process significantly at 1% level of significance. The pair wise comparison of influence of length and angle of soil separator indicated that the 60 cm gave lowest soil separation index in comparison to other two lengths and 20° angle of soil separator observed higher soil separation than other two levels of soil separator angle as the mean difference was found negative for it in pair wise comparison at 5% level of significance. The length of soil separator influenced soil separation index most, followed by soil separator angle as indicated by F-values (Table 4). Hence, it could be inferred that in the given range of the variables, lowest soil separation index was observed at 25° rake angle, 60 cm length of soil separator and 20° of soil separator angle.

Power requirement

Power is the main constraint for any digging operation. Power requirement will depend upon the depth of operation, soil metal friction and tool geometry.

Table 5. Descriptive statistics of Power requirement for different level of variables

Levels of variables	*Power requirement (kW)*		*CV (%)*	*F – Value*
	Range	*Mean*		
Length of soil separator (cm)				
40	4.29 – 5.70	5.04	10.7	0.32
60	4.45 – 5.80	5.10	8.6	
80	4.22 – 5.83	5.12	10.3	
Rake angle (degree)				
15	4.22 – 4.72	4.44	3.55	27.09**
25	5.05 – 5.70	5.30	4.38	
35	5.36 – 5.80	5.57	2.51	
Angle of soil separator (degree)				
0	4.51 – 5.80	5.19	9.60	0.49
10	4.34 – 5.61	5.07	8.70	
20	4.22 – 5.57	4.96	8.90	

*** significant at 1% level of significance*

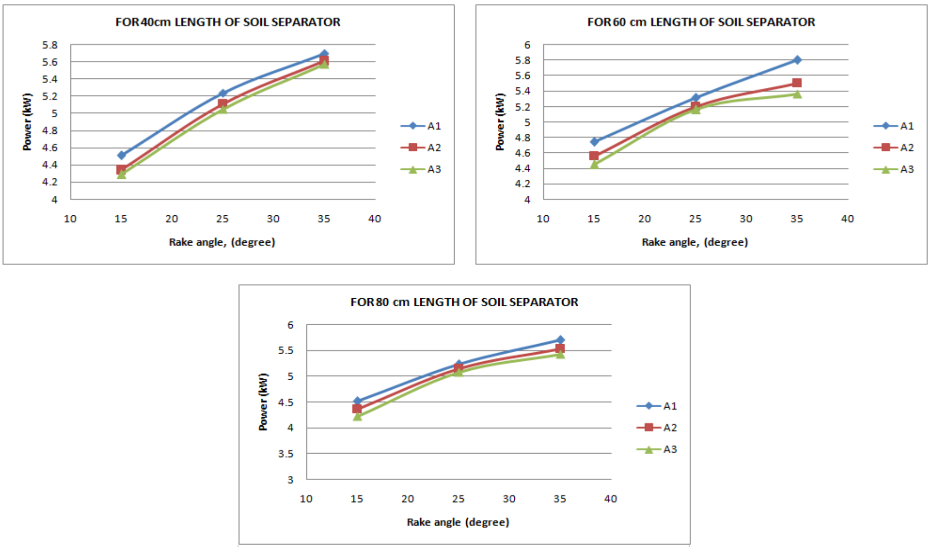

Figure 4. Effect of different variables on power requirement

The power requirement increased with increase in rake angle and very small change with increase in length and angle of soil separator. The average power requirement at 15°, 25° and 35° rake angle was 4.44, 5.3 and 5.57 kW with coefficient of variation 3.55, 4.38 and 2.51%, respectively (Table 5). The power requirement in case of 15° rake angle was least followed by 25° and 35°. The power requirement was almost same at three selected levels of angle of soil separator. The average power consumption was found 5.19, 5.07 and 4.96 kW which are almost same at soil separator angle of 0°, 10° and 20° with coefficient of variation 9.6, 8.7 and 8.9%, respectively. Similarly, for different length of soil separator the power required is almost same i.e. 5.04, 5.1 and 5.12 kW with coefficient of variation 10.7, 8.6 and 10.3%, at 40, 60 and 80 cm length.

CONCLUSIONS

- The mechanical carrot harvester gave an average maximum percentage of carrots harvesting of 97.18, 97.4 and 97.21% at 60 cm length of soil separator, rake angle of 25° and 20° angle of soil separator, respectively.
- The average minimum percentage of carrots damage of 4.87% was obtained at 40 cm length of soil separator and 5.02% at 20° soil separator angle. Carrots damaged obtained in the range of 4.63 to 4.97% between 25° and 35° rake angle.
- Soil separation was maximum at average minimum soil separation index of 0.24 was obtained at all rake angles and 0.23 when angle of soil separator was at 20° with horizontal surface. Soil average soil separation index is obtained same for both 60 and 80 cm length of soil separator.
- Power requirement is very less effected by length and angle of soil separator, so any of the levels can be considered. As the rake angle increases, power requirement increased. An average power requirement was 4.44, 5.3 and 5.75 kW at 15°, 25° and 35° of rake angle.

Overall, 60 cm length of soil separator, 25° of rake angle and 20° of soil separator angle was considered for efficient carrot harvesting at 12% optimum moisture content.

