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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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EDITORIAL

The record-breaking rise in food prices is driving us into a crisis of food shortage throughout the world. Particularly it has a serious effect on the poor in developing nations. Rural areas in African countries, where they have constantly suffered from food shortage due to the drought and other reasons, are now in this dreadful condition. Increasing numbers of people are starving to death there.

The United Nations urgently called the agricultural ministers and related government leaders of worldwide nations to organize the World Food Summit in Rome early in June this year. The food problem was also taken up at the G8 Summit held in Japan this month. The members of the G8 Summit agreed to support the measures to increase food production in Africa by two or three times.

In a granary in the Middle West of the U.S. damaged by the flood, the harvest area of soy beans is estimated to be reduced by 15 %. The continuing drought in Australia is creating serious concerns about food and meat production. Meanwhile, new rising countries with enormous population like China and India are importing great amounts of food, primarily feed grains, in the midst of prominent economic growth and the demand for better food.

The grain prices, which have risen by three times in the past three years, are not likely to drop. Last year grain producing farmers in the U.S. and Canada earned as much as their total income for the past four years.

The rise in food prices gives various negative impacts on our living. However, at the same time, there is indication that agriculture revives again as a new attractive industry. Agriculture is being recognized as a big political issue around the world. It is expected that the investment in agriculture will be rapidly expanding.

We see the historical change in the global food condition, from an excessive supply for a long time to a short supply in developed countries. In order to get over this crisis, we have to make the best use of all available science technologies related to agriculture. In particular agricultural engineering technologies will play a key role.

Timely and appropriate farm work is needed to raise agricultural productivity, especially in the current environment that is easily affected by abnormal weather or global warming. Thus, the demand for agricultural mechanization has been greatly mounting. In this historical restoration of agriculture, it is time for us involved in agricultural mechanization to work together to promote new mechanization everywhere in the world.

AMA will work harder than ever to link the people engaged in that historical task.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
July, 2008

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol.39, No.2, July 2008

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Tillage Implements Performance and Effect on Some Soil Physical Properties

by

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Abstract

A chisel plough, disk plough and ridger were tested to evaluate their effect on selected soil physical properties along with their performance and power requirements. Implement type had a consistent significant effect ($P \leq 0.01$) on soil moisture content (%), whereas, bulk density (g/cm^3) and porosity (%) showed inconsistent response. However, the chisel plough recorded the highest moisture content and basic infiltration rate values as compared to the ridger and disk plough. The chisel plough had the highest power requirement and fuel consumption. The ridger had the lowest power requirement and fuel consumption, but recorded the highest field capacity and efficiency.

Introduction

Success or failure of any crop production system largely depends on seedbed environment, amongst other factors. A harsh seedbed environment may kill the seedling or stress it severely enough to limit the crop's productive potential. Generally, tillage positively affects soil bulk density, porosity, water storage capacity, infiltration, penetration resistance and compaction. A thorough understanding of tillage effect on soil physical properties is essential for wise application of tillage for crop production (Erbach, 1987). The effectiveness of any tillage practice should be evaluated depending on the change it brings about in soil physical properties, rather than depending on crop yield only. Economic considerations should be added to tillage evaluation parameters especially field capacity and energy utilization efficiency particularly when comparing two implements. Implement type, tillage depth and speed affect the draft and the unit draft power in a particular soil as well as the tractor's driving wheel slippage, draw bar power, fuel consumption, and field capacity and efficiency (Belel and Dahab, 1997 and Ahmed, 2000).

The objectives of this study were:
1. To study the effect of tillage implement and sampling depth on some soil physical properties.
2. To evaluate the power performance parameters of primary tillage implements.

Material and Methods

The experiments were conducted in the Demonstration Farm of the Faculty of Agriculture, University of Khartoum in Shambat (longitude 32º 32′ E, latitude 15º 40′ N and altitude of 380 m asl). The soil is classified as clay soil. The effect of tillage treatment and sampling depth on soil physical properties was studied for two consecutive winter seasons, namely 2000/01 and 2001/02, using the split plot design. Power performance parameters of tillage implements under investigation were evaluated using the randomized complete block design. The experimental area (0.42 ha) was divided into 3 blocks, each of which was divided into 4 main plots. The main plot dimensions were 24 × 14.5 m.

Tillage practices included:
· Disk ploughing to a depth of 20 cm (conventional tillage).
· Chisel ploughing to a depth of 30 cm (conservation tillage).
· Ridger ploughing to a depth of 15 cm (reduced tillage).
· No tillage (control).

The specifications of the applied tillage equipments were as follows:
1. A standard disk plough, with three disk bottoms each 64 cm in diameter.
2. Chisel plough, with five shanks, 150 cm wide (0.30 cm) shank spacing.
3. Ridger plough with a tool bar and three ridger bottoms, 80 cm apart.

Soil moisture content (%), bulk

density (g/cm³) and porosity (%) were determined for each tillage treatment from the soil surface down to 60 cm at 15 cm increments. Soil moisture content was determined gravimetrically before each tillage treatment and after the second irrigation. Soil bulk density was determined using the clod (paraffin wax) method. Soil total porosity was calculated using the formula proposed by Vomocil (1965). Infiltration rate measurements were carried out using a double ring infiltrometer described by Michael (1978). This was replicated three times for each tillage treatment and the mean was calculated. The materials used to test the performance of the imple-ments under study were a measuring tape, two stopwatches, two marking flags, two tractors (Ford 6600, 75 hp and Case International 975, 75 hp), a hydraulic dynamometer PIAB, NS 2650 (100 KN capacity) and a chain. The different parameters were tested following the methods recommended by RNAM (1983).

Results and Discussion

Table 1 shows the effect of tillage and sampling depths on soil bulk density, porosity and moisture content. The analysis of variance indicated a significant difference between the means in 2001/02 (P ≤ 0.05). The highest mean density in 2000/01 (1.57 g/cm³) was recorded under no-tillage, while the lowest mean (1.51 g/cm³) was recorded under ridging. The mean bulk density values under disk and chisel ploughing were 1.53 and 1.52 g/cm³, respectively. In 2001/02, no-tillage recorded (significantly) the highest mean bulk density of 1.68 g/cm³, while ridging recorded the lowest value of 1.47 g/cm³. Both disk and chisel ploughs recorded the same mean bulk density (1.53 g/cm³), which was not significantly different from that of ridging and no-tillage. However, the results were in accordance with those reported by Hammad and Dawelbeit (2001).

Table 1 The effect of tillage and sampling depth on soil bulk density (g/cm³), porosity (%) and moisture content (%)

Season	Parameters	Sampling depth	Tillage system				Mean
			Chiseling	Discing	No-tillage	Ridging	
2000/01	Soil bulk density, g/cm³	0-15 cm	1.54	1.42	1.46	1.39	1.45*a
		15-30 cm	1.50	1.48	1.59	1.53	1.53 ab
		30-45 cm	1.60	1.69	1.73	1.50	1.63 b
		45-60 cm	1.46	1.54	1.51	1.61	1.53 ab
		Mean	1.52	1.53	1.57	1.51	
	Soil porosity, %	0-15 cm	42.32	46.82	45.32	47.94	45.60*a
		15-30 cm	43.82	44.57	40.45	42.70	42.88 ab
		30-45 cm	40.07	36.70	35.21	43.82	38.95 b
		45-60 cm	45.32	42.32	43.45	39.70	42.70 ab
		Mean	42.88	42.60	41.10	43.54	
	Soil moisture content, %	0-15 cm	10.50	9.86	10.17	13.80	11.10**a
		15-30 cm	16.33	9.73	13.20	13.13	13.11 b
		30-45 cm	18.07	13.40	17.87	16.50	16.48 c
		45-60 cm	17.20	14.60	16.80	18.73	16.83 c
		Mean	15.53**a	11.90 b	14.51 a	15.53 a	
2001/02	Soil bulk density, g/cm³	0-15 cm	1.45	1.60	1.69	1.36	1.53
		15-30 cm	1.56	1.65	1.59	1.39	1.55
		30-45 cm	1.61	1.50	1.72	1.43	1.57
		45-60 cm	1.49	1.37	1.72	1.69	1.57
		Mean	1.53*ab	1.53 ab	1.68 a	1.47 b	
	Soil porosity, %	0-15 cm	45.69	40.07	36.70	49.06	42.90
		15-30 cm	41.57	38.20	40.45	47.94	42.09
		30-45 cm	39.70	43.82	35.58	46.44	41.39
		45-60 cm	44.19	48.69	35.58	36.70	41.29
		Mean	42.79*a	42.79 a	37.07 b	45.03 a	
	Soil moisture content, %	0-15 cm	9.90	10.30	11.68	13.60	11.37*a
		15-30 cm	17.03	10.53	11.40	13.03	13.00 b
		30-45 cm	18.47	12.67	16.17	16.57	15.97 c
		45-60 cm	17.93	13.80	16.80	17.97	16.63 c
		Mean	15.83**a	11.83 b	14.00 a	15.29 a	

Means followed by different letters within a row or a column are significantly different.
*, ** = Means are significantly different at (P ≤ 0.05) and (P ≤ 0.01), respectively.

Sampling depth (cm) had a significant effect (P ≤ 0.05) on the mean bulk density only in 2000/01. The lowest mean bulk densities (1.45 and 1.53 g/cm³) were recorded at 0-15 cm depth range in 2000/01 and 2001/02, respectively, while the highest value of 1.63 g/cm³ was recorded at 30-45 cm in 2000/01. In 2001/02 the highest bulk density of 1.57 g/cm³ was recorded at 30-45 and 45-60 cm depth ranges. However, in 2001/02 bulk density increased with sampling depth down to 30-45 cm, then decreased at the 45-60 cm depth range. The same trend was observed in 2001/02 except that bulk densities were similar at 30-45 and 45-60 cm depth range. Al-Tahan et al. (1992) reported the same trend.

The mean soil porosity was significantly affected by tillage system only in 2001/02 (P ≤ 0.05). It was observed that tillage effect on porosity followed the same trend as its effect on bulk density. The highest mean porosity was recorded under ridging in both seasons, while the lowest mean porosity was recorded under no-tillage. Chiseling recorded higher porosity values in 2000/01 as compared to disking while both tillage systems produced the same effect on soil porosity in 2001/02. However, these results are in accordance with those reported by

Erbach (1987).

Sampling depth had a significant effect on the mean soil porosity (%) only in 2000/01. The depth range of 0-15 cm recorded the highest porosity percentages. The same trend of bulk density response to tillage was noticed when porosity response to tillage was examined. However, in 2000/01, the mean soil porosity decreased with depth down to the 30-45 cm range, then increased to 45-60 cm. This trend was well observed in 2001/02 where the depth ranges of 30-45 and 45-60 recorded the same mean value.

Tillage significantly affected the mean soil moisture content after the second irrigation during both seasons (P ≤ 0.01). In 2000/01, disking resulted in the lowest mean moisture content (11.9 %), which was significantly different from the other tillage systems. Chiseling and ridging recorded the same mean moisture content (15.53 %), which was higher than that recorded under no-tillage (14.51 %). However, moisture content under chiseling, ridging and no-tillage was statistically not different (P > 0.05). A slight difference was observed in 2001/02, as chiseling recorded a higher moisture content of 15.83 % compared to ridging, which recorded 15.29 %, while under disking and no-tillage it was 11.83 and 14.00 %, respectively.

However, only disking was statistically different from the other tillage systems (P ≤ 0.01), which were all statistically not different from each other (P > 0.05).

The effect of tillage on soil moisture content cannot be viewed separately from its effect on bulk density and infiltration. In both seasons moisture content (%) under chiseling was higher than under no-tillage and ridging, except in 2000/01 when ridging recorded the same value. Ridging, as well, resulted in higher moisture content when compared with no-tillage in 2000/01 and 2001/02. The high moisture content under no-tillage was attributed to the presence of cracks and large fissures, which facilitated water movement into the soil after irrigation. The high moisture content under no-tillage as compared to ploughing, was attributed to the decrease in evapotranspiration of unploughed soil. Sheikh et al. (1978) reported comparable results. The high moisture content under chiseling as compared to disking was also reported by Abuzaid (1999).

Sampling depth significantly affected the mean soil moisture content (%) in 2000/01 and 2001/02 at P ≤ 0.01 and P ≤ 0.05, respectively. A depth range of 0-15 cm recorded the lowest mean values of 11.1 and 11.37 % in both seasons, respectively,

Fig. 1 Effect of tillage on average infiltration rate (cm/h) for the 2000/01 season
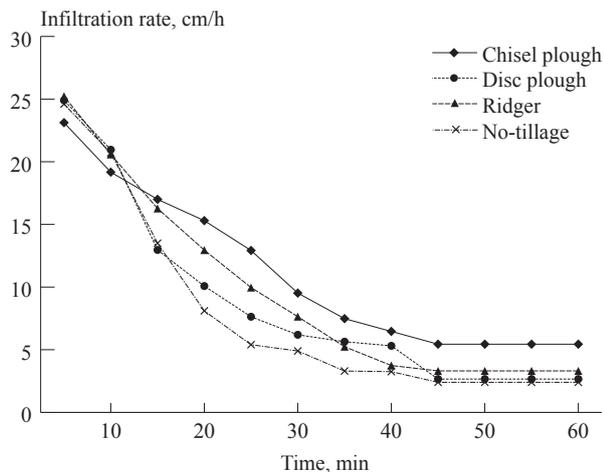

Fig. 2 Effect of tillage on average infiltration rate (cm/h) for the 2001/02 season
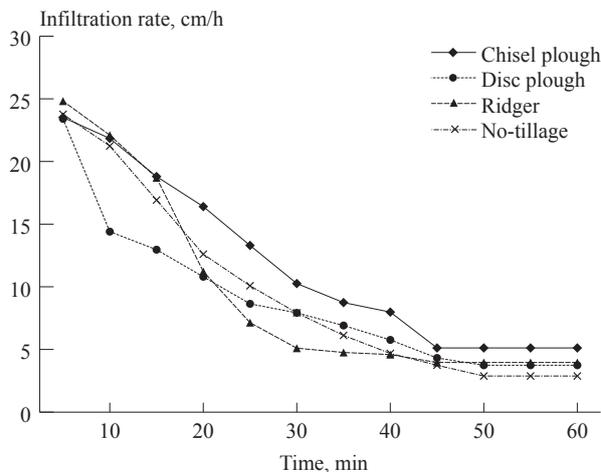
while the depth range of 45-60 cm recorded the highest mean values of 16.83 and 16.63 % in the same seasons, respectively. However, moisture content increased with sampling depth from the surface down to 45-60 cm depth range in both seasons. Depth ranges of 30-45 and 45-60 cm were statistically not different (P > 0.05) and were both different than 0-15 and 15-30 cm, which were statistically different from each other. This was attributed to the high rate of water evaporation from the surface layer, which was exposed to evaporation factors rather than deeper ones. Al-Tahan et al. (1992) reported comparable results.

The effect of tillage on soil infiltration rate (cm/h) for 2000/01 and 2001/02 is shown in **Figs. 1** and **2**. In 2000/01 the initial infiltration rate ranked in the following order: ridging > disking > no-tillage > chiseling. The basic infiltration rate rank varied a little and was in the following order: chiseling > ridging > disking > no-tillage.

In 2001/02 the initial infiltration rate ranks were: ridging > no-tillage > chiseling > disking. However, the basic infiltration rate was in the following order: chiseling > ridging > disking > no-tillage. The high initial infiltration rate under no-tillage over disking and chiseling in 2001/02 could possibly be attributed to the presence of large cracks and fissures and previous crop's root channels in the soil, while under disking and chiseling, the cracks were destroyed as the whole surface was ploughed,

leaving no room for high infiltration rate due to their presence. However, the effect of these cracks and fissures diminished when the soil swelled after saturation. The superiority of chiseling over the other tillage systems was reported by Maurya (1993) and Abdalla and Mohamed (1998). Results of the effect of tillage implement on working width and depth (cm), tractor's wheel slippage (%), field capacity (ha/h), field efficiency (%), working speed (km/h), fuel consumption (l/h), draught (KN), unit draught (N/cm^2) and drawbar power (KW) are presented in **Table 2**.

Implement type had a highly significant effect on forward speed (P ≤ 0.01). Disk plough recorded the highest speed of 3.1 km/h followed by the ridger and chisel plough, which recorded 2.8 and 2.2 km/h, respectively. However, the analysis of variance showed no significant difference between the disk and chisel ploughs. Apparently, forward speed was greatly influenced by the width of implement tines. However, the results show that ploughing depth was more influential than tine dimensions, which ranked second in determining forward speed. Implement type significantly affected the actual field capacity AFC (P ≤ 0.01), with the highest value of 0.34 ha/h recorded under ridger, while chisel plough ranked second (0.26 ha/h), and disk plough ranked last (0.16 ha/h). The effect of implement width on AFC is quite evident. Moreover, the negative effect of wheel slippage

can be compensated for by the implement width, as the case of chisel plough and ridger. Abuzaid (1999) and Farah (1999) reported similar ranks for the same implements.

Field efficiency (FE) was significantly affected by implement type (P ≤ 0.05). The ridger recorded the highest FE (67.4 %). Chisel and disk ploughs recorded efficiencies of 60.0 and 58.3 %, respectively. However, the analysis showed a significant difference in FE values between chisel and disk ploughs. In comparison, Farah (1999) reported the highest FE for the ridger followed by disk and chisel ploughs, respectively.

Drive wheel slippage was not significantly affected by implement type (P > 0.05). The highest slippage (14.3 %) was recorded under disk plough followed by ridger (11.1 %), while chisel plough ranked last (7.7 %). Width of the tines was the main attribute of wheel slippage increase as soil resistance increased as a result of any increase in the width of the cutting edge.

Fuel consumption was not significantly affected by implement type (P > 0.05). However, the highest fuel consumption of 2.10 l/h was recorded under chisel plough followed by disk plough and ridger (2.02 and 1.38 l/h), respectively. Ploughing depth along with draft contributes well to any increase in fuel consumption as mentioned by Bowers (1989).

Implement type had a significant effect on draft power (P ≤ 0.05).

Table 2 Machine parameters as affected by implement type

Tillage implement	Machine parameters									
	Working depth, cm**	Working width, cm*	Wheel slippage, %	Field capacity, ha/h*	Field efficiency, %*	Speed, km/h**	Fuel consumption, l/h	Draught, KN*	Unit draught, N/cm²**	Draw bar power, KW*
Disc plough	21.00 a	60.0 a	14.34	0.16 a	58.3 a	3.10 a	2.02	5.00 ab	3.96 a	4.3 a
Chisel plough	29.66 b	121.3 b	7.71	0.26 b	60.0 b	2.23 b	2.10	6.33 b	1.76 b	5.0 a
Ridger	15.43 c	211.67 c	11.11	0.34 c	67.3 c	2.83 a	1.38	3.33 a	1.02 b	2.1 b
LSD	3.19	3.40	NS	0.049	0.037	0.26	NS	2.21	1.08	1.75

Means followed by the same letter(s) within a column are not significantly different.
*, ** = Means are significantly different at (P ≤ 0.05) and (P ≤ 0.01), respectively.
NS = Means are not significantly different.
LSD = Least significantly difference.

The highest draft (6.33 KN) was recorded under chisel plough, which was statistically not different from the draft recorded under disk plough (5.00 KN). However, draft power under chisel plough was also significantly different from that recorded under ridger (3.33 KN). The effect of ploughing depth on draft power seems to be the main attribute to the high draft under chisel and disk ploughs when compared with ridger. The lower draft obtained under disk plough, compared to chisel plough, can be ascribed to the rotating disk element. Farah (1999) obtained the same draft ranks for the chisel plough, disk plough and ridger in the same location of this study.

Implement type had a highly significant effect on unit draft (P ≤ 0.01). Disk plough recorded 3.96 N/cm^2, which was significantly higher than both chisel plough and ridger. Chisel plough and ridger recorded no statistical difference in unit draft values of 1.76 and 1.02 N/cm^2, respectively. The variation in unit draft values of the different implements were attributed to the variation in cutting edge shapes between the tillage implements and the ploughing depth.