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UTICAJ PARAMETARA KONSTRUKCIJE NA MEHANIČKO UBIRANJE ŠARGAREPE

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Sažetak: Uticaj parametara konstrukcije na mehaničko ubiranje šargarepe proučavan je izvođenjem ogleda na test modelu uz promene vrednosti promenljivih veličina. Model za testiranje se sasoji od kopača i jedinice za izdvajanje zemlje. Parametri konstrukcije – ugao grablji, dužina separatora zemlje i njegov ugao su ocenjivani pri optimalnoj vlažnosti zemljišta od 12%. Parametri kao što su procenat ubranih šargarepa, oštećene šargarepe, indeks odvajanja zemlje i porebna snaga su mereni na različitim nivoima i određene su vrednosti različitih komponenti. Maksimalni procenat ubranih šargarepa od od 97.4% sa dužinom separatora od 60 cm, uglom grablji od 25° i uglom separatora od 20°. Minimalni procenat oštećenja šargarepa od 4.87% bio je postignut sa dužinom separatora od 40 cm i uglom separatora od 20°. Oštećenja šargarepa nalazila su se u opsegu od 4.63 do 4.97%, sa uglom grablji od 25° do 35°. Na indeks izdvajanja zemlje najviše su uticali dužina i ugao separatora zemlje. Minimalni indeks separacije od 0.23

se može ostvariti dužinom i uglom separatora od 80 cm i 20°, redom. Prosečna potrebna snaga za rad kombajna za šargarepu, pri radnoj brzini od 2.3 km·h^{-1}, bio je 4.44, 5.3 i 5.75 kW za uglove grablji od 15°, 25° i 35°.

Ključne reči: *kombajn za šargarepu, parametric konstrukcije, ugao grablji, odvajanje zemlje*

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MATHEMATICAL MODELING AND USE IN ACOUSTICS APPLICATIONS IN AGRICULTURE

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Abstract: The article presents a discussion and a comparison of modeling methods for acoustic sources, it compares performance models and presents possible applications.

The mathematical models are presented and compared: the natural and theoretical model that is based on the theoretical and empirical model of acoustic wave equation of noise spatial variation. The models are compared in terms of sound intensity level (which is calculated by exact formulas from the wave function solution of the acoustic waves equation) and noise levels provided by the theoretical and empirical model. It is shown that in most cases, both are models whose results must be calibrated in order to give results matching reality. Finally we compare the field application of each of the two models.

Key words*: acoustics theoretical model, theoretical-empirical model, applications, comparisons*

INTRODUCTION

Sound waves are acoustic waves with conventional frequencies between 16 and 20,000 Hz.

Purely theoretical and applicative approach to distribution problems and their effects on acoustic waves (sound or noise) in the environment, which I started a few years ago [1]. The theoretical and empirical approach to sound intensity distribution in space is often a surprise to theorists (mathematicians or physicists). It is surprising to see that the fundamentals of complex software used for creating noise maps [2, 3, 4], consist of simple functions, even elementary, with which one gets very close to the true

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distribution of environmental noise. Theorists expectation was that the foundation of these programs to use the wave equation and by calculating its solution for a given source distribution and a specified boundary of the domain, then build sound intensity level distribution in the target area. Surprisingly at the end of the comparison it is found that the two procedures lead to convergent results regarding the distribution of sound intensity level (theoretical result) and the noise levels from the source (result of the theoretical and empirical model). This convergence strengthens that the two survey instruments propagation of sound waves in space are trustworthy.

FUNDAMENTALS

In order be more clear, the definitions with which we operate must be specified. First, according to [5], an acoustic wave means an elastic wave of small amplitude. The same source defines:

- sound intensity level (L_I), is 10 times the natural logarithm of the ratio of acoustic sound intensity and sound intensity reference, equal to 10-12 $W{\cdot}m^{-2}$ (the unit is decibels, denoted dB);
- sound pressure level (L), being 20 times the logarithm of the ratio between the considered effective sound pressure sound and reference sound pressure p_0 = $2{\cdot}10^{-5}$ $N{\cdot}m^{-2}$ (unit dB);
- sound power level (L_p, L_W), being 10 times the logarithm of the ratio between acoustic power radiated by a source and reference power wich is 10-13 W (unit of measurement, dB).

From the engineering point of view, it is expressed for example, in accordance with the standard [6] IEC 61672-1, Section 3.9, "Definitions", according to which equivalent continuous sound level (*LAT*) is 20 times the base 10 logarithm of the ratio between the RMS value of frequency weighted sound pressure during a period of time and reference sound pressure (20 μPa). However, in current use, mainly for historical reasons *LAT* is used as *Leq*.

As shown, the theoretical-empirical mathematical model makes a sound frequency filtering by curve "*A*" frequency weighting, the curve being constructed to protect workers who are exposed to danger at workplace, [7].