Draw bar power was significantly affected by implement type (P ≤ 0.05). The chisel plough recorded 5.0 Kw followed by disk plough and ridger, which recorded 4.3 and 2.1 Kw, respectively. The statistical analysis, however, showed a significant difference between the values obtained under both chisel and disk ploughs compared to ridger. It can also be seen that drawbar power values ranked in the same manner as did draft and ploughing depth. This indicated that drawbar power was dependent on ploughing depth and draft rather than on ploughing speed and implement type. These results are in accordance with those reported by Belel and Dahab (1997).

Conclusion

The following conclusions were drawn from the results of this study:
· Tillage implements and sampling depth significantly affected soil moisture content (%), with the highest mean values recorded under chiseling.
· Amongst the tested tillage implements, the chisel plough had the highest power requirements and fuel consumption. This resulted in relatively higher basic infiltration rate and soil moisture content.
· The ridger had the lowest power requirement and fuel consumption, but recorded the highest field capacity and efficiency.

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Studies on Characterization of Selected Plant Oils and Their Bio-Diesels

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Abstract

Bio-diesel is a renewable alternate fuel for diesel engines. Studies were conducted on bio-diesels prepared from three plant oils, namely, rice bran oil, jatropha curcas oil, and karanji oil. Bio-diesel was prepared from plant oils using the esterification process. Fuel characteristics of these bio-diesels (washed and unwashed) were determined for their suitability as alternate fuel for diesel engines. Most of the fuel characteristics of these bio-diesels were quite close to those of diesel. However, heat values of bio-diesels, except that of rice bran, were lower than that of diesel.

Introduction

Petroleum oil reserves are limited but the oil consumption rate is increasing at an alarming rate. Diesel fuel is heavily used in agriculture but the supply is under threat of disruptions, quality deterioration and cost escalations. Scientists are in search of some biomass-based fuel that can be used as alternate fuel for diesel engines. Among the various biomass-based fuels, plant oils seem to be the most promising as a substitute for fossil-derived diesel fuel. These oils have the potential to make farming communities self-sufficient in case of any severe scarcity of diesel. Short-term tests have indicated that plant oils, neat or in blends with diesel fuel, can be used to run diesel engines. However, during extended operation on neat plant oils, serious problems such as injector choking, ring sticking, dilution of engine oil, gum formation and deposits in various engine parts have been reported by Ryan et al. (1984). High viscosity of the plant oils is considered to be the major problem causing inadequate fuel atomization and incomplete combustion. Several methods have been investigated for reducing the viscosity. But, the most promising method seems to be the esterification. This paper deals with the study of fuel characteristics of bio-diesels prepared from selected plant oils.

Materials and Methods

Plant oils selected for the study were physically refined rice bran oil, crude jatropha curcas oil, and crude karanji oil. These oils were converted to bio-diesels. Fuel characteristics of both washed and unwashed bio-diesels were determined to check their suitability as an alternate fuel for diesel engines.

Preparation of Bio-Diesel

The bio-diesel was prepared using the method standardized by Gupta (1994). Each oil sample was heated to below 60 ºC. The required volume of alkali-methanol mix (homogeneous solution of about 200 ml methanol and 5-10 g NaOH for each litre of oil) was added with the heated oil and the mixture was stirred

for 5-7 minutes. It was, then, kept undisturbed for 4 hours to allow the glycerol to settle at the bottom. The bio-diesel thus formed was decanted from top leaving glycerol at the bottom. The bio-diesel was given 2-3 washings with water to remove any dissolved glycerol, left over sodium hydroxide, excess (unused) methanol, and other impurities present in it.

Determination of Fuel Characteristics

The following methods were used to determine the characteristics of oils and their bio-diesels.

Density

Capillary-stopper relative density bottles of 50-ml capacity were used to determine density of plant oils and their bio-diesels. The relative density bottle was dried and weighed. Then a sample was filled in the bottle and a capillary stopper was placed gently on the neck of the bottle, taking care that no air bubble was left inside the bottle. The bottle was cleaned from outside with filter paper and then it was placed in an oven at 21 ºC. After few minutes, the bottle was taken out and cleaned from outside. The bottle was again kept in the oven to regain the temperature. Then it was taken out and weighed. Density was calculated using the following equation (Anonymous, 1972):

$$d = (M_2 - M_1) / 50$$

where,

d = density of sample, g/ml
M_2 = Mass of relative density bottle plus sample, g
M_1 = Mass of empty relative density bottle, g

Kinematic Viscosity

Kinematic viscosity of samples was measured by using Red Wood Viscometer No. 1 (Toshniwal make). Time of gravity flow of a fixed volume (50 ml) of fluid was measured. The experiment was performed at 38 ºC. Kinematic viscosity was calculated using the following formulae (Anonymous, 1976):

$$c = 0.26t - 179 / t$$
$$\text{for } 34 < t > 100$$
and $$v = 0.24t - 50 / t$$
$$\text{for } t > 100$$

where,

v = Kinematic viscosity in centiStokes
t = time of flow in seconds

Flash Point

Pensky-Martens flash point (closed) apparatus was used to measure the flash point of samples. The sample was filled in the test cup and was heated at a slow and constant rate. At the same time, a small test flame was diverted to the top of the cup at regular intervals. The flash point was taken as the lowest temperature at which the flame caused the vapour above the sample to ignite momentarily (Anonymous, 1970).

Cloud and Pour Point

A plastic container filled with an ice and sodium chloride mixture was insulated using glass wool in order to achieve low temperatures below the freezing point of water. Holes were provided in the top cover in order to insert the test tubes containing samples. A thermometer was placed in the tube coaxially. At every 1 ºC fall in temperature, tubes were taken out for observing the cloud/pour point condition (Anonymous, 1970).

Gross Heat Value

Gross heat value of samples was measured using a bomb calorimeter. The sample was placed in a gelatin capsule and then burnt in oxygen in the bomb calorimeter (model 1252 of Parr make, USA). The total weight of sample and the capsule was fed to the controller and the results, including the gross heating value, were taken on a printout. Knowing the weight and heat value of capsules, the heat value of the sample was calculated (Anonymous, 1984).

Free Fatty Acid (FFA)

A known amount of sample was titrated with aqueous solution of NaOH of known normality. Percent FFA was calculated as follows (McKillican, 1966):

Fig. 1 Viscocity of oils and their bio-diesels
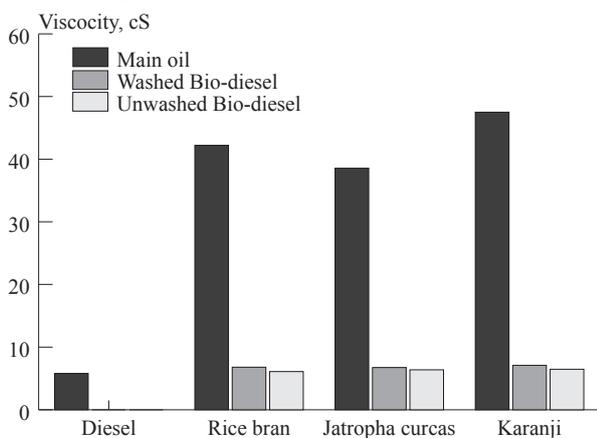
Fig. 2 Pour point of oils and their bio-diesel
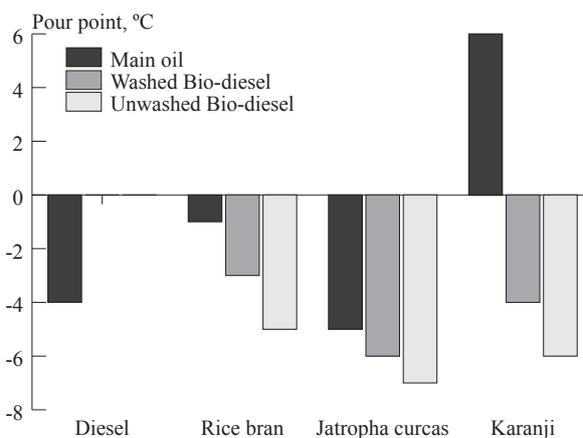
% FFA = (V × N × M) / 10w
where,
   V = Volume of NaOH used (ml)
   N = Normality of NaOH
   M = Molecular weight of fatty acid
   w = weight of sample (g)

Results and Discussion

Fuel characteristics of all the three oils and their bio-diesels (both washed and unwashed) were determined and are presented in **Table 1** and in **Figs. 1** to **7**.

Viscosity

Fig. 1 shows that the viscosity of plant oils was quite high. It was in the range of 38.6-47.5 cS and was 6.5-7.5 times than that of the diesel (5.8 cS). Karanji oil had maximum viscosity followed by rice bran oil and jatropha curcas oil. Pischinger

et al. (1982) reported high viscosity values of oils in the range of 30.3-41.2 cS. Esterification of these oils reduced the viscosity to a great extent. Viscosity of washed and the unwashed bio-diesels was reduced to almost 1/7th to 1/5th of that of their respective oils. As such, viscosity of the bio-diesels was quite comparable to that of diesel. It was 6.1 to 7.1 cS, i.e. only 1.1 to 1.2 times that of diesel. Verma et al. (1998) have reported viscosity of various bio-diesels to be in the range of 8.16 to 9.75 cS at 38 ºC. This clearly showed that most of the problems faced with plant oils as fuel for diesel engines (because of high viscosity of the oils) will be taken care of by the use of bio-diesels.

Pour Point

Pour points of oils, their bio-diesels, and the diesel fuel are given in **Fig. 2**. It is clear from the figure

that the pour point of karanji oil was very high (6.0 ºC) followed by rice bran oil (-1.0 ºC) and jatropha curcas oil (-5.0 ºC). The pour point for each bio-diesel was lower than that of its parent oil. Also each unwashed bio-diesel was found to have lower pour point than that of its respective washed bio-diesel. Pour points obtained were -3.0 ºC and -5.0 ºC for washed and unwashed rice bran bio-diesels respectively, -6.0 ºC and -7.0 ºC for washed and unwashed jatropha curcas bio-diesels respectively, and -4.0 ºC and -6.0 ºC for washed and unwashed karanji bio-diesels, respectively. These values differed little from that of diesel (-4.0 ºC). Therefore, like diesel, these bio-diesels will also not create a problem in engine operation at very low temperature.

Flash Point

In case of unwashed bio-diesels,

Table 1 Fuel characteristics of plant oils and their bio-diesels

Oils/bio-diesels	Density at 21 ºC, g/ml	Viscocity at 38 ºC, cS	Cloud point, ºC	Pour point, ºC	Flash point, ºC	Gross heat value, MJ/kg	Free fatty acid, %
Rice bran oil	0.923	42.2	11	-1	258	42.3	0.15
Rice bran bio-diesel (washed)	0.861	6.8	9	-3	164	42.6	0.08
Rice bran bio-diesel (unwashed)	0.854	6.1	4	-5	40, 152	41.2	0.00
Jatropha c. oil	0.902	38.6	16	-5	245	36.4	1.87
Jatropha c. oil (washed)	0.867	6.7	13	-6	175	34.5	0.16
Jatropha c. oil (unwashed)	0.848	6.4	11	-7	35, 144	34.8	0.08
Karanji oil	0.911	47.5	15	6	226	33.7	1.50
Karanji oil (washed)	0.864	7.1	12	-4	162	33.9	0.30
Karanji oil (unwashed)	0.872	6.5	10	-6	35, 146	34.2	0.30
Diesel	0.849	5.8	9	-4	74	47.4	0.00

Fig. 3 Flash point of oils and their bio-diesels
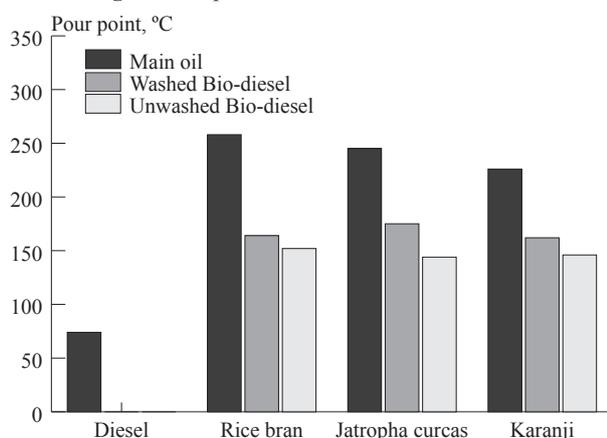
Fig. 4 Heat value of oils and their bio-diesels
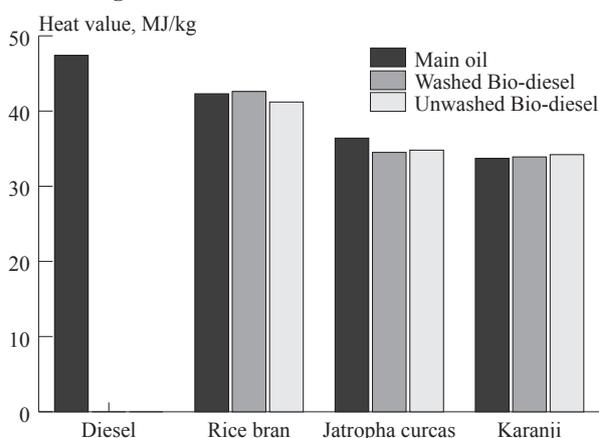
two flash points were observed (**Table 1**). The lower one was observed at about 35 ℃ and may be because of the presence of methanol in the unwashed bio-diesels. However, only the higher flash point has been given in **Fig. 3**. It is obvious from the figure that the flash point of each bio-diesels was lower than that of its respective oil. But the bio-diesels had much higher flash point (144-175 ℃) than that of diesel (74 ℃) thus ensuring more safety during their transportation and handling. High flash points of bio-diesels were also reported by Pischinger et al. (1982) in the range of 127-183 ℃. Flash point of each unwashed bio-diesel was somewhat lower than its respective washed bio-diesel. The higher flash point of bio-diesel than diesel was attributed to their longer carbon chain (Tahir et al., 1982).

Gross Heat Value

Fig. 4 indicates the gross heat values. The figure shows that oils had less gross heat value (33.7-42.3 MJ/Kg) compared to that of diesel (47.4 MJ/Kg). This was because of presence of oxygen (about 11 %) in the plant oils. The gross heat value (33.9-42.6 MJ/Kg) of the bio-diesels (both washed and unwashed) was quite close to that of the respective oils but was quite low compared to that of diesel. The gross heat values of karanji and jatropha curcas bio-

diesels were about 73 % of that of diesel while the rice bran bio-diesels had heat values about 89 % of that of diesel. Tahir et al. (1982), and Hawkins and Fuls (1982) also reported lower heating values of bio-diesels in comparison to diesel.

Density

Density values of oils, bio-diesels and the diesel have been presented in **Fig. 5**. It could be inferred from the figure that the density of plant oils (0.902-0.923 g/ml) and their bio-diesels (0.848-0.872 g/ml) was quite close to that of diesel (0.849 g/ml). The density of different bio-diesels was 1 to 1.027 times than that of the diesel. Jatropha curcas and rice bran unwashed bio-diesels had lower density than their corresponding washed bio-diesels but the trend was reverse for karanji bio-diesel. This may be attributed to gel formation in unwashed karanji bio-diesel under low ambient temperature. Bio-diesels will have higher mass flow rate due to their high density. This will outweigh, to some extent, the lower heat values of the bio-diesels. Lower densities of bio-diesels compared to those of their respective oils have also been reported by Sangha et al. (2000).

Cloud Point

Cloud point indicates the start of clogging in fuel lines and filters because of presence of saturated

fatty acids. **Fig. 6** shows that the cloud points of both washed and unwashed bio-diesels were lower than that of their parent oils (11-16 ℃). Unwashed bio-diesels had lower cloud point (4-11 ℃) than that of the respective washed bio-diesel (9-12 ℃). Therefore, the cloud points of washed bio-diesels were quite close to that of the diesel (9 ℃).

Free Fatty Acid Content

At elevated temperatures, fatty acids react with metal parts and fatty acid metal can be introduced into the engine cylinder and can increase wear. The percentage of free fatty acid in plant oils selected for study was not so high, which could interfere with conversion and recovery of bio-diesels (**Table 1**). **Fig. 7** shows that among the oils studied, jatropha oil had highest FFA (1.87 %) followed by karanji oil (1.5 %) and rice bran oil (0.15 %). On esterification, the values of FFA reduced drastically. Free fatty acid content of washed bio-diesels and their respective unwashed bio-diesels was almost the same. Hassett and Hasan (1982) have also reported reduction in value of FFA on esterification of sunflower oil.

Conclusion

It could be concluded from the characterization study that almost

Fig. 5 Density of oils and their bio-diesels
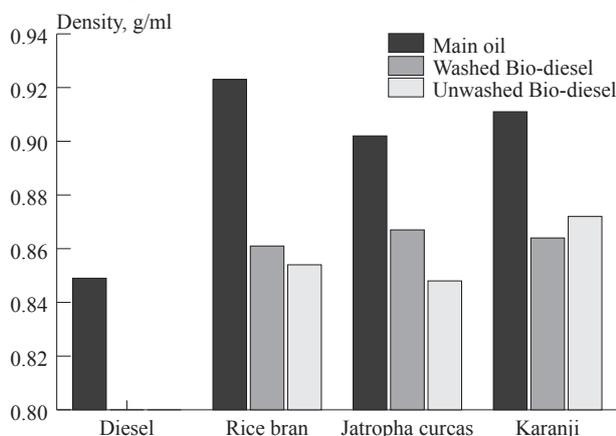
Fig. 6 Cloud point of oils and their bio-diesels
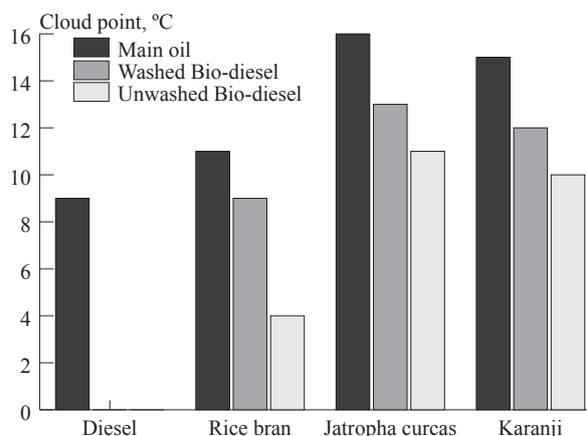
all the characteristics of bio-diesels, prepared from different oils, are similar to those of diesel. Therefore, it can be used as an alternate fuel in diesel engines without making modifications in the existing diesel engines.

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Fig. 7 Free fatty acid of oils and their bio-diesels
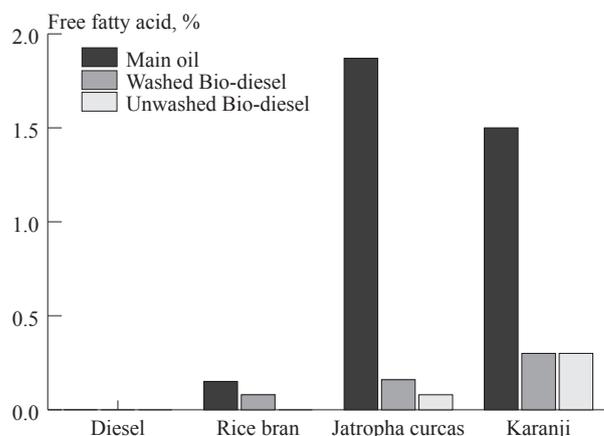
Efficient Utilization of Conventional Fuel Through the Improvement of Traditional Stove

by

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Abstract

The fuel efficiency of a traditional stove is very low. Therefore, an improved version of was developed by incorporating a perforated screen in the stove cavity, an ash port by the side of the stove and reducing pot rest height from 8 to 2 cm of the ground traditional stove. In the improved stove, the fuel efficiency was increased by 40 % compared to the traditional ground stove. The cost of the stove was very low, which included only the cost of an earthen screen and labour. The BRRI cost of the developed earthen screen was 75 % less than the similar sized metal screen.