THEORETICAL MODEL

A punctual sound source is considered that produce spherical acoustic waves in a boundless medium and without obstacles around. We chose spherical waves because they are the most basic solutions of the wave equation showing attenuation with distance (cylindrical waves are not physically as close to reality as the spherical). The next wave equation is considered:

$$\Delta\psi - \frac{1}{c^2}\frac{\partial^2\psi}{\partial t^2} = 0 \tag{1}$$

where ψ is the wave function, c is the speed of sound in air at normal physical conditions and Δ is the Laplace operator. The spherical shape solution is:

$$\psi(t,r) = \frac{\psi_0}{r}\cos\left(\omega t - kr + \phi\right) \tag{2}$$

satisfies the wave equation (1), if the following conditions are met:

$$v_f = \frac{\omega}{k} = \frac{\lambda}{T} = c \tag{3}$$

where v is the wave frequency, ω is the angular frequency of the wave, k is the wave number (with dimension of length to the -1 power), λ is the wavelength, T is the wave period and ψ_0 is a constant. It is noted that we consider a monochromatic wave (a single frequency). The constant, which not many authors comment, must have a dimension length to the power of two. The variable r is the distance from the current point to the point where the source is located in space:

$$r(x,y,z) = \sqrt{(x-x_0)^2 + (y-y_0)^2 + (z-z_0)^2} \tag{4}$$

Accepting a solution of type (1) for monochromatic point sources and considering ρ as the air density, we obtain the kinetic energy of the wave:

$$w_c = \frac{1}{2}\rho\left(\frac{\partial \Psi}{\partial t}\right)^2 \tag{5}$$

and the potential energy of the same wave is:

$$w_p = \frac{1}{2}\rho c^2\left(\nabla\Psi \cdot \nabla\Psi\right) \tag{6}$$

Then the total energy of the wave is:

$$w = w_c + w_p \tag{7}$$

The square root average value of energy in a time interval is:

$$W = \langle w \rangle = \sqrt{\frac{1}{T}\int_0^T w(t)^2\,dt} \tag{8}$$

and the energy intensity of the acoustic wave energy flux passing through unit area in the direction normal to this surface is:

$$I_s = W \cdot c \tag{9}$$

Sound intensity level is given by:

$$N_s = 10\lg \frac{I_s}{I_{s0}} \tag{10}$$

where I_s is the magnitude of the energy intensity and I_{s0}= 10^{-12} W·m^{-2} is the reference magnitude of the energy intensity and lg is the logarithm in base 10.

According to [8], the effective acoustic pressure is defined by the relation:

$$p_{ef} = \sqrt{I_s \rho c} \tag{11}$$

and accordingly, the reference pressure:

$$p_0 = \sqrt{I_0 \rho c} \tag{12}$$

Then, it is easily deduced that:

$$L = 20\lg \frac{p_{ef}}{p_0} = 20\lg \left(\frac{I_s \rho c}{I_0 \rho c} \right)^{\frac{1}{2}} = 10\lg \frac{I_s}{I_0} = N_s = L_I \tag{13}$$

A similar calculation shows that L_{eq}=N_s:

$$\begin{aligned} L_{eq} &= 10\lg \frac{\sqrt{\frac{1}{T_2 - T_1} \int_{T_1}^{T_2} \left(p_{ef} \right)^2 dt}}{p_{ref}} = 10\lg \frac{\sqrt{\frac{1}{T_2 - T_1} \int_{T_1}^{T_2} \left(I_s(t) \right)^2 \rho^2 c^2 dt}}{p_{ref}} = \\ &= 10\lg 10\lg \frac{\rho c \sqrt{\frac{1}{T_2 - T_1} \int_{T_1}^{T_2} W^2 c^2 dt}}{p_{ref}} \frac{\rho c \sqrt{\frac{1}{T_2 - T_1} \int_{T_1}^{T_2} \left(I_s(t) \right)^2 dt}}{p_{ref}} = \\ &= 10\lg \frac{\rho c \sqrt{\frac{1}{T_2 - T_1} \int_{T_1}^{T_2} W^2 c^2 dt}}{p_{ref}} = 10\lg \frac{\rho c I_s}{\rho c I_{s0}} = N_s \end{aligned} \tag{14}$$

GENERALIZATION

Since the wave equation is linear, we can obtain the wave field generated by many discrete sources located in x_{0i}, y_{0i}, z_{0i}:

$$\psi(t,x,y,z)=\sum_{i=1}^{n}\frac{\psi_{0i}}{\sqrt{(x-x_{0i})^2+(y-y_{0i})^2+(z-z_{0i})^2}}\cos\left(\omega_i t-k_i\sqrt{(x-x_0)^2+(y-y_0)^2+(z-z_0)^2}+\phi_i\right) \quad (15)$$

or, if the sources are spread over an area *Ω* (can be 1, 2 or 3 dimensional) continuous space:

$$\begin{aligned}\psi(t,x,y,z)=&\int_\Omega\frac{\psi_0(\xi,\eta,\zeta)}{\sqrt{(x-\xi)^2+(y-\eta)^2+(z-\zeta)^2}}\cdot\\ &\cdot\cos\left(\omega(\xi,\eta,\zeta)t-k(\xi,\eta,\zeta)\sqrt{(x-\xi)^2+(y-\eta)^2+(z-\zeta)^2}+\phi(\xi,\eta,\zeta)\right)d\Omega\end{aligned} \quad (16)$$

The generalization may extend to three dimensional waves, the wave function is a three-dimensional vector. For now is not for this article.