Introduction

Every year in Bangladesh more than 38 million tones of traditional fuel such as wood, straw, leaves and dried cow dung are being used for cooking and other purposes (BCSIR, 1990). Use of these traditional fuels is increasing day by day with the population growth. A country should have 25 % of its area covered with forest for sound environment but Bangladesh has only 9 % (BBS, 2002). For this reason, Bangladesh is loosing its natural balance. Desertification started at its northern part and salinity is threatening to its south. The incidences of drought, excessive rainfall and flood are regular occurrences in Bangladesh.

Once, it was our practice that farmers left straw in the field as an organic fertilizer at the time of harvest. Cow dung usually was applied to the field but now these valuable fertilizers are being burnt to meet the scarcity of fuel. As a result, fertility of our agricultural fields is declining. We must be very careful in the efficient use of fuel, otherwise we must accept further declining of the forest area, deterioration of the natural environmental harmony and decreased agricultural production.

The local term in Bangladesh for the widely used cooking device is Chula that is nothing but a stove. Most of the traditional stoves are installed in a corner of the kitchen or sometimes in one corner of the home yard in open sky. The farm families adopt the latter option usually in the dry season. The traditional stove is a very inefficient device for use of our valuable fuel. It was reported that these stoves could utilize only 5-15 percent of the total heat energy during burning of the fuel depending on the depth of the stove and size of the flue gas exists (Hasan et al.). The remaining 85-95 percent of the heat energy is lost to the environment. Furthermore, poisonous hot gases emitted by these stoves create health hazards and pollute the environment. Efforts are being made for the development, promotion and trade of a fuel-efficient stove. There was a feature on the preparation and trade of an earthen stove in The Daily Ittefaq. The report said that Maleka Begum, a woman of the Patuakhali district has taken stove making and selling as a profession. The cost of each stove was Tk 25-35 and she earns Tk 700-800 per month from this trade (Begum, 2005).

The Bangladesh Council for

Science and Industrial Research (BCSIR) has developed some versions of a portable type stove, which consumes 40-50 % less fuel than the traditional stove. The adoption rate of these stoves among the end users is very slow, because one must stop using their existing ground stove and then build a new stove.

Therefore, research was undertaken to modify/improve the existing ground stove for increased fuel efficiency.

Materials and Methods

A traditional version of the ground stove was constructed in the in the laboratory of Farm Machinery and Post Harvest Technology Division, BRRI (**Plate 1**). It was made in the corner of a kitchen and was more than 0.5 m deep. The height of the pot rest ranged from 6-8 cm. As a result there was a very wide gap between the stove body and cooking pot. The improved version of ground stove was constructed adjacent to the traditional stove (**Plate 2**). The improved stove was

Plate 1 Ground traditional stove

Plate 2 Ground improved stove

made with the following modifications: (a) the height of the pot rest was reduced from 8 cm to 2 cm; (b) a screen was incorporated at a depth of about 25 cm from the top to hold the fuel during burning; and (c) an opening was provided by the side of the stove to supply oxygen from the bottom of the fuel and to remove ash.

Major Parts of Improved Stove

The improved stove was com-

prised of the following parts presented in **Fig. 1**.

1. Pot rest
2. Fuel mouth
3. Ash port
4. Screen support
5. Fuel screen
6. Ash remover

1. Pot rest: The pot rest is a raised lump of clay which is used to hold the cooking pot on the stove. Usually they are three in number equally spaced on

Fig. 1 Schematic diagram of improved stove

All dimensions are in mm

1 Jhika
2 Fuel mouth
3 Ash port
4 Screen support
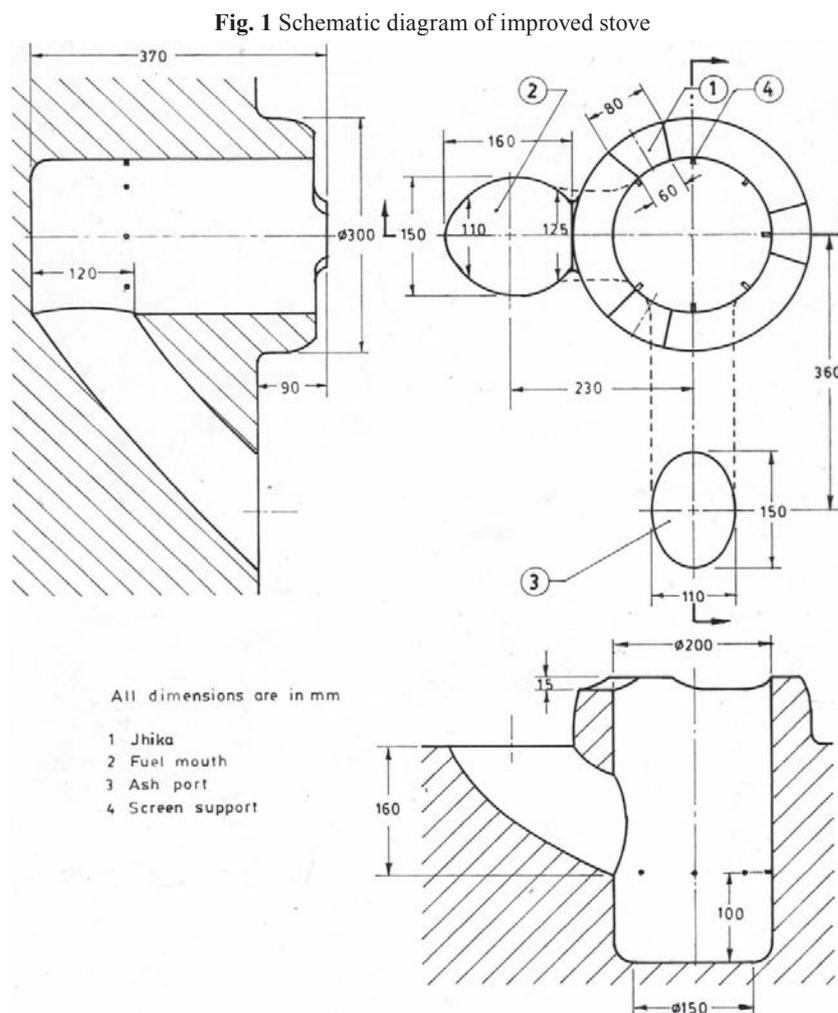
Table 1 Features of traditional and improved ground stove

Ground traditional stove	Ground improved stove
Height of pot test more (6-8 cm)	Height of pot test more (1.5-2.0 cm)
More heat loss through radiation	Less heat loss through radiation
Depth of stove more (45-60 cm)	Depth of stove more (35-40 cm)
Fuel burns at the bottom of the stove	Fuel burns on screen
Wide gap between heat source and sink	Gap between heat source and sink is less
Insufficient supply of oxygen to the fuel	Sufficient supply of oxygen to the fuel

the circumference of the stove hole. In the traditional stove the height of stove ranges from 7-10 cm through which most of the heat energy emitted from the fuel is radiated to the atmosphere rather being consumed by the cooking pot.

2. **Fuel mouth:** The fuel mouth is the opening through which traditional fuel is fed into the stove. In the traditional stove it is round and approximately 120-130 cm in diameter. In the improved stove it is oval with a long axis of 125 cm and a short axis of 110 cm.

3. **Ash port:** In the improved stove an opening was made at an angle of 90° from the fuel mouth and 15 cm away from the stove body. This port is nothing but an oblique hole extended from the earth surface to the bottom of the stove. It has a dual function i.e. to remove ash from the bottom of the stove and to supply air to the fuel from the bottom of the screen.

4. **Screen support:** These are metal rods placed on the inner surface of the stove to hold the fuel screen. These supports may be made of broken parts of earthen pots in order to reduce cost as well as to make good use of old and broken pots.

5. **Fuel screen:** This a screen on which the fuel burns. It is a round earthen plate of 19 cm diameter and 1.5 cm thickness. These dimensions should exist after drying and burning. It has a total of 16 openings in two rows. The rows are 3.5 cm apart. The length of the opening varies from 5.2-2.0 cm. It has three functions: to hold the fuel for burning near to the pot; to release white ash from the bottom of the stove; and allow air from the bottom for effective burning of fuel.

6. **Ash remover:** This is a 10 cm diameter metal cup made of 1.5 mm thick M S sheet. The cup is welded to a metal rod of 1 cm diameter and 58.5 cm long. The other end of the rod is pushed into a 10.5 cm long tapered wooden handle whose one end has a diameter of 2.2 cm, however, the other end is 2 cm diameter. This is used to remove ash from the stove.

Construction of Improved Ground Stove

The following steps were followed to construct the stove as per design mentioned in **Fig. 1**:

1. A hole of 20 cm diameter and 37 cm depth was made in the ground.
2. The screen supports were placed at about 10 cm up from the bottom of the stove.
3. A fuel mouth was made 125 cm long and 110 cm wide.

Fig. 3 Ash remover of improved stove

Fig. 2 Screen of improved stove
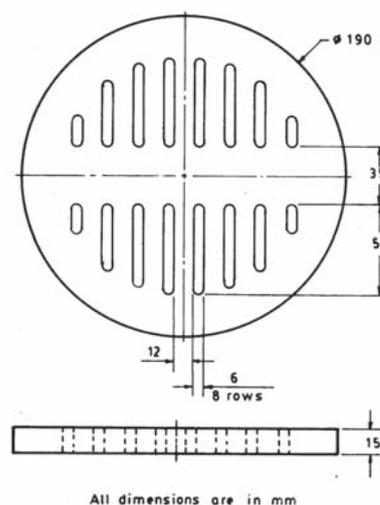
4. An ash/air supplying port was made at an angle of 90º from the fuel mouth and 15 cm away from the stove body. This port was only an oblique hole that extended from the earth surface to the bottom of the stove.

5. An earthen band of clay 5 cm wide and 9 cm high was put on the circumference of the stove.

6. The wet earthen band was dried in the sun for 3-5 days. The duration of drying will be varied in different seasons. The band should be smeared by water-mixed clay as and when necessary to prevent it from cracking.

7. At the proper degree of drying the pot rest should be made by cutting the earthen band with a sickle. Three pot rests, each 1.5-2.0 cm high, were made at equal intervals from each other.

8. When the stove was well dried the earthen screen was placed on the screen support and the stove was ready for use.

Test of Traditional and Improved Stove

Two aluminum pots were filled with 5 litres of water. The initial temperature of the water was recorded 29 ºC. The same amount (1 kg) of fuel i.e. tree leaves were taken for each of the stove. Two operators operated the two units of the stove simultaneously. The time required to raise the temperature of water to 100 ºC was recorded. During the course of heating, the temperature of the water was recorded at 5 minutes interval. After boiling, the left over fuel for each of the stove were measured. They were subtracted from the initial weight of the fuel to work out the fuel required by each stove.

Results and Discussion

A comparative salient feature of the improved and traditional ground stove is enumerated in **Table 1**. The

fuel consumption to raise the temperatures of 5 litres of water from 29 to 100 ºC in the ground traditional stove and ground improved stove was 849.20 and 554.80 gm, respectively (**Table 2**). Therefore, the fuel consumption in improved ground stove was about 35 % less than that in the traditional ground stove. The reason for fuel saving in improved stove was that the fuel was burnt on the perforated screen, which in turn reduced the gap between the heat source and the heat sink. Moreover, it provided opportunity to supply oxygen from both top and bottom of the fuel which resulted in more effective burning. In addition, heat energy in the improved stove can not be lost away as it has minimum pot rest height (1.5 cm) instead 8 cm pot rest height in the traditional stove. Also, an added advantage is the ability to remove ash from the stove while it is in operation. The time required to raise the temperature of 5 litres of water in the improved and traditional stove from 29 to 100 ºC was 28 and 26 minutes, respectively. The time required for initial firing in improved stove was less than 1 min, as compared to the traditional stove in about 3 minutes. A larger quantity of white ash was found in the improved stove.

Conclusion

1. Fuel efficiency of the ground traditional stove was increased

by 40 % through the incorporation of a perforated screen in the stove, an ash port by the side of the stove and reducing Pot rest height from 8 to 2 cm.

2. The cost of BRRI developed earthen screen is only Tk 10, which is 75 % less costly than a similar size metal screen.

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Table 2 Comparative fuel consumption in traditional and improved ground stove

Ground traditional stove (GTS)			Ground improved stove (GIS)			Fuel saving over traditional stove, %
Time, min	Temp., ºC	Fuel, gm	Time, min	Temp., ºC	Fuel, gm	
0	29		0			
5	37		5	29		
10	52		10	40		
15	70		15	52		
20	93		20	70		
25	98		25	98		
28	100	849.20	26	100	554.80	34.74

Note: GTS pot rest height = 8 cm; GIS pot rest height = 2 cm

Development and Evaluation of Anaerobic Type Sprouted Rice Drum Seeder and to Ascertain the Physiological Load on the Operator

by

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Abstract

A number of pre-germinated rice seeders have been developed and recommended as an alternative technology to the rice farmers who are practicing manual transplanting of rice seedlings. The studies conducted on drum seeders have proven that there is no difference in the yield levels as compared to transplanted rice. The wet seeding technology reduced the labor, water and the crop maturity period. The cost of drum seeders reported in India were in the range of Rs.2500-3000 during 2001. The physiological load on the operator for wet seeding operation with eight, six and four row drum seeders was reported as extremely heavy field work. These units required two workers to operate in fields. Therefore, the project to refine the design of pregerminated rice seeder of anaerobic type by making it light weight and easy to manouevre in small plots was taken. Based on theoretical analysis of two row drum seeders with 20 cm row spacing, the drum seeder was designed for seeding rates varying from 60-200 kg/ha. The cost of drum seeder was estimated as Rs.750/-. The developed seeder was evaluated for field performance on four varieties namely IR-36, Vandna, Krishna Hamsa and Kalinga-III. The seeding rates varied from 125-215 kg/ha and the high plant stand was achieved. The crop yield levels reported were for IR-36 4.07 tons/ha, Vandana 2.82 tons/ha, Krishna Hamsa 3.73 tons/ha and Kalinga-III 4.06 tons/ha. The operating load on the worker was measured in terms of increase in heart beat rate. The operator was allowed to work at different speeds and his heart beat rate was monitored. The operator covered the maximum area of 352 sqm/h by seeder but at the end of 30 minutes of operation his heart beat rate reached to 155-165 beats/min. The allowable heart beat rate increase of 40 beats/min was achieved with a field coverage of 198.9 sqm/hour. Thus, the developed two-row drum seeder was easily operated for anaerobic sowing of small plots at a field capacity of 199 sqm/h in backward walking mode of operation.

Introduction

The manual method of transplanting rice seedlings is very labor intensive and even the small rice farmers require hired farm labor during transplanting season. Recent studies using manually operated drum seeders at the various locations in India have shown the viability of the wet seeding technology, under the Crop and Resources Management Network Project financed by International Rice Research Institute, Phillippines. The wet seeding of pregerminated seeds helped the farmers to reduce the peak labor requirements as well as the crop growth period by at

least 10 days due to early maturity. Thus, wet seeding helped in reducing the total water requirements. Therefore, technique of wet seeding of pregerminated rice seeds is now recommended to the farmers. A number of designs of drum seeders such as eight, six and four row type have been developed, evaluated and recommended to the rice farmers. However, it is reported that two to three workers are required to operate these units in the field. Therefore, a project on refinement of design of a manual pull type seeder of small size, low cost and easy to operate and maneuver by a single operator was initiated to meet the needs of small rice farmers of eastern region of India. Thus, the adoption of wet seeding technology can help in mitigating the problems of small farmers in production of rice crop.

Review of Literature

In developed countries, the rice crop is established by wet seeding method. It is followed by use of selective herbicide for weed control and effective water management. The rice varieties grown are developed for local conditions and are of dwarf type. The wet seeding results in uniform crop establishment, saving in cost of production, labor and helps in increasing cropping intensity. In the developed countries, heavy machines are used for seed bed preparation and leveling of fields. Even the pregerminated seeds are broadcasted by aeroplanes. However, in many Asian countries, the wet seeding of aerobic type is practiced using small equipment and drum seeders. Thus, wet seeding technology can be made useful for the small rice farmers in India, where rice crop is raised along with efficient control on weeds, use of fertilizer and management of water.

The wet seeding of rice crop is done in three ways (i) aerobic (ii) anaerobic and (iii) water seeding. When seeds are sown on the surface of wet soils but the seeds are exposed to air, it is called aerobic seeding. In anaerobic seeding the seeds are placed in a small narrow rut (furrow) and are covered with moist soil. In water seeding the seeds are dropped on the seed bed which is covered with 1 to 2 cm depth of water. The seed rates are in the range of 60 to 100 kg/ha and in some cases the farmers even go for 150 kg/ha to guard against poor germination or other biotic factors. Among the wet seeding, the anaerobic wet seeding has resulted in better establishment of crop. The seeds used here refer to the sprouted seeds. The sprouted seeds are produced by soaking the clean sound seeds of paddy in water for 24 hours, followed by incubating them for 16 to 20 hours to have sprouts length of 1 mm size. The sprouted seeds are normally prepared for wet sowing on the same day in the field. The light immature seeds are

Table 1 Specifications of the manual pull two row drum seeder for anaerobic seeding

Name	Two row manual pull type sprouted seed drum seeder for anaerobic wet seeding
Function	For anaerobic sowing of sprouted seeds in wet puddles seed bed along rows
Make	CIAE, Bhopal
Model	Experimental
Cost	Rs.750/-
Weight, kg	11.0
Dimension	
Length, mm	1,780
Width, mm	480
Height, mm	840 in working position, 1,530 when handle is up right position
Seed drum	
Length, mm	250
Diameter, mm	205
Material	Aluminum
No. of rows of slots	Two
Row distance	20 cm nominal
Speed capacity	2 kg of sprouted seeds
Handle	T-shaped of M.S. conduit pipe
Length, mm	1,500
Width, mm	480
Gound wheel	Rigid steel wheels
No. of wheels	Two
Nominal diameter, mm	500
No. of spokes	8
Lugs	16
Material	Mild steel rod and flat
No. of furrow openers	Two
Type	Inverted shoe type
Length of opener, mm	40
Location	Based angle of the frame in the front
Flame	30 × 30 × 3 mm angle iron
No. of skids	3
Size of skids	50 mm wide at two ends 100 mm wide in the centre with 50 mm gap in between filled to seed drum frame
Material	Hard plastic, 6 mm thick
No. of openers required	One
Theoretical field capacity	500 sqm/h

removed from the seed lot by first soaking the seed lot in salt solution, thus only the bold heavy seeds are taken for soaking and incubation to ensure proper germination.

Requirements of Wet Seedbed

The rice fields should be properly puddled and leveled. This is essential to reduce the water infiltration rate in soil, control the weed growth and manage the thin layer of water for anaerobic seeding. The puddling depth of 15-20 cm is recommended for effective control on weed growth and for reduction of water infiltration. The top layer of soil should be well dispersed in water. This ensures that soil does not stick to the wheels and skids of seeder or operators feet and helps in achieving good contact between the sprouted seeds and the surrounding soil. The puddled soil is allowed a settlement period of 12 to 16 hours so that after the draining of excess water, the operation of the seeder would not cause the soil overflow at the end of seeder skids, which in some condition can cause soil overburden on the sprouted seeds sown in the rut. The field should be free of excess water at the ends so that turning of seeder is easy. The mobility of operator depends upon the uniformity of the puddling operation and the soil bearing capacity of the soil below the feet of operator. The settlement period of 12 hours is mostly required for the soil to decrease the sinkage of the operator. Sinkage of the operator should be limited to 10-12 cm (i.e. ankle deep) for the

drum seeder. This requires a soil bearing capacity of 0.1 Mpa at 10-12 cm depth. The efficient management of water in the rice field means that the field be irrigated and drained of excess water as required, for performing the seeding operation. In case of sandy soils, the mobility of operator is not a problem and settlement period is less as sand particles settle in a short period.

Manually Operated Seeders Evaluated

The drum seeder developed at International Rice Research Institute, Phillippines was eight row type. Seeders were used to spread the seeds along the rows over the well puddled and leveled fields (aerobic type). These seeders were used for sowing of dry and sprouted seeds. Pradhan (1968) reported the development of a paddy planter at Central Rice Research institute, Cuttack. The studies were conducted to establish the crop with the seeder to achieve the crop yield levels equal to manually transplanted rice. It was reported that the yield levels of transplanted rice were high. Therefore, wet seeding technology was not recommended. But, with the development of new rice varieties, availability of chemicals for better weed control, integrated nutrient management and the need for efficient utilization of water, wet seeding technology once again attracted the attention of rice scientists in India. Under the Directorate of Rice Research, Hyderabad (ICAR) and Crop and Resources Management

Network (CREMNET Project of IRRI), the evaluation of an8-row drum seeder was taken up for its evaluation at all India level during 1996-97. The recommended technique of preparation of seedbed and sowing of sprouted seeds with drum seeder were followed.

The field performance results of wet seeding experiments with the IRRI drum seeder at all the locations in India reported yield levels of 7 to 8 tons/ha with the wet seeding technology. This helped in planning a large scale trial by Directorate of Rice Research, Hyderabad with the drum seeder for wet seeding on local farmers fields (1999-2000). These trials resulted in the development of an 8-row modified drum seeder (**Fig. 2**). Its design was released and produced by local industry in Hyderabad to meet the demands of the farmers. The drum seeder (**Fig. 2**) developed at Hyderabad was provided with wheels on both sides. It was able to sow seeds at the rate of 50-75 kg/ha. The sprouted seeds were prepared by soaking the seeds for 24 hours in water followed by incubation of 24 hours before sowing with seeder (Krishnaiah, 1999).

The College of Agricultural Engineering of Tamil Nadu Agriculture University, Coimbatore reported the development of a successful eight row unit of light weight type fitted with a single wheel at the centre and two drums covering 8-rows with row spacing of 15 cm to suit the needs of local rice farmers. The cost of an 8-row seeder unit was

**Fig. 1** IRRI eight row drum seeder   **Fig. 2** DDR Hyderabad drum seeder   **Fig. 3** TNAU eight row wet paddy seeder
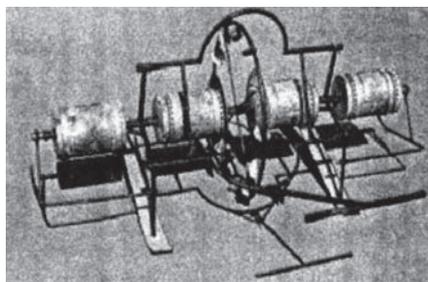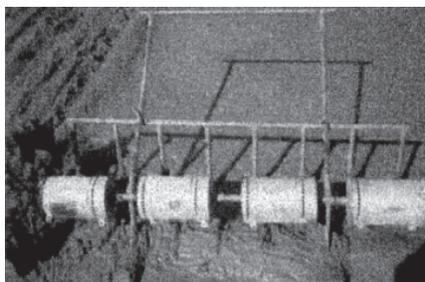
reported as Rs.3000/- (**Fig. 3**). The performance of seeder was reported as 0.12 ha/h field capacity and operating field efficiency of 65 %. Labor requirement for wet seeding was 15-20 man-h/ha. The cost of operation was Rs.600-700 per hectare (US $1 = Rs 43.50).

The six row germinated rice seeder was developed at CRRI-Cuttack. It was used for frontline demonstrations of equipment during 1999-2001. The performance of the seeder was reported to be satisfactory on the farmers fields. The crop yield levels of 3.5 tons/ha were reported and design was released for local production. (**Fig. 4**).

The development of the four row drum seeder for sprouted seeds was reported in the Annual Report of CIAE-Bhopal for 2000. The unit had a field capacity of 0.08 ha/h with pull requirements of 20 kgf (**Fig. 5**).

A team of Scientists under JICA Japan and Phillippines Rice Research Institute, Phillippines worked from 1994-98 on a project to develop a power tiller operated anaerobic type paddy seeder. (Sawamura, 1995). A 12-row unit was developed. It was able to sow the seeds at 40-120 kg/h with a field capacity of 3 to 5 hectares/day. The successful design of the seeder was developed and reported (Ryuji Otani, 1998).

Ergonomic Studies

The pregerminated seeders developed are manual pull type, therefore, attention was paid to the study of the physiological load on the operator. The earlier work conducted at CRRI-Cuttack by Nag and Dutt (1980) have reported that seeding with the four row type wet seeder, when operated at field capacity of 0.1 ha/h, resulted in the heart beat rate of 154 beats/min and oxygen uptake of 1.638 lit/min. It was reported as an extremely heavy type of job. The values of physiological responses of Indian farm workers for different agricultural operation,

including operations in a wet puddled field, were compiled by Gite (1997). It was noted that even walking in a wet puddled field consumed about 70 % of workers' energy. The maximum aerobic capacity of Indian male agricultural worker was listed as 2.0 to 2.24 lit of oxygen per minute (Gite and Singh).

The physiological load on the operator while working with the manually pull type drum seeder was studied by Karthivel and Sivakumar (2002) for eight, six and four row type seeders with furrow openers and having one or two wheels. The energy expenditure for the operation of these units varied from 24.8 kJ/min to 31.74 kg/min. It was reported as an extremely heavy task for the operator. The heart beat rate increased from a minimum of 128 to maximum of 150 beats per minute. It was recommended that two operators be employed the drum seeders for 15 minutes followed by a rest of 8 minutes. After working in paddy field, the operators reported body discomfort in shoulders legs and knees.

Small farmers in the traditional rice region raise the rice crop by dry seeding or by broadcasting seed on a prepared field. Row sowing is practiced by country plough, sowing device or a seed drill. They do wet seeding: broadcasting of dry or sprouted seeds on wet field (beushening) or by dibbling of seeds on wet seed bed. The main problem of rice farmers is to establish the crop and manage the water. The suitable design of a drum seeder can help farmers adopt the wet seeding technology to overcome shortage of labor during transplanting season. A need for refinement of seeder design for the small farmers was considered to mitigate the problems and encourage spread of the wet seeding technique. The following objectives were established for this project.

1. To refine the design of the manual pull type pregerminated rice seeder for anaerobic wet seeding,
2. To evaluate its field performance and

Table 2 Calibration of drum seeder with dry seeds of IR-36 variety.

Slot opening	Weight of seeds collected in 20 revolution		Total	Average/ revolution	Seed rate
5	10.78	13.15	23.93	2.393	38.59
6	19.71	21.29	41.00	4.100	66.12
7	31.64	30.83	62.47	6.270	101.13
8	36.36	38.69	75.05	7.550	121.78
9	52.89	49.20	102.09	10.209	164.66
10	75.94	68.36	144.30	14.430	232.74
11	95.08	93.78	188.96	18.886	304.60
12	110.94	109.74	220.68	22.068	356.00

No. of slots/row: 17, width of slot: 10 mm,
Weight of seeds in drum: 2.0 kg 1000 seed weight = 18.4 g
The slot setting of 7 mm provided the desired seed rate of 100 kg/ha

Fig. 4 IRRI eight row drum seeder   **Fig. 5** CIAE four row pre-germinated rice seeder
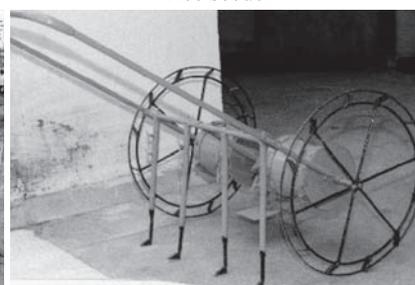
3. To determine work capacity within allowable physiological load on the operator.

Development of Drum Seeder

The review of literature indicated that eight, six and four row type drum seeders of aerobic and anaerobic type have been developed and found useful for rice farmers. But working in wet fields with even a four row unit was reported as extremely heavy work. For example, it required more than one operator to work it in the field while making the turn. Thus, the aim of this design was to make a seeder of small size, light weight and easy to pull and turn in the field. It was to be an anaerobic type. The design was prepared and unit fabricated during 2002. Preliminary field trials and improvements were made during

Fig. 6 Two row drum type manually operated seeder with pivoted handle for close operation near bunds
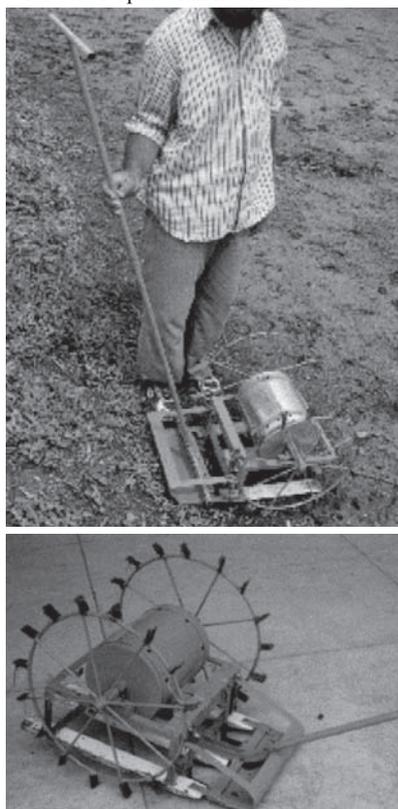
2002-2003. A brief description of the developed unit is given below.

The unit consisted of (i) seed drum (ii) frame (iii) pulling handle (iv) furrow markers (v) wheel (vi) skids (vii) front end float and leveling skid (**Fig. 6**).

An eight liter aluminum container was used as the seed drum. The open end of container was closed with the end cover fitted with nylon bushes to support the axle made of 19 mm diameter conduit pipe. The two 50 cm diameter wheels were fitted at the two sides of the seeder. The wheels were made from m.s. rod fitted with eight spokes and 16 lugs. The seeder drum was fitted on a 30 × 30 × 3 mm angle iron frame. The height of the frame was 8.0 cm. The furrow markers were of inverted shoe type 40 mm size and mounted at the base angle in the front of frame. At the front end, a leveling float and skid were provided. The hinged bracket for the handle was fixed at the end of the front float. The seed drum had three skids for the two rows. The width of the skids were 5, 10, 5 cm, respectively, with 5 cm gap in between so that the seeds drop in the small rut made by the furrow openers.

The row skids were made from a 21 × 40 cm plastic board. This hard plastic board was available in the market as a kitchen chopping board. The seeder was fitted with a 1.5 m

long handle hinged at the base of the front skid and given a T shape for pulling with the both hands of the operator (**Fig. 6**). The hinged handle helped to easy the pulling of the seeder up to the end of field close to the bund and helped in turning of the unit without lifting at the corners.

The seed drum was provided with two rows of slots of 10 × 20 mm size. There were 17 slots for each row that were spaced 40 m apart along the circumference of drum. A square slot with cover was provided on the seed drum for filling and emptying of seeds. The slots were covered with a 20 mm wide m.s. strip for adjusting the seed rate. The sliding of this strip over the slots changed the length of slot opening. The slot opening regulated the seed rate and provided for seeds of different length. The slot provided for seed rates from 40 kg/ha to 200 kg/ha. The two row developed drum seeder is shown in **Fig. 6**.

Calibration of Drum Seeder

The seed rates recommended for wet seeding of paddy were 60-90 kg/ha. The high seed rates recommended were 400 seeds/sqm for highest yields. The thumb rule for calculation of seed rate was 40 seeds/sqm equal to 10 kg/ha. The 60 kg/ha seed rate was close to 240 seeds/sqm. In order to overcome

Table 3 Calibration of drum seeder with pregerminated seeds of IR-36 variety: June 2003

Slot opening setting, mm	Weight of seed collected in 20 revolution		Total, g	Av. wt. of seeds per revolution, g	Seed rate, kg/ha	Seeds dropped per sqm., no
	Row-I	Row-II				
8	15.94	18.04	83.98	3.487	56.2	2.09
	17.66	18.10	35.76			
10	23.86	24.00	47.86	4.869	78.6	293
	25.50	26.02	49.52			
12	33.16	40.54	73.70	7.169	115.5	4.31
	31.20	38.48	69.68			
13	49.10	51.60	100.72	10.017	161.0	600
	46.14	63.48	99.62			

No. of slots/row: 17, width of slot: 10 mm,
Weight of seeds in drum: 2.0 kg 1000 seed weight = 26.8 g
10 mm slot opening gave the desired seed rate of 75 kg/ha

the various constraints the farmer broadcast seeds at the rate of 100 to 150 kg/ha. The aim of calibration was to determine the slot size opening to achieve the desired seed rate. It was done for dry and with sprouted seeds.

Dry seeds of IR-36 variety were taken for calibration of seeder. The drum was set on blocks. The slot opening for each row was set from 5 mm to 12 mm. The amount of seed dropped from the slots was collected in trays for 20 revolution of the ground wheel. The seed collected in the trays were weighed and the seed rate reported in **Table 2**. A seed rate of 100 kg was achieved with a slot opening of 7 mm. The variation in seed rate between two rows for low seed rate was high but decreeased as the seed rate increased to 100 kg and above.

Calibration for sprouted seeds was also conducted for IR-36 variety. The sprouted seeds were produced by soaking the seeds in plain water for 24 hours followed by 16-18 hours of incubation at room temperature (**Fig. 7**). Calibration was done with sprouted seeds with slot openings of 8, 10, 12 and 13 mm. The seed collected for each row were weighed and are reported in **Table 3**. The seed rates were calculated by taking the average values of seeds dropped per revolution of seed drum. The seed rate at 13 mm slot opening was 161 kg/ha. Hence, readings were recorded up to a slot opening of 13 mm.

In order to avoid seed damage, it was necessary to keep the slot opening equal to or more than the length of sprouted seeds. The walking speed for the manual pull type seeder was very low but the seed flow was due to forces of gravity and the level of seeds in the drum. The best method of calibration would be to count the number of seeds dropped per unit revolution of drum or unit area covered. The dropping of 240 seeds/sqm or 48 seeds/metre row length would be equal to 60 kg/ha seed rate. The recommendation for seed rates were based on dry weight basis. The sprouted seed calculation was made on dry weight basis. Therefore, when dropping seeds per unit area, farmers could easily count and set the drum properly. It was suggested that the seed rates for wet seeding be reported on wet weight basis. The dropping of seeds for the seeder along the row are shown in **Fig. 8**.

Measurement of Wheel Slippage of Seeder in Wet Field.

A field trial was conducted to measure the distance covered by the developed seeder in one revolution of the wheel as it was required in calculation of the seed rate sown in the field. The wheels used on the drum seeder were rigid type and the outer diameter of wheel was 50 cm. The theoretical distance covered by a 50 cm diameter wheel was equal to 1.570 m.

The observation of wheel diameter of the seeder was recorded and the average value was 49.86 cm. Therefore, theoretical distance covered would be 1.566 m by the wheel in one revolution.

The distance covered by a wheel in a wet field was measured. The distance covered in three trials was recorded. The overall average was determined. The average distance covered in one revolution of the wheel was 1.537 m. Thus, slippage of the wheel was 2 % in the wet field.

Measurement of Walking Speed of the Operator

The walking speed of the operator was measured by operating the seeder in walk backward mode. For convenience of the operator, walking in the forward direction was more appropriate. The backward movement of operator was studied. It helped in operation, in dropping of seeds and when flow was blocked, with attention given to accumulation of soils on wheels and in front of the seeder. Therefore, the operational problems were easily attended. Thus, the excessive burial of seeds were avoided with wet soil. During the operation the sinkage of the operator was 8-10 cm. The sinkage of the drum seeder was 2-3 cm as it was supported on the skids. The top soil moisture level was 35.3 % of on wet weight basis. The walking speed was measured by stop watch for straight movement of the seeder for the distance of 11.4

Fig. 7 Pregerminated rice seed for seeder

Fig. 8 Seed dropping along with rows with drum seeder model-II

Fig. 9 View of plot seeded with developed rice seeder
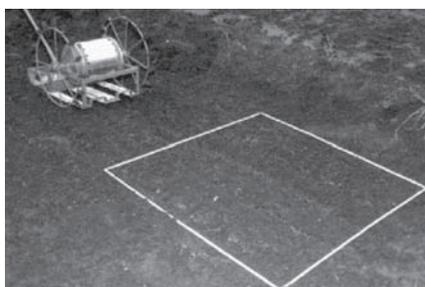
Note: the seeds deposited along rows in squire meter frame

m. The average walking speed was 22 m/min and varied from 19.6 to 24.7 m/min. The value was close to the average walking speed of 1.3 kmph. However, the average operating speed during the field operation was less than the above value due to time spent in making turns.

Measurement of Pull Required for Drum Seeder

The force to pull the seeder was measured with a spring balance with a minimum force of 0.25 kg. The value of pull was affected by the weight of seeder with seed (2 kg), the soil forces due to adhesion of soil on the seeder skids, soil forces required to over come the soil resistance offered to the lugged wheels, furrow openers and the force required to make the soil gathered in front of seeder to flow and spread. The value increased as the wet soil accumulated in the front of the unit due to dozing effect. At this stage, the operator was advised

to lift the handle upward slightly so that the seeder unit moved over the soil layer. The value of pull was measured several times in the field and it varied from 6.0 kg (min) to 10 kg (max) with an average force of 8.0 kgf.

Field Experiments

The field trials on the drum seeder were conducted during July 2003 at CIAE farm, Bhopal, with two main objectives (i) to ascertain the field performance of seeder in terms of crop establishment at yield levels achieved (ii) to study the physiological load on the operator during the field operation and suggest suitable mode of operation for the operator. The experimental plot of 1600 sqm area was selected and cultivated with a tractor operated sweep cultivator for shallow tillage and leveled during May 2003. The main plot was divided in to eight plots of ap-

proximately 180-200 sqm area. The plots were bunded to store rain and irrigation water. They were also provided with a drain to remove excess water to facilitate anaerobic wet seeding. The plots were fertilized with farm yard manure, single super phosphate and zinc sulphate at the recommended dozes during field preparation. The monsoon rains were received from June 16, 2003. The rainfall received up to June 30 was 231 mm. With the rainfall and irrigation water, the plots were puddled and leveled and prepared for wet seeding. The puddling was done with a tractor fitted with cage wheels and leveling was done with an animal drawn planker. The pre-emergence weedicide (Butachlore) was sprayed in the plots with manual sprayer. The wet seeding was done with the drum seeder for the four varieties of paddy. These were Vandana & Kalinga-III of CRRI, Cuttack; IR-36 and Krishna Hamsa of Directorate of Rice Research,

Table 4 Plot-wise performance data of drum seeder trials conducted with pregerminated seeds of four varieties (2003)

Particulars	Plot I	Plot II	Plot III	Plot IV	Plot V	Plot VI	Plot VII	Plot VIII
Date of sowing	July 8, 2003	July 8, 2003	July 2, 2003	July 2, 2003	July 4, 2003	July 4, 2003	July 10, 2003	July 11, 2003
Variety	IR-36	IR-36	Vandana	Vandana	Krishna Hamsa	Krishna Hamsa	Kalinga-III	Kalinga-III
Area, sqm	190.12	184.24	185	175.6	188	176.5	198.85	196.8
Slot opening, mm	12	12	1	11	1	11	11	12
Seed sown, kg	4	4	2.4	2.3	2.4	2.3	2.5	3.1*
Seed rate, kg/ha	210	217	131	131	127.5	130.28	125.7	157.5
Time taken for sowing, min	46	52	50	50	50	30	60	50
Soil moisture, % (wb)	37	35	38	36	NA	NA	40	38
Field capacity, sqm/h	248	212.6	221.5	211	225.6	353.0	198.8	236

*Sown after 24 hours holding in refrigerator
Note for Plot VIII: Weight of 100 seeds, g: 3.5 (pre-germinated)

Fig. 10 View of plot established by drum seeder in the test plot

Fig. 11 Plant stand measured for Vandana variety after 20 days of sowing with srum seeder

Fig. 12 Plant stand for Kalinga III variety at CIAE Bhopal (20 DAS)
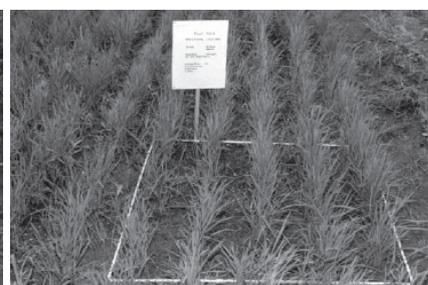
Hyderabad. These varieties were considered suitable for the local conditions. The sprouted seeds were prepared by soaking the clean seed for 24 hours in water, it was followed by an incubation of 16-20 h. Therefore, plots were prepared, leveled during the soaking of seeds and were allowed settlement period of overnight. They were finally leveled manually and excess water removed for anaerobic seeding. The wet seeding on eight plots was performed on July 3, 4, 8, 10 and 11, 2003 for the four varieties (**Figs. 9** and **10**).