ENGINEERING SOLUTIONS

To mitigate the noise prediction and sound intensity level engineers chose a simple function, possibly inspired by theoretical solutions, which is calibrated, then using a wide range of situations. For example, for a point source, [3] the following formula is used:

$$L_{eq}=L_W-20\lg r-11 \quad (17)$$

where L_{eq} is the noise level of the source, L_w is the source power, and r is the distance. Following [11], a formula for an industrial source complex:

$$L_{eq}=L_i+10\lg S-20\lg r-14 \quad (18)$$

where L_i is the inner power of the source, and S is its outer surface. In general such formulas for different types of sources, they have the form:

$$L_{eq}=A-B\lg r \quad (19)$$

with constants A and B. We used such a formula in this paper, for theoretical and empirical modeling of a source. More complicated formulas are used, for example, in [2, 11].

NUMERICAL APPLICATION OF NOISE FOR THE MECHANICAL MOWERS

To test and understand how theoretical and engineering solutions will apply these solutions to simulate noise from mechanical mowers. These devices produce a very intense noise and therefore must be tested in order to establish a continuous working time limit for the user but also for those accidentally found further around the area of operation.

In particular, a source of theoretical monochromatic sound, such as (2), with which we try to mathematically model a mower noise emission as in Fig. 1. Noise measurements were made at different distances from the camera, in open terrain, without barriers, except some negligible dimensions. The mower type was Rx8 RURIS (Fig. 1). Measured noise level at 50 cm above the mowers engine, showed the following values of noise intensity estimators: L_{eq} = 95.1 dB. The frequency at which that signal was maximum is 250 hz.

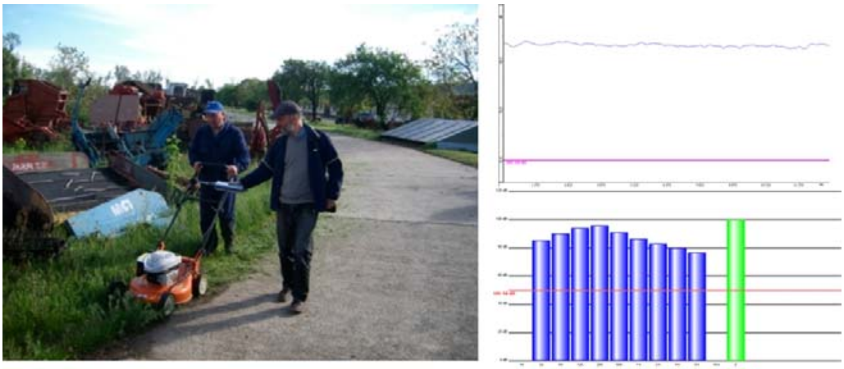


Figure 1. Mechanical mower during noise measurements

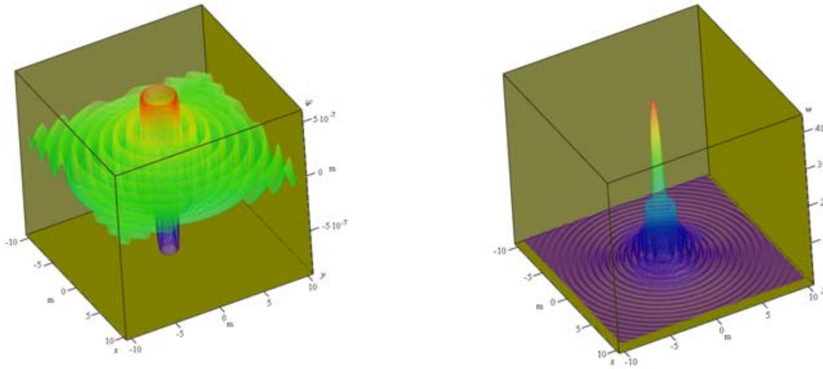
Through measurements, the complete attenuation of mowers noise is made at a distance of 51.79 m, which is equal to the background noise, 56.7 dB. Sound intensity level attenuates at background noise level at 39,725 m, while the noise level L_{eq} calculated by calibration at 41.58 m. It is noted that the model had no background noise.

For theoretical and empirical modeling of noise variations with distance at mowers, we used a type (19) formula:

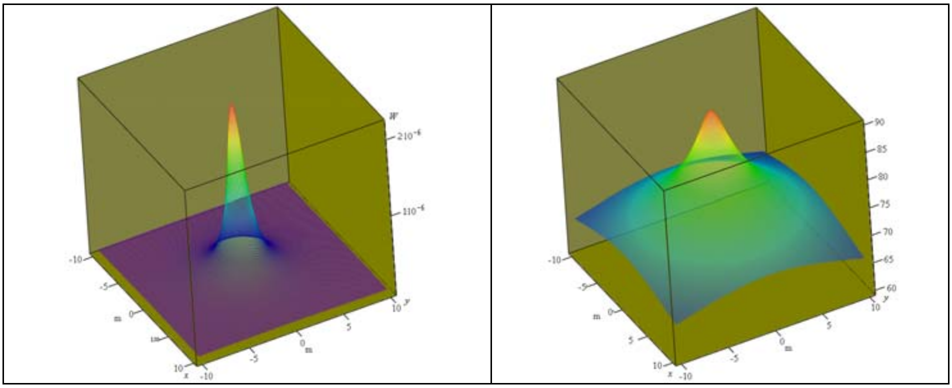
$$L_{eq} = 89.079 - 20\lg r \tag{20}$$

Formula (20) will be used for theoretical and empirical modeling of this type of mower. Likewise formulas were developed for other sources of agricultural noise pollution equipment: harvesters, mowers self-worn, mills for grinding grain, etc.