The field observations such as date of sowing, area of plot, slot size opening, slot of the seeder drum, seed rate sown, time to cover the plot and soil moisture level were recorded. The heart beat rate of the operator was recorded at the beginning and end of the field operation. The plot wise performance date are given in **Table 4**. The plant stand values were collected from the different experimental plots after 14 to 20 days when the seedlings had attained the height of 15-20 cm. The sample plant stand in test plot is shown in **Figs. 11** and **12**. A square frame of 1 m size was used to count the plants along the row **Table 3**.

The four varieties planted with the developed drum seeder were harvested October 10 to October 20, 2003 at the time of their maturity. The variety Vandana and Kalinga-III were harvested October 10 and the varieties IR-36 and Krishna Hamsa were harvested October 20, 2004. The crop condition after 60 days of growth are shown in **Figs. 12**, **13** and **14**. The crop yield levels achieved are reported in **Table 6**. Only the crop Vandana which grew very well had lodging effect due to winds close to harvest time.

Physiological Load Studies

During the wet anaerobic seeding in the experimental plots, the physiological load on the operator was studied. For this, the walking speed of the operator in the wet field was measured. The force required to operate the seeder was 8 kgf. The average walking speed was 20 to 22 mpm. Thus, the operator with a two-row seeder, walking at speed of 20 mpm, would cover an area of 8 sqm/min at 100 % field efficiency. Normally time was lost in turning at the ends of fields due to minor adjustments, clearing of soil, etc. With a theoretical capacity of 8 sqm/min or 480 sqm/h the operator will be working at the rate of 8 kgf × 20 m/min = 160 kgf m/min or 2.67 kgf-m/sec. The plot of 200 sqm area could be covered in a period of 25 minutes at 100 % efficiency. It was decided to monitor the heart beat rate of operator as the measure of physiological load. Thus, at the start of operation and after he had covered the test plot the readings were taken. The Insta Pulse Monitor used for the trials is shown in **Fig. 15**. The operator was allowed to take different time intervals varying from 30 to 60 minutes to cover the plots. The values recorded for heart beat rates with Insta Pulse are reported in **Table 7**. From this the work rates performed by the operator were calculated. The actual work rate values waere maximum at 5.88 sqm/min and minimum at 3.31 sqm/min. Based on work data and the heart beat rates recorded, the recommended work rate for the operator was determined.

Based on the values of heart rate reading recorded for the operator, the safe working capacity was 3.31 sqm/min (198.6 sqm/h). The maximum working capacity was 5.88 sqm/min (352.8 sqm/h) and the allowable work capacity was 3.96 sqm/min (225.6 sqm/h). The safe working capacity was equal to 40 % theoretical maximum value.

Results and Discussions

The two row drum seeder design was refined to make it suitable for anaerobic seeding in the wet seed bed. The seed drum was provided with 17 slots of 10 × 20 mm size for each row. The slot openings were adjustable for controlling the seed rate. The seeder was able to drop the pregerminated seeds in a continuous row formed by the small furrow openers at the shallow depth like a wet seed drill. The sowing of seeds varied from 125 to 217 kg/ha. These high seed rates were achieved for a slot setting varying from 11 to 12 mm. To achieve the high plant stand in the field, the farmer normally sows the seed at high rates. The field observations on the plant stand measured after 20 days of sowing indicated that for IR-36 the plant stand was 500 plants/sqm at the seed rate of 215 kg/ha. Taking into account the 1000 pregerminated seed weight for IR-36 of 26.8 g, 62 % of the seeds sown were established. For the lower seed rate of 127 kg/ha the plant stand of 240 plants/sqm was achieved for the Krishna Hamsa variety. The high plant stand achieved in the test plots indicted the proper placement of seeds in the small ruts made by the furrow openers and proper coverage of seed

Fig. 13 Crop of Krishna Hamsa 56 days after sowing with drum seeder

Fig. 14 Kalinga-III crop after 53 days of sowing with drum seeder at CIAE Bhopal

with soft soil layer. The slot opening of 10 mm reduced the seed rate below 100 kg/ha rates. The seed rates increased rapidly as the slot opening was increased beyond 11 mm. This was because of fall of seeds from the number of slots. Thus, for sowing low seed rate, the setting of slot should be set at 10 mm opening. Thus, the pregerminated seeds at the desired depth and seed rate for proper establishment of crop were achieved.

The four varieties of paddy raised by the drum seeder were harvested on October 10 to October 20, 2004. The varieties Vandana and Kalinga-III were harvested on October 10 as they were ready for the harvest. The varieties Krishna Hamsa and IR-36 were harvested on October 20, 2004. The crop yield data are reported in **Table 6**. The moisture content at harvest was high and, therefore, the yield of crop was calculated in kg/ha on 10 % moisture content on dry basis for comparison purpose. Yields of Vandana was 2.822 tons/ha, Kalinga-III 4.064 tons/ha, Krishna Hamsa 3.73 tons/ha and IR-36 4.076 tons/ha. The grain yield of IR-36 and Kalainga were close to 4 tons/ha. The low yield of Vandana was due to lodging of crop. The crop growth for all the varieties was good. The rainfall received during the rain season was well distributed.

Based upon the plant stand and the crop yield obtained from the four varieties, the performance of the developed seeder was excellent from crop considerations.

Physiological Load Studies on Operator

In the wet puddled field, the developed drum seeder required an average pull of 8 kgf for its operation. The observation of speed of walking of operator in puddled field was 20 m/min. Thus, the operator had to work at the rate of 160 kgf-m/min or 2.66 kgf/sec for seeder operation. Working at this rate, the maximum field area covered with the two row drum seeder with 20 cm row spacing calculated was 8 sqm/min. The aim of designing the two row unit was to make it easy to operate in the field. The studies at Tamil Nadu agriculture University and other places indicated that 70 % of energy of worker was consumed in only walking in the puddled field. Hence, only a small portion of energy was left for performing the seeder pulling operation. With the limited instruments available, it was decided to monitor the heart beat rate of the operator to keep the work rate within the allowable limits. Normally, heart beat rates and oxygen consumption rates are monitored in physiological studies.

In field trials, the heart beat rate of the operator was measured with Insta Pulse Monitor. The heart beat rate was measured at the beginning of trial and at the end of trial. In the first trial operator was directed to cover the test plot with minimum inoperative time. Thus, he was able to cover the plot of area 176.5 sqm in the duration of 30 minutes. At the end of operation his heart bear rate was 155/160 beats/min and he was completely exhausted. Afterwards, he was allowed to operate the unit at slow walking speed. Thus time taken for four test plots were 50 minutes. The heart beat rate values of operator at the completion of these plots were close to 138-142 beats/min. In plot number VII, the time taken to cover an area of 198.8 sqm was 60 minutes. The heart beat rate value for operator was close to 108. The safe value of heart beat rate for operator to do physical work was considered as 112 beats/min. The allowable heart beat rate for a working operator is 140 for the physical activity. At the lowest value of heart beat rate of 108 beat/min, the work capacity was 3.31 sqm/min and at 140 beat/min the field coverage was 3.76 sq/min. The maximum work output of operator was 5.88 sqm/min. The theoretical maximum capacity calculated was 8 sqm/min. Therefore, the two row drum seeder, when operated at 3.31 sqm/min, was

Table 5 The plant stand observed in plots sown with two row drum seeder after 14 to 20 days of sowing (2003, CIAE-Bhopal)

Plot	Variety	Average plant stand, plant/m row length	Seed rate sown, r/m row length (calculated)
I	IR-36	105	4.2
II	IR-36	96	4.4
III	Vandana	57	2.6
IV	Vandana	61	2.6
V	Krishna Hamsa	48	2.55
VI	Krishna Hamsa	61	2.60
VII	Kalinga-III	76	2.51
VIII	Kalinga-III	84	3.15

Table 6 Crop yield data obtained from test plots sown by drum seeder (2003) at CIAE, Bhopal

Plot	Variety	Average plot yield g/sqm (at moisture content in %)	Yield calculated in kg/ha (@10 % m.c. (dry basis))
I	IR-36	508 (29)	4330
II	IR-36	438 (26)	3823
III	Vandana	262 (12)	2537
IV	Vandana	324 (16)	3072
V	Krishna Hamsa	(25)	3700
VI	Krishna Hamsa	432 (26)	3770
VII	Kalinga-III	480 (28)	4125
VIII	Kalinga-III	440 (22)	4003

under safe work load. For the short period or to overcome field variation, he can work with heart beat rates up to 140 beats/min or work output of 3.7 sqm/min. Thus, the average walking speed of the two-row drum seeder was 8-9 meters/min. The field efficiency at this rate of loading was 41 % of the theoretical value. This low value was because of energy consumed by the operator in moving in the wet field and overcoming the soil resistance. Thus, the small two row seeder can be considered within physiological loads of the operator.

Conclusion

A light weight, simple in design, easy to operate, low cost two row, pregerminated drum seeder of manually pull type was developed and evaluated at CIAE, Bhopal. The unit was able to sow the seeds in small ruts along the rows at a proper depth with seed rates of 127 to 215 kg/ha. At this seed rate the plant stand in the test plots were in the range of 240 to 505 per sq meter. The four varieties of paddy sown resulted in crop yields of 3 to 4 tons/ha which is close to the transplanted rice. The physiological load on the operator was measured in terms of increase in heart beat rate per minute. The operator was able to achieve a maximum of 70 % of field efficiency, at the heart beat rate of 155-160 beats/min. This rate the work was

considered as extremely heavy for the worker. The work rate of 41 % of maximum value was considered as safe at the increase in operator's heart beat rate values were within 40 beats/min. The two row drum seeder was useful for sowing of pregerminated seeds in small field plots by a single operator.

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Fig. 15 Insta Pulse Heart beat Monitor used for measuring the physiological load on the operator during operations

Table 8 Specification of Insta Pulse Heart-rate monitor

Type	Grasp type instrument for measuring electro cardiographic signals
Model	105
Weight	225 grams with battery
Size	38 × 230 mm
Make	Biosig Instrument, Canada

Table 7 The heart rate monitor readings of the operator while operating the drum seeder at different walk rates

Plot no.	Area of plot, sqm	Time taken to cover plot, mm	Actiral work rate sqm/min	Heart beat rate at the end of operation	Remarks
I	190.12	46	4.13	145	Heavy work
II	184.24	52	3.54	132	Medium work
III	185.4	50	3.70	138	Medium work
IV	175.6	50	3.51	132	Medium work rate
V	188.0	50	3.76	140	Medium work
VI	176.5	30	5.88	155/160	Extremely heavy work. Operator was tired
VII	198.85	60	3.31	108	Easy on the operator, ready to work for more time
VIII	196.8	50	3.93	142	Heavy work

Name of operator: Mr. Satish, Age of operator: 30 years, Weight of operator: 65 kg, Initial pulse rate: 72/73 beats/min

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Evaluation and Improvement in Design of Self Propelled Vertical Conveyer Reaper

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Abstract

Harvesting is one of the important operations of farming. As a step towards mechanization of harvesting operation for cereals, many alternatives are available to day. The self propelled vertical conveyor reaper is the best alternate in India because of crop straw requirement for animal feed and size of fields. The original IRRI design of self propelled vertical conveyer reaper was introduced in India for harvesting of cereal crops. However, due to inherent short comings like drudgery of operation and non suitability to handle/harvest taller fodder crops that increase the utility of reaper, the machine has not become popular among the Indian farmers.

In the year 1994 the original IRRI design reaper machine was tested on wheat, paddy and safflower crops. The following necessary scope of design improvements have been observed & suggested in order to make it more functional and cost effective: (i) Providing a power cut off mechanism for the harvesting unit. (ii)
Providing a reversing mechanism. (iii) Providing a lower horse power engine and (iv) Providing reduced width steel wheels and provision of attaching rubber tyre wheels when required. The improved reaper design was tested on cereal and fodder crops to increase utility. An adjustable third belt attachment has been fabricated for the reaper to improve conveying effectiveness for tall fodder crops (1.0 to 1.7 m). The shape of the un-cut crop divider, star wheels and row crop dividers (cover plates) was modified. The modified reaper was tested in crops like jowar, bajara, maize, safflower and wheat.

The modified machine worked very well for harvesting fodder crops like bajara & jowar of about 1.2 to 1.7 m, height. For the windrowing quality, it was observed that for fodder crops more then 80 % of the cut crop was laid satisfactorily. Thus, the improved machine can be used conveniently and effectively for harvesting of both fodder and cereal crops.

The cost of harvesting including the heap and bundle making reaper machine was Rs.590/-($13.11) per
hectare where as the cost of harvesting manually with a sickle was Rs.840/-($18.67) per hectare. Therefore, harvesting with the help of the vertical conveyer reaper resulted in an average savings of 30 %, which was Rs.250/($5.56) per hectare.

Introduction

Harvesting is one of the important operations of farming. This is a labour intensive seasonal operation consuming about 18-20 % of the labour required for growing cereal crops. The traditional method of harvesting with sickle is both labour as well as time consuming, where both are scarce during the peak harvesting season. As a step towards mechanization of the harvesting operation for cereal crops, the alternatives available were considered such as (1) Self propelled combine harvesters, (2) Tractor mounted combine harvesters, (3) Tractor front mounted vertical conveyer reaper, (4) Power tiller mounted vertical conveyer reaper and (5) Self propelled vertical conveyer reaper.

The use of combine harvesters mentioned above at No. (1) and (2) have their limitations. The farmers want to recover both grains as well as the straw from wheat and paddy crops, because the cost of straw is about 15-20 % of the grain from the same area. Moreover, the use of a big machine like tractor front mounted reapers are not preferred due to (i) large cutting width which required more labourers (ii) normally paddy field plots are smaller in size (iii) traction and compaction problems and (iv) poor visibility from operator's seat. Moreover, power tiller mounted reapers have not found wide applicability as the use of power tiller itself is limited in India.

The original IRRI design reaper was adopted to some extent in India, particularly for harvesting of cereal crops. Due to its inherent short comings like drudgery of operation and non-suitability to handle/harvest taller (fodder) crops, the machine does not become more popular among the farmers of India. It was required to modify the IRRI design reaper machine to increase the applicability and utility among the farmers.

Materials and Methods

The study Included evaluation of existing original IRRI design of self propelled vertical conveyer reaper for harvesting cereals as well as tall fodder crops. Further improvements and evaluation were required in the existing IRRI design reaper. The existing IRRI design reaper was purchased in March-1993, from M/S Fine fabrication, Bhopal (India). The same machine was tried on paddy, wheat and safflower crops at different locations and crops grown areas of Gujarat State. The field performance and cost analysis data of original IRRI design reaper are given in **Table 1**.

The working of the above machine was unsatisfactory and full of drudgery. In spite of favorable economic feasibility of introducing such a reaper machine in India, the following necessary scope of design improvements have been suggested by the department of farm engineering, GAU, Junagadh, during the year 1994-95, in order to make it more functional and cost effective: (i) Providing a power cut-off mechanism to harvesting unit; (ii) Providing a reverse gear facility; (iii) Matching of size of prime mover and the size of machine and (iv) Providing a reduced width of steel

Table 1 Field performance and cost analysis data of reaper (original IRRI design)

Particular, unit	Harvested crops		
	Paddy, Avg.	Wheat, Avg.	Safflower, Avg.
Condition of the crop			
Crop variety	Guj-17	GW-49/R-1553	Bhima
Width of row, m	0.15	0.15	0.10
Row spacing, m	0.45	0.45	0.60
Plant height (Avg.), m	1.00	0.77	0.81
Condition of the fields			
Location (Place)	Ahmedabad	Jetpur/Arnej	Arnej
Length, m	47.00	68.92	100.00
Width, m	16.50	39.18	25.00
Area, m^2	775.5	2,700	2,500
Labour cost			
No. of operator, M.D./ha	0.80	1.00	0.70
No. of helper, M.D./ha	0.80	1.00	0.70
No. of labourers (Reaper), M.D./ha	1.60	1.00	1.40
No. of labourers (Manually), M.D./ha	26	15	10
Labour cost of harvesting (Reaper), Rs./ha	152 ($3.38)	151 ($3.36)	133 ($2.96)
Labour cost of harvesting (Manual), Rs./ha	1,040 ($23.11)	600 ($13.33)	400 ($8.89)
Cost of harvesting (Reaper)			
Fixed cost, Rs./ha	5.81 ($0.13)	5.81 ($0.13)	5.81 ($0.13)
Variable cost, Rs./ha	32.79 ($0.73)	26.36 ($0.59)	31.89 ($30.71)
Net cost of harvesting (Reaper), Rs./ha	401 ($8.91)	411 ($9.13)	342 ($7.6)
Benefit, Rs./ha	639 ($14.2)	189 ($4.2)	58 ($1.29)
Field performace			
Date of test	Nov.-94	March-95	March-95
Actual operation, min	30	138	83
Time lost			
Turning, sec	280	645	388
Clogging etc., sec	60	96	478
Effective working width, m	0.80	0.80	1.20/0.90
E.F.C., ha/hr	0.155	0.130	0.180
Speed of machine, kmph	2.27	1.86	1.80
T.F.C., ha/hr	0.21	0.17	0.16/0.22
Field efficiency, %	76	75	111/83
Fuel consumption, lit/hr	0.510	0.320	0.350
Lubricant consumption, ml/hr	20	20	20
Estimated B.H.P.	2.40	1.26	1.40
Height of cut, m	0.15	0.15	0.13

Assumptions: (i) Cost of machine (Rs.): 36,000/-($800); (ii) Salvage value: 10 % of (i); (iii) Depreciation: 10 %; (iv) Interest (Avg.): 15.5 %; (v) Life of machine (Yrs.): 15; (vi) Repair and maintenance: 10 %; (vii) Annual use (hr): 900; (viii) Rte of fuel (Rs./lit.): 8.00 ($0.18); (a) Operator (Rs./day): 60.00 ($1.33); (b) Helper (Rs. /day): 50.00 ($1.11); (c) Labour (Rs./day): 40.00 ($0.89)

wheels and a provision for attaching rubber tyre wheels when required.

Most of the above research findings/recommendations of farm engineering department, GAU, Junagadh during the years 1994-2001 were adopted by one manufacturer in Gujarat (India). The improved design of vertical conveyer reaper was purchased during March-1998 and tested in cereals as well as tall fodder crops. The further following improvements and evaluation work have been carried out for improving the harvesting quality and field capacity of the above reaper machine.

Rubber Tyre Wheel in Place of Cage Wheel

Power tiller rubber tyre wheels (15.5 × 30.5 cm - 61.0 cm O.D.) were adopted to reduce vibrations, turning efforts and increasing field capacity of the machine. To maintain proper height of cutter bar and its angle with respect to vertical as necessitated by the adoption of power tiller conventional wheels, necessary changes in the framework were made. As a result, of several permutations and combinations of change of engine speed, cutter bar speed, an appropriate speed was determined.

Harvesting of Safflower and Fodder Crops

The original 'varadan' reaper (Two conveying belts) was designed to harvest and windrow cereal crops up to a height of about 0.7 m. Its performance in tall crops was unsatisfactory. At harvesting tall fodder crops, efforts have been made to successfully harvest and windrow safflower crop by one additional adjustable third conveying belt which was incorporated in the vertical conveyer reaper machine to improve conveying effectiveness in case of tall (fodder) crops.

As shown in **Fig. 1**, an adjustable third belt attachment was fabricated for 'Varadan' reaper. The third belt could be adjusted to handle tall crops of 1.0 to 1.7 m. In spite of best adjustments, the original vertical conveyer reaper with the third belt arrangement provided about 75 % plants unevenly laid in the windrow form for maize, bajara & jowar like fodder crops. Therefore, it was considered essential to make further design improvements in the conveying unit.