Using this source and measuring data from a distance of 0.5 m from the source, the theoretical solution is calibrated by choosing the constant ψ_0 to teke the value 0.00000116275 m^2, for a frequency of 250 Hz. It was considered that c = 343.2 m·s^{-1} and ρ = 1.29 kg·m^{-3}. The obtained graphics data is in Fig. 2, the theoretical and graphical solution in Fig. 3 Theoretical and empirical solution and theoretical (dotted curve in Fig. 3, b). A possible interpretation for the constant of the solution (2) for the wave equation is that it is outside the scope of the power, performance similar to that of constant S from the theoretical and empirical formula (18).

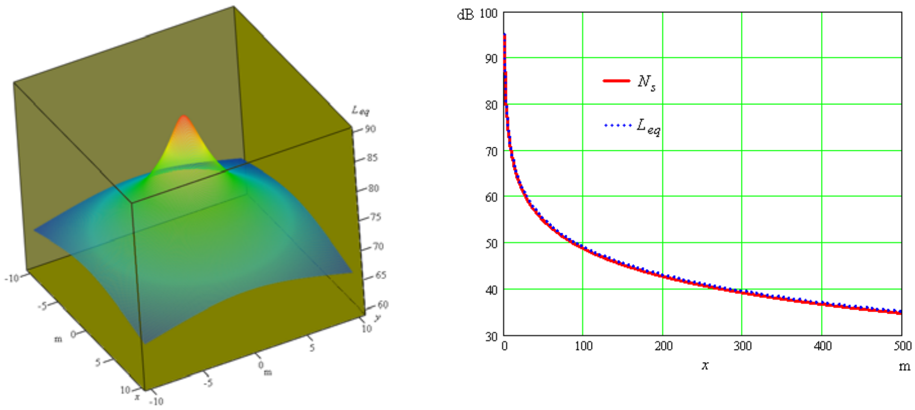


a) Acoustic wave elongation b) Acoustic wave energy



c) Average acoustic wave energy d) Sound intensity level (formula (10))

Figure. 2 Graphical representation of the main parameters a monochromatic spherical wave



a) Sound noise level formula (20) b) Comparison between the intensity of sound

Figure 3. Noise level from the generated acoustic wave and comparison between the intensity of sound and noise. The continuous curve is calculated from equation (10), and the dotted, using formula (20)

CONCLUSIONS, POSSIBLE APPLICATIONS

The study presented in this article shows that the theoretical and theoretical-empirical solutions converge. In addition, it looks like many from the estimators of sound intensity or noise expresses the same result, a sound intensity level.

A complete theoretical solution is logical, but solving the wave equation for a wide variety of sources and, especially for a multitude of obstacles with different properties (absorption, reflection, refraction), is difficult to obtain, if not impossible. So it seems that the engineering solution of choice for empirical formulas for types of sources and types of obstacles is for now, the best solution. This solution is based on all major software products that are on the market at this time: Predictor-Lima (Bruel & Kjaer), Encustica (Canarina Environmental Software), SoundPLAN, etc.

Among the possible applications of the theoretical proposed solutions are:

- simulation of acoustic fields produced by a series (small in number) of discrete sources, placed on a continuous structure, without requiring any complex measurement;
- theoretical solutions also allow calculation of quantities that engineering tool do not give: acoustic pressure, acoustic wave composition effects.

Problems in solving fundamental problems such as absorption, reflection and refraction of waves still remain, of course, for now. Also finding theoretical and engineering solutions that have singularities is still a problem. For engineering solutions in [1] already a solution was proposed.

The theoretical solutions can be applied to configurations composed of a small number of sources in specific situations agriculture: agricultural machinery field configurations, mills additional nearby equipment, stationary or semi-stationary agricultural machines located near inhabited areas or nature reserves (which have a negative influence on wildlife), etc.

As spherical wave expression, formulas (17), (18), (19), have the singularity disadvantage in the point location source. Alternatives at singularities of theoretical-empirical formulas (17), (18), (19), were given in [1].

Another problem of theoretical and empirical formula type is a dimensional one. This problem is due to the *r* variables appearance, which has the dimension of a length, directly under the decimal logarithm. Then the logarithm of this quantity has no physical dimension with the correct meaning. In [1] we gave a solution that solves this problem.

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MATEMATIČKO MODELIRANJE I PRIMENA U AKUSTIČNIM APLIKACIJAMA U POLJOPRIVREDI

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Sažetak: U radu je predstavljeno ispitivanje i poređenje metoda modeliranja za akustične izvore, poređene su performance modela i predstavljene moguće aplikacije.