Improvements in Crop Cutting Devices

The shape of the original un-cut crop divider, star wheels and row crop dividers (cover plates) were changed as shown in **Figs. 1** and **2**.

The improved design was tested for harvesting of tall crops like jowar, bajara & safflower at Gujarat Agricultural University farm and nearby farmers field. It's cutting and conveying performance was compared with original IRRI design as given in **Table 2**.

For successful harvesting row crops like jowar, bajara and safflower were grown at row spacing of say 45 cm. The row crop dividers and star wheels unit should be adjusted in such a manner as the rows fall in between a pair of deflectors.

Fig. 1 Cutter head unit showing improved design for tall crops
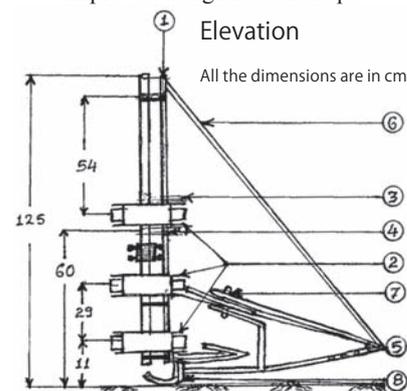
1: Vertical crop supporting platform, 2: Vertical conveyer belts (three), 3: Discharge plate, 4: Original crop supporting platform, 5: Row crop dividers (three), 6: Un-cut crop divider, 7: Star wheels (three), 8: Cutter bar bottom support (skid)

Table 2 Comparative field performance (windorowing quality) of the original and improved reaper machine

| Crop | Average windrowing percentage | | | |
| | Original design | | Improved design | |
	Satisfactory, %	Not-satisfactory, %/degree	Satisfactory, %	Not-satisfactory, %/degree
Jowar	32	68 (15-45)	78	22 (60-75)
Bajara	22	78 (15-40)	85	15 (55-70)
Maize	60	40 (15-40)	82	18 (60-75)
Safflower	15	85 (10-25)	55	45 (45-70)
Wheat	92	8 (65-70)	94	6 (70-75)

* Satisfactory means crop laid nearer to 90º w.r.t. the direction of travel.
* Not-satisfactory means crop laid with angle w.r.t. the direction of travel.
N.B.: Improved design means modified star wheels, row crop dividers and Un-cut crop divider

| Crop | Crop data | | | |
	Height, m	Stem diameter, mm	Row to row distance, cm	Plant population, Nos./sq.m
Jowar	1.00-2.10	05-07	45.0	267
Bajara	0.90-1.70	03-10	45.0	148
Maize	1.10-2.00	12-22	22.5	65
Safflower	0.60-0.71	06-14	60.0	12
Wheat	0.64-0.77	02-05	22.5	345

Fig. 2 Improved design of star wheel and row crop divider for tall crops
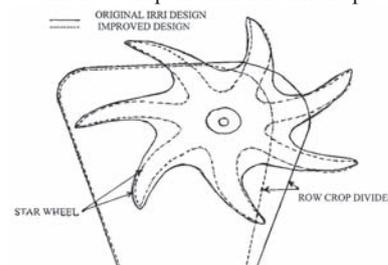
Windrowing Quality

The performance of the completely improved reaper machine (**Fig. 3**) has been tested in bajara, jowar, maize and wheat crops harvesting, the required data presented in **Table 3**.

Harvesting Cost Calculation:

The cost of the improved machine (**Plate 1**) was worked out as Rs.55,000/($1,222.22) (year-2001) including the original designed machine and improved attachments. The cost of operation was computed by the straight-line method.

Results and Discussion

Performance of Original IRRI Design Reaper

As seen from the **Table 1** the effec-

Fig. 3 Improved self propelled vertical conveyer reaper machine for cereals and tall fodder crops
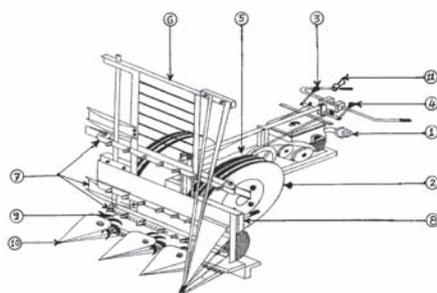
1: Petrol/Kerosene engine (3.1 hp), 2: Pneumatic tyre, 3: Power cut-off clutch, 4: Lever for reversing, 5: Gear box, 6: Vertical crop supporting platform, 7: Vertical conveyer belt (three), 8: Original crop supporting platform height, 9: Star wheels (three), 10. Row crop dividers (three), 11. Speed control lever

Plate 1 Improved self propelled vertical conveyer reaper machine for cereals and tall fodder crops

tive field capacity worked out for harvesting of paddy, wheat and safflower is 0.155, 0.130 and 0.180 hectare per hour, respectively. The maximum benefit of Rs.639/($14.2) per hectare has been found in paddy crop. While that of wheat and safflower it is Rs.189/($4.20) and 58/($1.29) per hectare respectively, significantly higher benefit was found in paddy particularly due to need of more manual labourers during manual harvesting of paddy and comparatively higher effective field capacity.

Benefit being in favour of harvesting with the reaper in view of non-availability of labourers during the harvesting seasons, there appears to be good scope of improvements in cutting and conveying units of vertical conveyer reaper for harvesting of cereals as well as fodder crops also, which increase the utility of above reaper machine.

Providing a Lower Horse Power Engine

The main expensive components of this machine was a 5.0 hp diesel engine. As seen from the **Table 1**, the average horsepower requirement from the reaper engine was found to be 2.40, 1.26 and 1.40 hp, for paddy wheat and safflower crops, respectively. This led to an important design

improvement in the reaper machine i.e. the size of engine would reduced, thus, reducing the cost of operation, because the cost of engine amounts to be nearly about 50 % of the total cost of complete reaper machine.

Reduced Width of Steel Wheels and Provision of Rubber Tyre Wheels on Harvesting

The results indicate that lower conveying speed of 0.73 m/sec is satisfactory for low-density crops. But same conveying speeds are not found suitable for high-density crops, as it resulted in chocking of crop at the cutting platform of the machine. At higher conveying speed, i.e. 1.57 to 1.95 m/sec. (50 to 70 % increase), there was unsatisfactory windrowing. Use of rubber tyre wheels not only resulted in reduction of vibration but it also made turning easy. It was also observed that the reduced width of steel wheels made turning easy, particularly in paddy field.

Effects of Cutting Unit Improvements:

As seen from the **Table 2** the modified designed resulted in less sideways deflection of the crop while approaching the cutter unit and, as such, the plants while being cut re-

Table 3 Comparative field performance (windorowing quality) of the improved reaper machine with original machine for fodder and cereal crops

Crop	Average windrowing percentage			
	Original design		Improved design	
	Satisfactory, %	Not-satisfactory, %/degree	Satisfactory, %	Not-satisfactory, %/degree
Jowar	53	47 (15-30)	84	16 (30-35)
Bajara	22	78 (60-70)	85	15 (20-25)
Maize	58	42 (25-40)	80	20 (45-50)
Wheat	92	8 (70-75)	94	6 (65-70)

* Satisfactory means crop laid nearer to 90º w.r.t. the direction of travel.
* Not-satisfactory means crop laid with angle w.r.t. the direction of travel.

Crop	Crop data			
	Height, m	Stem diameter, mm	Row to row distance, cm	Plant population, Nos./sq.m
Jowar	1.05-1.37	3-8	36.6	385
Bajara	0.94-1.60	3-10	40.5	165
Maize	1.00-1.50	10-25	36.6	225
Wheat	0.64-0.77	2-6	22.5	345

main almost vertical which are easily carried by the conveyer belt and smoothly deposited in the windrow. The windrowing quality obtained from the modified design is quite acceptable and this design is just able to handle tall crops successfully.

Effect of Improvements on Windrowing Quality

As seen from **Tables 2** and **3**, the improved star wheels accommodate more volume of cut crop since chocking occurrence was very low. The working of the improved row crop dividers (cover plates) and un-cut crop divider was also observed satisfactory in separating the working rows as well as un-cut crop portion, which resulted in better conveying and less chocking. The machine worked very well for harvesting of fodder crops like bajara and jowar that was about 1.2 to 1.7 m high. With respect to the windrowing quality for fodder crops, more than 80 % of the cut crop was laid satisfactorily. Thus, the improved machine can be used conveniently and effectively for harvesting of fodder and cereal crops.

The improvements made in the IRRI design have resulted in successful harvesting of fodder crops (**Table 3**). Also, the performance of the improved reaper for harvesting cereal (wheat) was the same as that of the original machine.

Harvesting Cost Analysis

Harvesting by Reaper Machine: The average field capacity was 1.86 hectares per day, with six labourers required to bundle and heap one hectare, along with one operator at Rs.100/($2.22) per day and one helper at Rs.60/($1.33) per day. The total cost of harvesting by reaper machine was Rs.590/($13.11) per hectare.

Manual Harvesting: Fourteen labourers per hectare were required to harvest, bundle and heap. The cost of harvesting by manual was Rs.840/($18.67) per hectare.

Therefore, harvesting with the improved vertical conveyer reaper resulted in a saving of 30 %, i.e. Rs.250/($5.56) per hectare as compared to manual harvesting. As a result of research work conducted during 1994 to 2001, the meeting of Agricultural Engineering Sub Committee, Gujarat (India, 2001-02) suggested the release of improvements carried out in the existing reaper machine for harvesting of cereals and tall fodder crops for the benefit of farmers and commercial exploitation.

Conclusions

1. The average horsepower requirement from the IRRI design reaper engine was found to be 2.40, 1.26 and 1.40 hp. for paddy, wheat and safflower crops respectively.
2. The reduced width of steel wheels made turning easy, particularly in the paddy field.
3. Use of rubber tyre wheels resulted in enhanced mobility, ease of handling, reduction in undulating vibration and made turning easy.
4. The provision of a cut-off mechanism was very useful, particularly when turning and saving the cutting unit from working without crop cutting time.
5. The provision of reversing mechanism useful particularly in chocking of crops and turning time.
6. The modified shape of un-cut crop divider, star wheels and row crop dividers (cover plates) resulted in less side ways deflection of crops, easier conveying and smooth depositing in the windrow.
7. The provision of an adjustable third belt attachment easily handles the tall fodder crops of 1.0 m to 1.7 m height.
8. The average field capacity of the improved machine was 1.86 ha/day.
9. The required cost of harvesting by machine comes to Rs.590/($13.11) per hectare (year-2001).
10. Harvesting with the reaper machine saves 30 % of cost, i.e. a saving of Rs.250/($5.56) per hectare as compared to manual harvesting (year-2001).

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Energy Requirement of Different Weed Management Practices for Aerobic Rice in India

by

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Abstract

An analysis of the energy requirements for the rice (Oryza sativa L.) was conducted at the Research farm of Project Directorate for Cropping Systems research, Modipuram, Meerut during the year of 2000-01 to 2003-04. Selected weed management practices: hand weeding twice, herbicides + one hand weeding, criss-cross sowing + one hand weeding, criss-cross sowing + herbicides + one hand weeding, unweeded check were subjected to aerobic rice crop to assess the energy use, out put energy obtained and net return of energy. Results revealed that the total input energy utilization in rice varied from 31,230.6 MJ/ha to 32,252.3 MJ/ha in unweeded check and criss-cross + herbicides + hand weeding, respectively. The energy use by irrigation represented the major part of total energy use, accounting about 47.6 percent followed by fertilizers about 32 percent in all treatments, where-as, machinery consumed from 11.5 to 12.5 percent of total input energy. Total amount of energy use in weed management varied from 1.18 to 2.88 percent of the total input energy. Hand weeding twice was more energy consuming than other treatments. This was followed by herbicides + hand weeding once as well as criss-cross sowing + herbicides + hand weeding once. The energy utilization for weed management was slightly higher in traditional seedbed as compared with stale seedbed.

The output energy in criss-cross sowing + herbicides + hand weeding once was from 83 to 89 percent higher than unweeded, 55 percent higher than criss-cross sowing + hand weeding once, from 9 to 13 percent higher than hand weeding twice and 4 percent higher than herbicides + hand weeding once. The net return energy, among five treatments, was found to be significantly high in criss-cross sowing + herbicides + hand weeding once (i.e. 51,043.5 MJ/ha in stale seedbed and 44,363.7 MJ/ha in traditional seedbed) than other treatments, which was statistically at par with treatment herbicides + hand weeding once (i.e. 47,789.6 MJ/ha in stale seedbed and 44,847.2 MJ/ha in traditional seedbed). This was followed by hand weeding twice (i.e. 40,806.6 MJ/ha in stale seedbed and 37,591.5 MJ/ha in traditional seedbed) and criss-cross sowing + hand weeding once (i.e. 6,214.9 MJ/ha in stale seedbed and 1,534.2 MJ/ha in traditional seedbed) which had significant difference in the same seedbed preparation. However, the unweeded treatment gave negative net return energy. So, without weed management, practices adopted will not able to get output energy.

Introduction

Energy consumption in Indian agriculture has been steadily increasing from 1953-54 onwards, recording a quantum jump between

1965-66 and 1975-76. In fact, modernization of agriculture has enhanced the energy consumption in different inputs used. It is invested in various forms such as mechanical (from machines, human labour, animal draft), chemical fertiliser, pesticides, herbicides), electrical, etc. It was realized that crop yields and food supplies are directly linked to energy (Stout, 1990). Bridges and Smith (1979) developed a method for determining the total energy input for agricultural practices. Numerous studies have been made to quantify energy consumption in agricultural production (Heslop and Bilanski, 1989; Ouellette-Babin, 1982; Swanton et al., 1996; Vinten-Johansen et al., 1990; Zentner et al., 1984, 1989; Zucchetto and Bickle, 1984).

The primary objectives of mechanizing crop production are to reduce human drudgery and to raise the output of farm by either increasing the yield per unit area or increasing the area under cultivation. These can only be done by supplementing the traditional energy input, i.e. human labour with substantial investments in farm machinery, irrigation equipment, fertilizers, soil and water conservation practices, weed management practices. These inputs and methods represent various energies that need to be evaluated so as ascertain their effectiveness and to know how to conserve them. Energy analysis, therefore, is necessary for efficient management of scarce resources for improved agricultural production. It would identify production practices that are economical and effective. Other benefits of energy analysis are to determine the energy invested in every step of the production process (hence identifying the steps that require least energy inputs), to provide a basis for conservation and to aid in making sound management and policy decisions. For example, proper management of weeds and operation of machinery or irrigation

pumps reduce input energy.

The rice is grown in a variety of practices such as transplanting, direct seeding in wet and dry bed. But in India, it is mainly grown by transplanting of seedlings under puddled field conditions which requires a huge amount of the input energy for the growing the seedlings, puddling, transplanting, weed management, irrigations, etc. Rice is the most staple food of millions of people throughout the world, more particularly in Asia. It is the major crop in India which covers about 40.5 M ha with production about 85 M tonnes. With the advancement in technology and general agricultural developments, the use of the energy resources has increased markedly. Under direct seeding in dry bed conditions, weeds are a major constraint to rice productivity because rice germinates almost simultaneously. Uncontrolled weeds reduce the rice yield up to 97 percent in the direct sown rice (Saxena and Vaishya, 1993). Direct seeded rice covers 26 and 28 percent of the total rice area in South Asia and India, respectively (Panday and Velasco, 1999). Thus, the energy aspects need to be analyzed for an appropriate weed control measures for controlling the weeds will be of

immense importance to the farming community.

The weed management in the rice crop is one of the major targets to get higher production to feed the increasing population. It is also difficult with aerobic rice. The information on energies of comparative use of different weed management practices is lacking. It is required, in order, to make deductions on the efficiencies of the energies and suggestions on which energy sources or their combinations need to be used and at what levels. In the present study, it is proposed to analyze agricultural energy utilization patterns and net return energy of rice from farm studies. The present study has been undertaken in order to compare different weed management practices adopted in aerobic rice production, using the satisfactory energy inputs and output.

Methodology

Site and Climate

The experiment was carried out at the Research farm of the Project Directorate for Cropping Systems Research, Modipuram, Meerut from

Table 1 Energy conversion factors used

Power source, units	Equivalent energy, MJ
Human labour (adult), man-hour	1.96
Diesel, L	56.31
Chemical fertilizers	
Nitrogen (N), kg	60.60
Phosphorus (P), kg	11.10
Potash (K), kg	6.70
Plant protection (superior)	
Granular chemical, kg	120
Liquid chemical, mL	0.102
Crop produce (grain)	
Rice, kg	14.70
Wheat, kg	15.70

Souce: Binning, A. S., B. S. Pathak, and Panesar (1983).

Table 2 Energy used in different weed management practice in rice-wheat cropping system, MJ/ha

Treat.	Rice		
	Herbicides	Manual	Total
a. Stale seedbed			
T_1	0.0	689.9	689.9
T_2	480.0	125.4	605.4
T_3	0.0	376.3	376.3
T_4	480.0	125.4	605.4
T_5	0.0	0.0	0.0
b. Traditional seedbed			
T_1	0.0	925.1	925.1
T_2	480.0	203.8	683.8
T_3	0.0	439.0	439.0
T_4	480.0	203.8	683.8
T_5	0.0	0.0	0.0

T_1: Hand weeding twice, T_2: Herbicides + hand weeding once, T_3: Criss cross sowing + hand weeding once, T_4: Criss cross sowing + herbicides + hand weeding once, T_5: Unweeded check

2000-01 to 2003-04. The site is located at 29.40º N latitude, 77.4º E longitude and at 237 m above mean sea level, and categorized as a hot-dry semi-arid subtropical climate with summers and severe cold winters. The mean annual rainfall of the site is about 837 mm and evapo-transpiration of 1,540 mm. The chemical and physical properties of soil are given as sandy loam consisting of 63.7, 19.1 and 17.2 percent sand, silt and clay, respectively. The soil pH, electrical conductivity, organic carbon, available P, available K, were 8.20, 0.47 dS/m, 0.37 percent 3.4 mg/kg and 35 mg/kg of soil.

Experimental Details

The experiment was designed to assess the energy use, out put energy and net return energy of different weed management practices adopted for rice crop. The rice (Oryza sativa L. cv. Pant-12) was grown in two seedbed preparation practices (i.e. stale seedbed and traditional seedbed) in main plot. Each main plot was divided into five sub-plots according weed management practices treatments, viz. hand weeding twice, herbicides + one hand weeding, criss-cross sowing + one hand weeding, criss-cross sowing + herbicides + one hand weeding, unweeded check. The crop was sown in line with 20 cm spacing at a seed rate of 60 kg/ha. In case of criss-cross sowing, the seed rate and line spacing in each side was the same. The treatments were replicated thrice in split-plot design. Each main plot was 12.5 m long by 6 m wide, and equally divided into 5 sub-plots using 6 m long by 2.5 m wide. The net area under experiment was 0.045 ha (consisting of 30 plots having 6 × 2.5 m size each). The data were analyzed in split-plot design as suggested by Panse and Sukhatme (1967).

The stale seedbed preparation for rice crop, after harvesting wheat in April, was irrigated once, two cross harrowing + one cultivator + one planking were performed, thereafter, the field was left for germination of weed seeds for about 15 days. After germination of weed seeds, the field was finally prepared by resorting by one shallow plowing with cultivator followed by planking. Whereas, in a traditional seed bed, at sowing time two harrowing + two cultivator + one planking were done to prepare a well pulverized seedbed. A uniform dose of fertilizer was applied at 37 kg N, 60 kg P and 60 kg K plus 20 kg Zn per ha as a basal dose and rest nitrogen in two spilts of 56.5 kg N doses at 25 days after sowing (DAS) and at 55-60 DAS was top dressed uniformly.

Weed management practices. Weeds were controlled with appropriate herbicides as required in rice crop and hand weeding according the treatments. Herbicide for pre-emergence weeds control included: (per ha) 4 L pendimethalin (Pendimethalin 35 % EC) was sprayed after 1-2 days after sowing (DAS) for rice. The first and second hand weeding was done at 25-30 DAS and 50-55 DAS crops according treatment.