Predstavljeni i poređeni su sledeći matematički modeli: prirodni i teorijski model koji se zasniva na teorijskom i empirijskom modelu jednačine zvučnih talasa prostorne varijacije buke. Modeli su poređeni prema nivou intenziteta zvuka (koji je računat po egzaktnim formulama iz rešenja funkcije talasa jednačine zvučnih talasa) i nivoa buke dobijenih teorijskim i empirijskim modelom. Pokazano je da u najvećem broju slučajeva rezultati oba modela moraju da se kalibrišu da bi se dobili rezultati koji se slažu sa stvarnim vrednostima. Konačno, uporedili smo i poljske aplikacije oba modela.

Ključne reči: *akustični teorijski model, teorijsko-empirijski model, aplikacije, poređenja*

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WEAR CHARACTRITICS OF COMMERCIALLY AVALABLE TRACTOR DRAWN CULTIVATOR SWEEPS IN ABRASIVE SAND

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Abstract: Wear of soil engaging components occurs because the materials used are normally softer than the natural abrasives in the soil. Most of sweeps of cultivator are manufactured locally which are hardly as per with the standards which affects operational life of tillage tool. So, there was a need to study wear characteristics of sweeps so as to provide the suitable sweeps. Study was conducted in rotary soil bin in abrasive sand. Sweeps of three different makes were tested at speed 1 $m \cdot s^{-1}$ and depth100 mm respectively. After running the sweeps for 20 h in the soil bin, sweeps were weighted and loss in weight and dimensional wear loss was noted down. Similar procedure was followed for 100 h time intervals. It was observed that the weight of sweeps decreased linearly with increase in working period for all the tested sweeps. The maximum cumulative wear was observed for sweep S_2 (18.25 gm) followed by sweep S_1 (15.4 gm) and sweep S_3 (13.8 gm). The maximum cumulative tip wear was observed for sweep S_2 (1.78 mm) followed by sweep S_1 (1.48 mm) and sweep S_3 (1.31 mm) and maximum cumulative edge wear was observed for sweep S_2 (1.20 mm) followed by sweep S_1 (0.96 mm) and sweep S_3 (0.84 mm) when operated for 100 h. The sweep S_3 was found best in this study which has minimum gravimetric wear, tip wear and wing wear.

Key words: *sweeps, soil bin, abrasive sand, wear*

INTRODUCTION

Agriculture in India is unique in its characteristics about 250 different crops cultivated in different agro climatic zones. It is one of the most important sector of

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Indian economy, contributing to 18.5% of national income; about 15% of total export and supporting two third of the work force. Agricultural engineering inputs have played an important role in increasing production through appropriate mechanization [8]. At present in India tractors are being used for tillage and sowing of 22.78% and 21.30% of total area [5]. Cultivator is one of the most important tillage tools used by Indian farmer. Even many organic farmers say that a pass with the cultivator has the same effect on the crop in dry weather as a half inch of rain It is primarily, the type of tillage implement which is used for opening the land, preparing the seedbed for sowing of the seeds as well as after the crop has come up a few cm above the ground [3]. The field cultivators are about often used as secondary tillage tools for seedbed preparation.

The small scale industries are manufacturing tillage tools like ploughs, cultivators, harrows, etc in large quantities which are being used on large scale among farmers. These parts are subjected to wear due to friction. In agricultural machines, wear is the most rapid and common form of damage, this is responsible for most of the idle time and maintenance, apart from heavy expenditure on repair and spare parts. The wear in agricultural machinery is basically abrasive in nature because such tools usually come in contact with the soils which are abrasive due to quartz, stone and sand contents etc. abrasive wear means removal or displacement of material from solid metallic surface due to pressure exerted by continuous sliding of hard soil particles.

It has been observed that a large number of sweeps shovels wear out sometimes in one season only. This results in high maintenance cost, frequent stoppage of work and loss of time during peak hours till replacement. It is also well established that a blunt sweep requires draught comparatively on higher side and therefore it increases the cost of field operations. The quality of work is affected adversely and a large amount of energy is wasted by continuous use of blunt sweeps.

Keeping this was view the study is planned to find suitable sweep for farm operation to improve performance. In view of the above, the present study was undertaken in accelerated wear test set up on cultivator shovels with the following objective: To study the wear loses of different commercially available sweeps in abrasive sand.

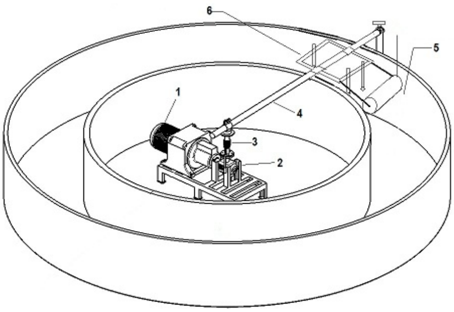
MATERIAL AND METHODS

Experimental Set-up

The experimental set-up comprised of an indoor circular soil bin, a power transmission unit, control panel, tool frame and a soil compaction unit. A schematic diagram of the experimental set up is shown in Fig. 1.

Plan of Work

The experiments were conducted in indoor circular soil bin for selection of commercially available sweep which has low wear characteristics. The research plan for is explained below. Hardness test of sweeps were conducted for the available sweeps using Rockwell hardness tester.