Method of Energy Calculation

Evaluation of manual energy input: Manual energy was estimated based on conversion coefficient given in **Table 1**. The total manual labour was recorded in each operation with working hours which were converted into man-hours. All other factors affecting manual energy were neglected. Thus for a worker, the manual energy expended was determined by:

$$E_m = 1.96\ N_m\ T_m\ \text{MJ}$$

Where, N_m = Number of labour spent on a farm activity

T_m = Useful time spent by a labour on a farm activity, h

Evaluation of mechanical energy use: Mechanical energy input was evaluated by quantifying the amount of diesel fuel consumed during the tillage, sowing, threshing and winnowing, etc. The total time spent was also recorded. Diesel consumption was also recorded during irrigation for the irrigation pump. Hence, for every farm operation, the

Table 3 Level and pattern of energy use in different weed management practices adopted in rice crop, MJ/ha

Energy source	T_1	T_2	T_3	T_4	T_5	Mean
a. Stale seedbed						
Seed	882.0	882.0	882.0	882.0	882.0	882.0
Herbicides	0.0	480.0	0.0	480.0	0.0	192.0
Fertilizers	10,158.0	10,158.0	10,158.0	10,158.0	10,158.0	10,158.0
Insecticides & pesticides	511.4	511.4	511.4	511.4	511.4	511.4
Diesel (Irrigation)	15,203.7	15,203.7	15,203.7	15,203.7	15,203.7	15,203.7
Diesel (Machinery)	3,660.2	3,660.2	3,998.0	3,998.0	3,660.2	3,795.3
Human labour	1,505.3	940.8	1,191.7	940.8	815.4	1,078.8
Total energy	31,920.5	31,836.0	31,944.8	32,173.9	31,230.6	31,821.2
b. Traditional seedbed						
Seed	882.0	882.0	882.0	882.0	882.0	882.0
Herbicides	0.0	480.0	0.0	480.0	0.0	192.0
Fertilizers	10,158.0	10,158.0	10,158.0	10,158.0	10,158.0	10,158.0
Insecticides & pesticides	511.4	511.4	511.4	511.4	511.4	511.4
Diesel (Irrigation)	15,203.7	15,203.7	15,203.7	15,203.7	15,203.7	15,203.7
Diesel (Machinery)	3,660.2	3,660.2	3,998.0	3,998.0	3,660.2	3,795.3
Human labour	1,740.5	1,019.2	1,254.4	1,019.2	815.4	1,169.7
Total energy	32,155.7	31,914.4	32,007.5	32,252.3	31,230.6	31,912.1

T_1: Hand weeding twice, T_2: Herbicides + hand weeding once, T_3: Criss cross sowing + hand weeding once, T_4: Criss cross sowing + herbicides + hand weeding once, T_5: Unweeded check

diesel fuel energy input was determined by:

$$E_f = 56.31 \, D \, MJ$$

Where, 56.31 = unit energy value of diesel, MJL^{-1}

D = amount of diesel consumed, L

Other inputs: The inputs used for different operations under rice crop sequences were used for calculating energetics of systems. The energy use inputs were also calculated based on input-wise given source during crop period, namely, (i) seed, (ii) chemical fertilizers, (iii) herbicides, (iv) plant protection (insecticides/pesticides), (v) diesel (pump), (vi) diesel (machinery), (vii) human labour etc. The different field operations performed for completion of each activity in the experiment were measured in terms of time taken for human/machinery, fuel consumption and expressed as energy input in megajoules (MJ) using corresponding constants as detailed in **Table 1**. The farm production (i.e. grain yield) was also converted in terms of energy output (MJ) using four years average yield under rice-wheat crops and units of energy as available (Gopalan et al., 1978).

Results

Energy Utilization Pattern in Weed Management Practices

Total amount of energy use in weed management was varied from 1.18 to 2.88 percent of the total input energy. The traditional seedbed used higher energy for weed management, which varied from 11.55 to 25.41 percent as compared to stale seedbed in all treatments. It was due to the effect of tillage on weed germination. Among the five weed treatments, the hand weeding twice was found to be more energy consuming (i.e. 689.9MJ/ha in stale seed bed and 925.1 MJ/ha in traditional seedbed) than other treatments because it required a higher number of labours for twice

weeding. This was followed by herbicides + hand weeding once as well as criss-cross sowing + herbicides + hand weeding once which was 605.4 MJ/ha in stale seedbed and 683.8 MJ/ha in traditional seedbed. The least energy was consumed by criss-cross sowing + hand weeding once which was 376.3 MJ/ha in stale seedbed whereas 439.0 in traditional seedbed. For unweeded treatment, there was no weed management practices adopted with view of comparison of other treatments (**Table 2**).

For comparison of different weed management practices adopted, the manual labour for one hand weeding consumed 376.3 MJ/ha in stale seedbed and 439.0 MJ/ha in traditional seedbed, whereas, after herbicides were used, one hand weeding expended only 125.4 MJ/ha energy. This was due to higher weed density in the case of no use of herbicides plots and it was also higher in traditional seedbed. In stale seedbed, the seedbed was prepared in such way to maximize germinated weeds were destroyed before sowing of rice. This was one of the reasons for lower energy consumption for weed management in stale bed sowing rice than traditional bed. The herbicides consumed 480.0 MJ/ha energy for one spraying for controlling weeds. No weed management practices were adopted in the unweeded check treatment.

Input-Wise Energy Utilization Pattern

Energy inputs expressed in absolute terms (MJ/ha) for seed, fertilizer, insecticides and pesticides, irrigation were the same for both methods of seedbed preparations. This was because of the same seed rate, fertilizer, insecticides and pesticides and number of irrigations for all thirty plots. However, when expressed as total input energy used in rice, this varied from 31,230.6 MJ/ha to 32,252.3 MJ/ha in for treatments unweeded check and criss-cross + herbicides + hand weeding, respectively (**Table 3**). The variation in total input energy was due to different weed management practices adopted, machinery and herbicides and human labour.

For energy use in human labour, the maximum energy use was in hand weeding twice (i.e. 1,505.3 MJ/ha in stale seedbed and 1,740.5 MJ/ha in traditional seedbed) followed by criss-cross sowing + hand weeding once (i.e. 1,191.7 MJ/ha stale seedbed and 1,254.4 MJ/ha in traditional), criss-cross sowing + herbicides +hand weeding once (i.e. 940.8 MJ/ha in stale seedbed and 1,019.2 MJ/ha traditional seedbed) and herbicides +hand weeding once (i.e. 940.8 MJ/ha in stale seedbed and 1,019.2 MJ/ha traditional seedbed). The human labour energy shown was consumed not only in weeding but also other operations performed in the system. The un-

Table 4 Input and output energy of different weed management practice in aerobic rice

	T_1	T_2	T_3	T_4	T_5
a. Stale seedbed					
Input energy, MJ/ha	31,920.5	31,836.0	31,944.8	32,173.9	31,230.6
Output energy, MJ/ha	72,727.1	79,625.0	38,159.7	83,217.4	14,340.3
Output-input ration	2.3	2.5	1.2	2.6	0.5
b. Traditional seedbed					
Input energy, MJ/ha	32,155.7	31,914.4	32,007.5	32,252.3	31,230.6
Output energy, MJ/ha	69,747.2	76,761.8	33,541.7	76,616.0	82,63.9
Output-input ratio	2.2	2.4	1.0	2.4	0.3

T_1: Hand weeding twice, T_2: Herbicides + hand weeding once, T_3: Criss cross sowing + hand weeding once, T_4: Criss cross sowing + herbicides + hand weeding once, T_5: Unweeded check

weeded check consumed 815.4 MJ/ha as human labour energy in the both seedbed preparation which was used in different operations except weeding. The herbicides consumed about 480.0 MJ/ha energy in all treatments in both seedbeds. The energy used in machinery was found higher in criss-cross sowing (i.e. 3,998.0 MJ/ha) than normal sowing (i.e. 3,660.2 MJ/ha). It was because of higher machinery use during criss-cross sowing methods.

All other inputs used in the crop are the same in all treatments. The input energy in irrigation consumed was highest at 15,203.7 MJ/ha followed by 10,158.0 MJ/ha for chemical fertilizer, from 3,660.2 to 3,998.0 MJ/ha for machinery and 511.4 MJ/ha for insecticides and pesticides. The energy use by irrigation represented the major part of total energy use, accounting about 47.6 per cent followed by fertilizers, about 32 percent in all treatments (**Fig. 1**). Machinery consumed from 11.5 to 12.5 percent of total input energy of the system (Chaudhary et al., 2004 a and b).

Output Energy Pattern

The maximum output energy was obtained in treatment criss-cross sowing + herbicides + hand weeding once (i.e. 83,217.4 MJ/ha in stale seedbed and 76,616.0 MJ/ha in traditional seedbed) and almost equal output energy was obtained by herbicides + hand weeding once (i.e. 79,625.0 MJ/ha in stale seedbed and 76,761.8 MJ/ha in traditional seedbed) as detailed in **Table 4**. Hand weeding twice ranked third in obtaining output energy as 72,727.1 MJ/ha in stale seedbed and 69,747.2 MJ/ha in traditional seedbed. This was followed by criss-cross sowing + hand weeding once, which varied from 38,159.7 MJ/ha in stale seedbed to 33,541.7 MJ/ha in traditional seedbed. The unweeded check treatment produced the least amount of output energy which was 14,340.3 MJ/ha in stale seedbed and 8,263.9 MJ/ha in traditional seedbed (**Table 4** and **Fig. 2**). The criss-cross sowing + herbicides + hand weeding once gave from 83 to 89, 55, from 9 to 13 and 4 percent higher output energy as compared with unweeded, criss-cross sowing + hand weeding once, hand weeding twice and herbicides + hand weeding once, respectively.

The output-input ratio in the both cases of treatments as criss-cross sowing + herbicides + hand weeding once and herbicides + hand weeding once shown almost equal as 2.6 and 2.5, respectively. Whereas, the least output-input ratio was obtained by unweeded plot (i.e. 0.5). The criss-cross sowing + herbicides + hand weeding once was the most efficient weed management treatment in terms of energy output. The more efficient treatment was due to consuming low input energy and giving higher output energy.

Net Return Energy Pattern

The net return energy was significant with respect to weed management practices whereas seedbed preparation was non significant. The treatment criss-cross sowing + herbicides + hand weeding once (i.e. 47,703.6 MJ/ha) was the statistically at par with herbicides + hand weeding once (i.e. 46,318.2 MJ/ha) which were significantly higher than other treatments (**Table 5**). This was followed by hand weeding twice (i.e. 39,199.1 MJ/ha), which was significantly higher than criss-cross sowing + hand weeding once (i.e. 3,874.6 MJ/ha).

When comparison was made between weed management practices in each seedbed preparation of input and output energy, among five treatments, the net energy return of the system was found to be significantly high in criss-cross sowing + herbicides + hand weeding once (i.e. 51,043.5 MJ/ha in stale seedbed and 44,363.7 MJ/ha in traditional seedbed) than other treatments and which was statistically at par with treatment herbicides + hand weeding once (i.e. 47,789.0 MJ/ha in stale seedbed and 44,847.4 MJ/ha in traditional seedbed) as given in **Table 5**. This was followed by hand weeding twice (i.e. 40,806.6 MJ/ha in stale seedbed and 37,591.5 MJ/ha in traditional seedbed) and criss-cross sowing + hand weeding once (i.e. 6,214.9 MJ/ha in stale seedbed and 1,534.2 MJ/ha in traditional seed-

Fig. 1 Average input energy consumed in different inputs in aerobic rice crop in different seedbed

①Seed .... 3 %
②Herbicides........................ 1 %
③Fertilizers ....32 %
④Insecticides & Pesticides   2 %
⑤Diesel (Irrigation)   ....47 %
⑥Diesel (Machinery) ....12 %
⑦Human labour.................. 3 %
(a) Stale seedbed

①Seed .... 3 %
②Herbicides........................ 1 %
③Fertilizers ....31 %
④Insecticides & Pesticides   2 %
⑤Diesel (Irrigation)   ....47 %
⑥Diesel (Machinery) ....12 %
⑦Human labour .... 4 %
(b) Traditional seedbed
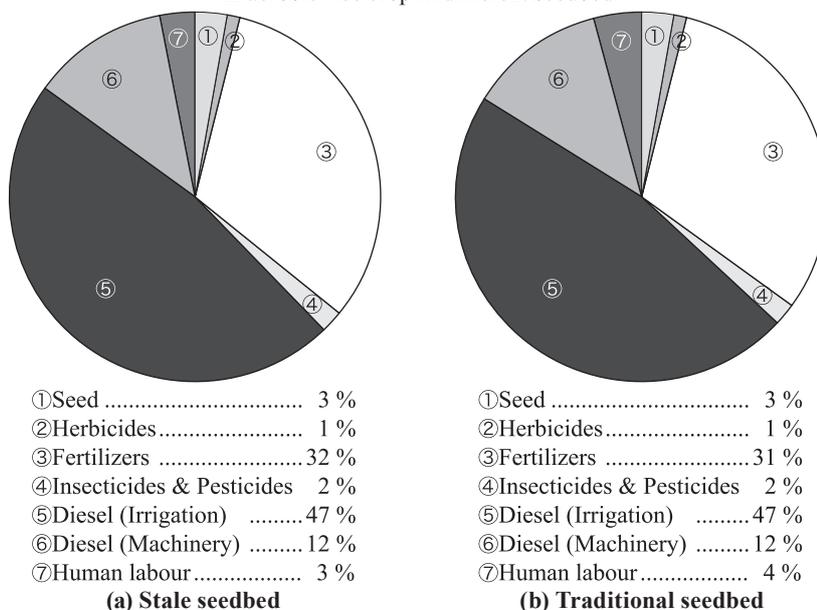
bed) which had significant difference in same seedbed preparation.

The net return energy in criss-cross sowing + herbicides + hand weeding once was from 86 to 95 percent higher than criss-cross sowing + hand weeding once, from 15 to 20 percent higher than hand weeding twice and 6 percent higher than herbicides + hand weeding once. However, the unweeded treatment gave negative net return energy, which means the output energy was less than input energy (**Fig. 2**). So, without weed management, practices adopted will not able to get output energy.

Discussions

It is seen from data (**Table 2**) that the hand weeding expended more energy than herbicides managements. Herbicides plus one hand weeding management spent somewhat less energy than hand weeding twice and it was the best weed management practice for aerobic rice crop. Hand weeding twice and herbicides plus one hand weeding expended almost same amount of input energy. Weeding by manual labour was a very tedious and difficult job and due to shortage of labour at weeding time because of

industrial employment. This was one reason for selecting chemical for weeds control. Pendimethalin was used as pre-emergence herbicide to reduce the germination of weeds and resulted in less energy (i.e. 125.4 in stale seedbed and 203.8 MJ/ha in traditional seedbed) consumed in one hand weeding as compared to hand weeding twice. For criss-cross sowing of rice plus one hand weeding the energy was halved as compared to other treatments (**Table 2**). In this method, the rice was sown in criss-cross manner, which resulted in less density of weeds and caused lower energy to be used in one hand weeding (i.e. 376.3 in stale seedbed and 439.0 MJ/ha in traditional seedbed). After herbicide use, weed population was reduced and resulted in less energy spent for one hand weeding (i.e. 125.4 MJ/ha as compared to 376.3 MJ/ha which is almost three time higher). The criss-cross sowing + herbicides + one hand weeding was the best treatment for complete weed management.

In unweeded check, where there were no weed management practices, the weeds grew more vigorously and rapidly than rice growth, which caused suppressed rice growth. At the time of the second hand weeding, the whole rice crop was cov-

ered and ultimately resulted in only weeds being seen in the field. It is worthy to say that both herbicides plus one manual weeding is advisable for both methods of sowing rice as stale and traditional seedbed.

The highest energy input for rice crop, with irrigation was from the diesel used in the irrigation pump (about 47.6 percent) (**Table 3**), and second highest energy input was from inorganic fertilizers, which had consumed about 32 percent. This was also found by Chaudhary et al. (2004 a and b). Energy use is the conversion of fossil fuels into diesel and fertilizers which has higher conversion coefficient and was supported by Stout (1984). Energy inputs expressed in absolute terms (MJ/ha) for seed, fertilizer, insecticides and pesticides, irrigation were the same for both methods of seedbed preparations in all treatments except labour, machinery and herbicides.

Maximum output energy was found to be in criss-cross + herbicides + hand weeding once as well as herbicides + hand weeding once (**Table 4**). This was because of better management of weeds by both herbicides and manual labour. However, hand weeding twice also gave good weed management but it was done by only two manual weeding.

Fig. 2 Input, output and net return energy pattern of different weed management practices in different seedbed
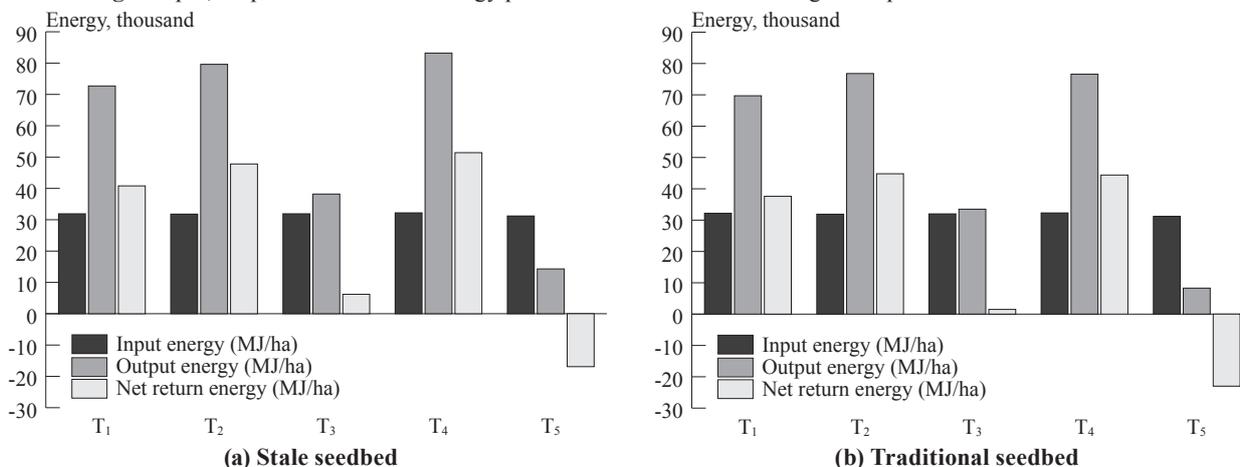
(a) Stale seedbed

(b) Traditional seedbed

T$_1$: Hand weeding twice, T$_2$: Herbicides + hand weeding once, T$_3$: Criss cross sowing + hand weeding once, T$_4$: Criss cross sowing + herbicides + hand weeding once, T$_5$: Unweeded check

It gave 9 to 13 percent lower output energy than the maximum gained energy because weeds were left during hand weeding. The criss-cross + hand weeding once gave 55 percent less output energy than the maximum, i.e. criss-cross + herbicides + hand weeding once (**Table 4**). Hand weeding once was not sufficient to complete weed management for aerobic rice. The unweeded treatment gave 83 to 89 percent less output energy than the maximum. So, output results were totally dependent on weed management practices, which consumed only 1.38 percent of total input energy for the best weed management treatment in the aerobic rice crop (Abu-Hamdes, 2003).

The net return energy obtained was statistically the same for criss-cross sowing + herbicides + hand weeding once and herbicides + hand weeding once in both seedbed preparations (**Table 5**). This was because of weed management was done by both as herbicide and manual labour which resulted higher yield and because there was little difference in input energy among different treatments. It is clear (**Table 5**) that criss-cross sowing + herbicides + hand weeding once produced about 95 percent higher net return energy than criss-cross sowing + hand weeding once. This was because of less weed management in case of one hand weeding. Also, output energy was about 55 percent higher in criss-cross sowing + herbicides + hand weeding than criss-cross sow-

ing + hand weeding once (**Table 4**).