1.D.C Motor 2. Gear box 3.Verticle shaft 4. Horizantle shaft
5.Soil bin 6. Tool frame 7. Compaction roller

Figure 1.Isometric view of experimental set up

Table 1. Different levels of parameters considered in the study of this experiment

	Independent parameters	Levels	Values	Dependent parameter
1	Sweeps	3	S_1, S_2, S_3	1. Gravimetric wear (gm) 2.Dimentional wear (mm)
2	Operating hours	5	20,40,60,80,100 h	
3	Speed of operation	1	1 $m \cdot s^{-1}$	
4	Depth of operation	1	10 cm	

Test procedure

For this study the soil bin was filled with abrasive sand up to the height of 800 mm. The height of sand was maintained uniform in the soil bin. Commercially available sweeps (Fig. 2) were mounted on the shanks and were set to operate at a depth of 100 mm from the top surface of the sand.

Figure 2.Different commercially available sweeps used for experiments

The tool carriage was rotated at a peripheral speed of 1 $m \cdot s^{-1}$ [1]. The wear tests were conducted for 100 hours and gravimetric and dimensional wear were measured at a regular interval of 20 hours. At the end of each interval, the sweeps were detached from shanks and thoroughly washed in water before measurement. The gravimetric wear losses of sweeps were determined by taking the difference in weight of sweeps before and after the operation. The reduction in dimensions with respect to tip length (the distance from the bolt hole to the tip), edge length (the minimum distance from the bolt hole to the cutting edge on the wing) [2] was measured with digital vernier caliper (LC 0.1 mm) (Fig. 3). Three replications were taken for each sweep. The worn out sweeps after 100 h of operations are shown in Fig. 4.

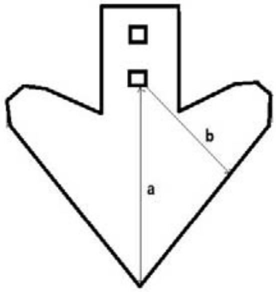



Figure 3. Measurement of gravimetric and dimensional wear

Figure 4. Different commercially available sweeps after operation in sand for 100 h

RESULTS AND DISCUSSION

Gravimetric wear

In this study, the gravimetric wear of different commercially available sweeps of tractor drawn cultivator was observed and is discussed as under.

Effect of working period

The relationship between gravimetric wear and time is shown in Fig. 5. It is clear from the Fig. 5 that the weight of sweeps decreased linearly with increase in working period for all the tested sweeps. The maximum cumulative wear was observed for sweep

S_2 (18.25 gm) followed by sweep S_1 (15.4 gm) and sweep S_3 (13.8 gm) when operated for 100 h. These results are similar to findings of [4] and [5] who also reported a linear relationship between cumulative wear and period of work. It was interesting to note that higher average wear rate of 0.17 gm·h^{-1} was observed during first 40 h of operation and the same reduced to 0.14 gm·h^{-1} in the next 60 h of operation for all three sweeps. This may be due to oxide coating of sweep which might have worn out at initial 40 h. This may result in more corrosion of sweep after 40 h use.

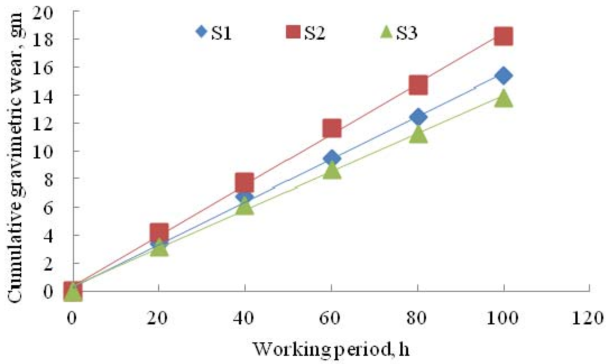


Figure 5. Relationship between cumulative gravimetric wear and working period of different sweeps

Dimensional Wear

Dimensional wear loss was measured at two points of the sweeps as explained in the previous section. The cumulative wear loss in tip and edge of sweeps S_1, S_2, S_3 were recorded for 100 h at an interval of 20 h.

Effect of working Period on tip wear

It is clear from the Fig. 6 that cumulative wear of tip increases linearly with increase in working period for all the tested sweeps.

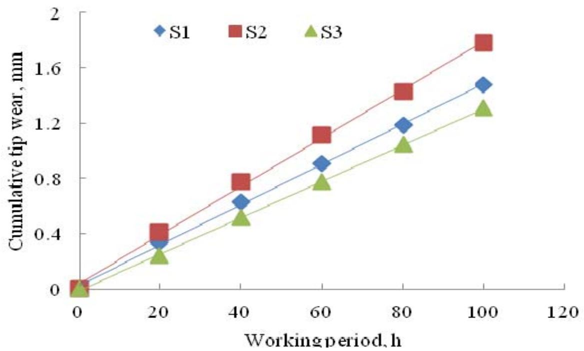


Figure 6. Relationship between cumulative tip wear and working period of different sweeps

The maximum cumulative tip wear was observed for sweep S_2 (1.78 mm) followed by sweep S_1 (1.48 mm) and sweep S_3 (1.31 mm) when operated for 100 h. These results are similar to findings of [2]. A higher average wear rate of 0.018 $mm \cdot h^{-1}$ was observed during first 20 h of operation and the wear rate reduced to 0.015 $mm \cdot h^{-1}$ in the next 80 h of operation for sweepsS_1 and S_2. Sweep S_3 worn out at higher rate of 0.02 $mm \cdot h^{-1}$ during first 40 h of operation and the wear rate reduced to 0.012 $mm \cdot h^{-1}$ in the next 60 h. This may be due thin section of sweep at the tip which might have worn out at initial 20 h and 40 h.

Effect of working period on edge wear

It is clear from the Fig. 7 that wear of edge increases linearly with increase in working period for all the tested sweeps.

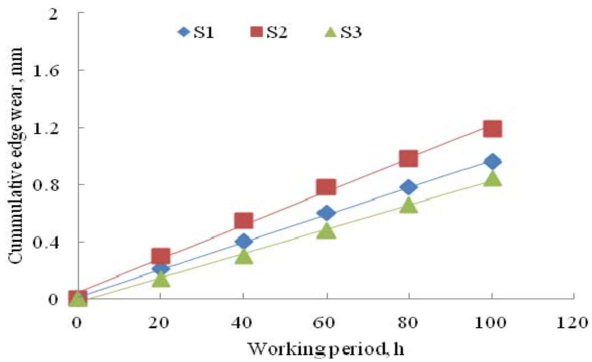


Figure 7.Relationship between cumulative edge wear and working period of different sweeps

The maximum cumulative edge wear was observed for sweep S_2 (1.20 mm) followed by sweep S_1 (0.96 mm) and sweep S_3 (0.84 mm) when operated for 100 h. These results are similar to findings of [2].The higher average wear rate of 0.011 $mm \cdot h^{-1}$ was observed during first 20 h of operation and same reduced to 0.009 mm/h in the next 80 h of operation for all three sweeps. This may be due to oxide coating of sweep which may wear out at initial 40 h. The minimum edge wear was found in S_3 at each interval of 20 h when operated for 100 h . This may be due to maximum hardness of sweep S_3.

CONCLUSIONS

It is observed that that the weight of sweeps decreased linearly with increase in working period for all the tested sweeps. The maximum cumulative wear was observed for sweep S_2 (18.25 gm) followed by sweep S_1 (15.4 gm) and sweep S_3 (13.8 gm) when operated for 100 h. The cumulative wear loss in tip and wing of sweeps S_1, S_2, S_3 was recorded for 100 h at an interval of 20 h. The maximum cumulative tip wear was observed for sweep S_2 (1.78 mm) followed by sweep S_1 (1.48 mm) and sweep S_3 (1.31 mm) when operated for 100. The maximum cumulative edge wear was observed for sweep S_2 (1.20 mm) followed by sweep S_1 (0.96 mm) and sweep S_3 (0.84 mm) when operated for 100 h. The sweep S_3 was found best in this study which has minimum gravimetric wear, tip wear and wing wear.

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KARAKTERISTIKE HABANJA MOTIČICA VUČENOG KULTIVATORA U ABRAZIVNOM PESKU

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Sažetak: Radni organi se troše u didru sa zemljištem jer su materijali od kojih su izrađeni uobičajeno mekši od prirodnih abraziva u zemljištu. Većina kultivatorskih motičica su izrađene u lokalnim radionicama, i retko odgovaraju standardima koji se odnose na radni vek radnog organa za obradu zemljišta. Zato je bilo potrebno ispitati karakteristike habanja motičica dostupnih na tržištu, kako bi se izdvojile one koje odgovaraju standardima. Ispitivanje je izvedeno u kružnom zemljišnom bazenu sa abrazivnim peskom. Motičice tri različita proizvođača ispitivane su pri brzini rada od 1 $m \cdot s^{-1}$ i na dubini od 100 mm. Posle rada u trajanju od 20 h u zemljanom bazenu, motičice su merene da bi se dobili gubitak mase i smanjenja dimenzija zbog habanja. Sličan postupak je ponovljen i posle 100 časova rada. Utvrđeno je da se masa motičica smanjuje linearno sa povećanjem radnog perioda kod svih ispitivanih modela.

Maksimalno kumulativno habanje ustanovljeno je kod motičice S_2 (18.25 g), zatim kod motičice S_1 (15.4 g) i najmanje kod modela S_3 (13.8 g). Maksimalno kumulativno smanjenje dimenzija dobijeno je kod modela S_2 (1.78 mm), zatim kod motičice S_1 (1.48mm) i najmanje kod modela S_3 (1.31 mm), a maksimalno kumulativno habanje ivica bilo je dobijeno kod motičice S_2 (1.20 mm), zatim kod motičice S_1 (0.96 mm) i najmanje kod modela S_3 (0.84 mm), posle 100 časova rada. Zaključeno je da je motičica S_3 pokazala najbolje rezultate u ovom ispitivanju, sa najmanjim habanjem po svim merenim kriterijumima.

Ključne reči: *motičice, zemljani bazen, abrazivni pesak, habanje*

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