Conclusions

It may be concluded that the net energy return of different weed management practices in aerobic rice can be quantified and stratified for sound planning of increasing productivity. In the present investigation, among five weed management treatments, the criss-cross sowing + herbicides + hand weeding once as well as herbicides + hand weeding once gave the highest energy gained as compared to other treatments. Unweeded treatment cannot be used without weed management.

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Table 5 Net return energy of different weed management practices in aerobic rice

	Hand weeding twice	Herbicides + hand weeding once	Criss-cross sowing + hand weeding once	Criss-cross sowing + herbicedes + hand weeding once	Unweeded	Mean
Stale seedbed	40,806.6	47,789.0	6,214.9	51,043.5	-16,890.3	25,792.7
Traditional seedbed	37,591.5	44,847.4	1,534.2	44,363.7	-22,966.7	21,074.0
Mean	39,199.1	46,318.2	3,874.6	47,703.6	-19,928.5	23,433.4
Main plot (Seedbed)	7,872.4					
Sub-plot (Weed management)	2,942.3					
Intraction (1)	4,161.0					
Intraction (2)	8,257.2					

Intraction (1): For comparing two weed management practice for same main plot, Intraction (2): For comparing two main plots at same or different weed management

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Effect of Selected Parameters on the Performance of a Semi-automatic Vegetable Transplanter

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Abstract

Studies were conducted on a two-row semi-automatic vegetable transplanter to assess its performance at different speeds, soil moistures and seedlings ages with respect to plants missing, planting angle, planting depth, plants in lying down position and plant mortality for two vegetable crops viz. tomato and chilli. Best transplanting results were obtained at 10 percent soil moisture content with 5-week seedlings in tomato and 17 to 19 weeks seedlings in chilli crop. The machine could be operated at 1.0 km/h and 1.2 km/h speed with missing of 3 to 4 percent. Labour and time saving of about 70 to 75 percent and 75 to 78 percent was obtained with the machine over manual transplanting.

Introduction

India is the second largest producer of vegetables in the world next to China with a production of 90.8 million tones from an area of 6.0 million hectares. However, in India, transplanting of vegetable seedlings is done manually allover the country, as no machine is yet available for this work. Transplanting of seedlings manually is very tiresome and labour consuming as the operation is done in a bending posture. High labour requirement and shortage of labour during peak transplanting season causes delay in transplanting and affects timely operation.

In developed countries like USA, China, Holland, Japan and Canada, transplanting of vegetable seedlings is done with mechanical transplanters. Transplanters used for bare root seedlings mostly have finger type metering mechanism. Many research workers have reported the development of semiautomatic transplanters with multiple loading stations features, which significantly increased the operator's plant loading capacity and reduced plants missing at higher speeds (Suggs, 1979; Dooley, 1983; Hsieh 1989; Way et al., 1987). However, no such commercial transplanter is available in the market (Anonymous b 2002). The tendency of operators to commit errors in feeding the seedlings in a repetitive loading operation increased in an exponential manner with the increase in speed and the operators tend to commit errors even at very slow feeding rate of 45 plant/min (Splinter, W. E. et al., 1968). With two operators feeding seedlings per row missing reduced from 10.6 to 3.1 percent at a feeding rate of 68 plant/min; however, interference between the operators while feeding reduced the potential feeding rate (Suggs, 1979). Hernandez et al. (1996) evaluated a mechanical transplanter in loam soil at moisture content of 18-30 percent with cabbage seedlings. Results showed that out of the total seedlings transplanted, 18.4 percent remained well placed, 37.1 percent remained inclined, and 44 percent remained unplanted. The low transplanting quality was attributed to the high soil moisture content.

In India, some attempts have been made in the recent years to develop semi-automatic vegetable transplanters for adoption under our conditions. Chaudhari et al. (2001) evaluated two imported models of vegetable transplanters and reported that the imported machines were very costly, had high power requirements and during transplanting plants were found in lying down positions where soil was moist or seedlings were small. Garg et al. (2002) reported the development and evaluation of a single row semi-automatic transplanter with cone type metering mechanism. The cost of transplanting with the machine was higher than manual transplanting due to low capacity of the machine. It also required a special type of seedlings with soil on roots. Therefore, a two-row semi-automatic transplanter was developed with finger type metering and planting mechanism to suit traditional bare root seedlings. However, optimum soil moisture, seedling age and speed at which transplanting should be done to have better ma-

chine performance was not known. Therefore, research studies were conducted to study the effect of these parameters on the performance of the semi-automatic vegetable transplanter and compare with the traditional system of manual transplanting.

Materials and Methods

Brief Description of the Machine

The two row vegetable transplanter used in the study consisted of a frame, two lugged wheels, seedling trays, seat for the operators, furrow openers, compaction wheels, finger guide tunnel, finger type metering mechanism and a water tank. Picking fingers had spring mounted rubber flappers, which opened before passing through the tunnel and closed during its passage. Again the flappers opened at the bottom end of the tunnel to release the seedlings in a furrow. The inclined wheels compacted the soil around the seedlings. Power from the ground wheel shaft was supplied to the planting mechanism through chain and sprockets. The plant spacing obtained with the machine was 30 cm but provision was there to change the plant spacing by changing the sprockets or number of fingers. Provision was made to apply a small quantity of water to the plants soon after transplanting by the watering system. A furrow shaper was provided to maintain the shape of the channel between the two transplanting beds, which facilitates uniform flow of water during subsequent irrigation. Stationary view of the machine is shown in **Fig. 1** showing different components and a brief specification of the machine is given in **Table 1**.

Evaluation Procedure

Initially the machine was calibrated in the laboratory for plants missing at different machine travel speed with both one and two operators feeding seedlings and the proper speed of operation was selected. Then the

machine was evaluated in the field at three levels of soil moisture content of 14 percent, 10 percent and 6 percent and three levels of seedling age of 4, 5 and 6 weeks for tomato crop and 15, 17, and 19 weeks for chilli crop as per recommended agronomic practice [2]. The field experiments were planned with a split-plot design with soil moisture content as the main factor and seedling age as the sub-main factor with three replications of each factor combination.

Calibration of the Machine in Laboratory

The laboratory calibration set up consisted of a 5 hp electric motor, a speed reduction gearbox and a belt and pulley type variable speed drive (**Fig. 2**). The machine travel speed was varied by varying the rpm of the of the ground wheel shaft by changing pulleys or adjustments in the variable speed drive. The operator was given fifty seedlings of 15-20 cm length for feeding in to the picking forks. For chilli crop, alternate fingers were removed so as to double the plant spacing as chilly seedlings are transplanted at plant spacing double that of the tomato seedlings. The operators were given

fifty seedlings to feed in to the fingers in each experiment and missing was noted. Doubles were almost negligible. Therefore, percentage plant missing was then calculated by using the following formula.

Plant missing (percent) = $M / (50 + M) \times 100$

Where,

M = Number of missing

50 + M = Total number of fingers that passed before the operator while feeding the 50 seedlings

Field Evaluation

Nursery of tomato and chilli crops was grown on raised beds in the traditional method as per recommended agronomic practice (Anonymous a, 2002). Seedling age was varied by sowing in nursery at nine different dates. The detail of the general seedling characteristics is presented in **Table 2**. The field was irrigated and prepared at 16-18 percent soil moisture content and then periodical checking of soil samples was done to attain the desired level of soil moisture. Transplanting was first done at 14 percent moisture content. The field was prepared by two tiller operations followed by two planking. Transplanting beds were made

Table 1 Brief specifications of the vegetable transplanter

Particulars	Specifications
General	
No. of rows	Two
Row spacing, cm	67
Plant spacing, cm	30, can be adjested by changing sprockets or no. of fingers
Power source	35 hp tractor
Over all dimensions, cm	185 × 170 × 120 (L × W × H)
Metering mechanism	
Type	Finger type
Power transmission	From lugged ground wheel by chain and sprocket drive
No. of fingers/row	10
Furrow opener	Runner type with depth adjustments
Soil compacting unit	at 15º with vertical
Watering systems	
Tank capacity, liters	140
Water flow regulation	Guide valve provided
Watering arrangement	Two showers fitted on a iron pipe
Furrow shaper	
Dimensions, cm	38 × 38 × 17 (L × W × H)
Furrow cross-section	Trapezoidal

with a tractor operated bed planter developed in the department. The tractor speed was set at the desired level by adjusting the hand throttle and gear position. Transplanting was then carried out at this constant speed with seedlings of different age. Similarly, transplanting was carried out after 2-3 days interval as the soil moisture reached to the desired levels of 10 percent and 6 percent. A view of the machine in operation is shown in **Fig. 3**. The procedures adopted for measurement of the various performance parameters are described below.

Planting Angle and Planting Depth

Planting angle is the angle of inclination of the plant with the vertical. The plants having planting angles of 0 to 30° were considered as likely to produce upright plants (Boa, W., 1984). Planting angle was measured for fifteen seedlings in each plot. Planting depth is the length of seedlings under the soil. Planting depth was measured for fifteen plants in each plot.

Plant Missing and Lying Down Plants

Plants missing, out of 100 hills in tomato and 50 hills in chilli crop were noted and the percentage-missing hills were calculated. Similarly, percentage plants in lying down position were calculated. Plants angled at less than 30° with the horizontal plane were considered lying down.

Plant Mortality

For plant mortality, number of seedlings transplanted and survived after 20 days of transplanting in fifteen-meter row length was noted at three different locations in each experimental plot and percentage plant mortality was calculated.

Draft and Fuel Consumption

Draft requirement of the transplanter was measured in the field according to the standard test procedure using a spring type dynamometer and two tractors (Anonymous, 1983). For precise measurement of fuel consumption, an auxiliary one-liter fuel tank was mounted on the tractor because of small size of experimental plots.

Compaction of Soil Around the Plant

Soil compaction around the plant was assessed by measuring the bulk density and cone index of soil after transplanting. For measuring bulk density, samples of soil compacted around the plant roots were collected with the help of a core sampler and then oven dried. Bulk density was calculated on dry weight basis and expressed in gm/cc. Cone index at 100 mm depth of penetration was measured by using a standard proving ring cone penetrometer.

Results and Discussion

Plant Missing

Laboratory calibration results of the machine indicated that plants

Table 2 General seedling and soil characteristics

Particulars	Tomato	Chilli
Variety	Punjab Upma	Suryamukhi
Age of seedlings, weeks	4, 5 and 6	15, 17 and 19
Height of seedlings, cm	14.3, 18.6 and 23.4	15.1, 19.5 and 24.9
Avg. number of leaves per plant	7.6, 16.4 and 21.3	4.7, 11.8 and 16.2
Soil type	Sandy loam	Sandy loam

Table 3 Results of machine calibration in laboratory

Machine speed, km/h	Plant missing tomato, operators/row		Plant missing chilli, operators/row	
	One	Two	One	Two
0.6	1.97	0.07	Nil	Nil
0.8	4.13	2.67	Nil	Nil
1.0	6.19	3.13	1.67	0.63
1.2	34.79	10.23	2.54	1.63
1.4	44.39	13.42	5.67	3.26
1.6	52.13	17.37	7.39	4.17

Fig. 1 Stationary view of vegetable transplanter

Fig. 2 Set-up for laboratory experiments
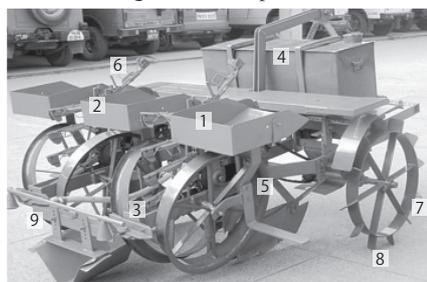
1: Seedling tray, 2: Seat, 3: Furrow opener, 4: Picking fingers, 5: Compaction wheels, 6: Water tank, 7: Shower, 8: Furrow shaper, 9: Ground drive wheel
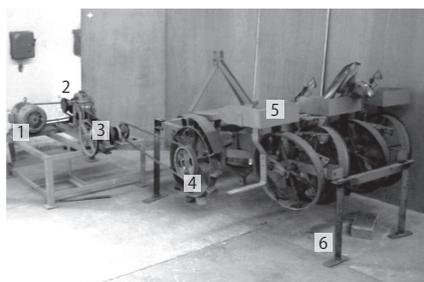
1: Electric motor, 2: Speed reduction gearbox, 3: Variable speed drive, 4: Drive pulley to the ground wheel, 5: Vegetable transplanter, 6: Jack-up stand

Fig. 3 A view of the vegetable transplanter in operation
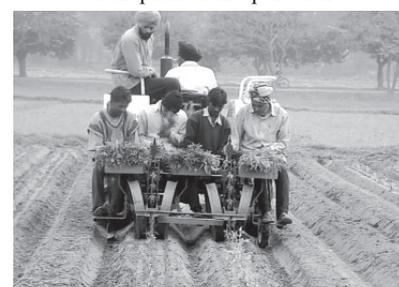
missing increased with the increase in the machine speed and reduced considerably with two operators as compared to one operator per row (**Table 3**). Plants missing up to of 3-4 percent was considered acceptable because of high productivity of these crops. It was found that plant missing was well within the acceptable limit of 3-4 percent at 1.0 km/h and 1.2 km/h with two operators feeding seedlings per row. Plants missing in the field was higher for smaller age seedlings, i.e. 4 weeks in tomato and 15 weeks in chilli crop, which was due to the difficulty faced by the operators in separating individual smaller seedlings while feeding in to the picking fingers. Plants missing in the field was found to be in the range of 3.50 to 8.11 percent at an average speed of 1.0 km/h in tomato crop and 1.97 to 4.00 percent at an average speed of 1.2 km/h in chilli crop respectively (**Tables 4** and **5**).

Lying Down Plants and Plant Mortality

Plants in lying down position and plant mortality were lower at 10 percent soil moisture content and at seedling age of 5 weeks in tomato and 19 weeks in chilli crop. Plants in lying down position varied from 3.36 to 6.11 percent in tomato crop and from 2.33 to 5.46 percent in chilli crop. The average plant mortality varied from 4.94 to 9.11 percent in tomato crop and 5.31 to 8.46 percent in chilli crop. The average plant mortality in mechanical transplanting, except incase of smaller age seedlings, was not significantly higher at 5 percent level of significance as compared to the plant mortality in case of manual transplanting, which was found to be 9.40 percent for tomato crop and 8.08 percent for chilli crop. The similar effects of soil moisture content and seedling age on plants in lying down position and plant mortality was due to the fact that the lying down plants died later during subsequent irrigations and intercultural operations.

Compaction of soil around the plant roots, as indicated by bulk density and cone index, decreased with the increase in the soil moisture content. However, the results indicated that the soil compaction was satisfactory at 10 percent soil moisture as at this moisture level the lying down plants and plant mortality was lowest.

Upright Plants and Planting Depth

Percentage of upright plants were highest at soil moisture content of 10 percent and seedling age of 5 weeks and 15 weeks for tomato and chilli crops, respectively, than at other soil moisture content and seedling age. The percentage of upright plants varied from 84.4 to 95.6 percent and 82.2 to 97.8 percent depending on the soil moisture and seedling age. Lower percentage of upright plant at higher moisture content was due to lesser soil flow towards the planting furrow, which resulted in poor soil coverage. On the other hand, at lower moisture content of 6 percent there was closing of the planting furrow before the plants were released due to excessive soil flow. Planting depth increased with increase in soil moisture content and seedling age. The average depth of planting varied from 2.33 to 5.32 cm in tomato crop and 2.31 to 5.16 cm in chilli crop. However planting depth at 6 percent soil moisture content and seedling age of 4 weeks and 15 weeks for tomato and chilli crops were found very low.

Machine Performance

Average field capacity of the machine was found to be 0.09 ha/h and 0.12 ha/h with corresponding field efficiencies of 71.5 percent and 67.2 percent at a machine speed of 1.0 km/h and 1.2 km/h respectively. The average fuel consumption and draft requirement of the machine varied from 31.4 to 24.9 l/ha and 28.6 to 29.2 N respectively (**Table 6**). The comparison between mechanical and manual transplanting is presented in **Table 7**. The labour requirement in transplanting with the machine was 55.6 to 64.6 man-h/ha while it was 184.7 to 253 man-h/ha in manual transplanting. However, the cost of transplanting was almost similar in both these cases. The cost of transplanting with the machine was 52.4

Table 4 Transplanting results at different soil moisture and seedling age in tomato crop

Parameters	M_1			M_2			M_3		
	A_1	A_2	A_3	A_1	A_2	A_3	A_1	A_2	A_3
Plant missing, %	6.67	3.50	4.00	7.67	4.44	4.45	8.11	4.00	4.22
Upright plants, %	88.8	93.3	86.6	93.3	95.6	91.1	86.7	91.1	84.4
Planting depth, cm	2.76	3.89	5.32	2.52	3.63	4.76	2.33	3.41	4.53
Lying down plants, %	6.11	3.73	4.89	5.34	3.36	4.16	5.73	3.54	4.67
Plant mortality, %	9.11	5.86	6.41	7.93	4.49	5.76	8.56	5.43	6.23
Bulk density, g/cc	1.14	1.16	1.12	1.24	1.26	1.27	1.35	1.36	1.32
Cone index, KPa	193	132	133	141	139	141	151	154	149

Table 5 Transplanting results at different soil moisture and seedling age in chilli crop

Parameters	M_1			M_2			M_3		
	A_1	A_2	A_3	A_1	A_2	A_3	A_1	A_2	A_3
Plant missing, %	3.56	3.11	2.66	4.00	2.21	3.34	3.34	2.23	1.97
Upright plants, %	93.3	95.6	88.9	93.3	97.8	91.1	91.1	93.3	82.2
Planting depth, cm	2.97	4.39	5.16	2.73	3.68	4.74	2.31	3.54	4.56
Lying down plants, %	5.46	3.45	2.47	3.76	2.97	2.23	4.35	3.13	2.58
Plant mortality, %	8.46	6.42	5.67	6.67	5.87	5.43	7.34	6.21	5.31
Bulk density, g/cc	1.14	1.16	1.12	1.24	1.26	1.27	1.35	1.36	1.32
Cone index, KPa	193	132	133	141	139	141	151	154	149

M: Soil moisture content (M_1 = 14 %, M_2 = 10 %, M_3 = 6 %)
A: Seedling age (A_1 = 4 weeks, A_2 = 5 weeks, A_3 = 6 weeks)

$/ha in tomato crop and 45.7 $/ha in chilli crop while in manual transplanting it were 57.5 $/ha in tomato crop and 42.0 $/ha in chilli crop.

Conclusions

1. Plants missing was within the acceptable limit of 3-4 percent at an average machine travel speed of 1.0 to 1.2 km/h with two operators feeding seedlings per row. With two operators per row the plant missing reduced considerably as compared to one operator per row but not to the desired extent, which was due to interference between the operators while feeding seedlings. It was found that the operators tend to skip in feeding even at lower speeds of operation. Plant missing was significantly affected by the seedling quality and missing was higher in case of smaller seedlings of lower age, which was due to the difficulty faced by the operators in separating individual seedlings while feeding.

2. Machine performance with respect to plant missing, lying down plants, upright plants and plant mortality was found better at 10 percent soil moisture with medium age seedlings of

5 weeks for tomato and 17-19 weeks for chilli crop.

3. There was labour saving of about 70 to 75 percent and time saving of 75 to 78 percent by transplanting with the machine over manual transplanting. However, the cost of transplanting with the machine was almost similar to the cost of manual transplanting. This was due to lower speed of operation and machine capacity. Average field capacity of the machine was found to be 0.09 ha/h and 0.12 ha/h with corresponding field efficiencies of 71.5 percent and 67.2 percent at a machine speed of 1.0 km/h and 1.2 km/h respectively.

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Table 6 Field performance results of the vegetable transplanter

Particulars	Tomato crop	Chilli crop
Speed of operation, m/s	0.27	0.33
Fuel consumption, l/ha	31.4	24.9
Time requirement, h/ha	10.8	9.4
Field capacity, ha/h	0.09	0.12
Field efficiency, %	71.5	67.2
Draft, N	28.6	29.2

Table 7 Comparison between mechanical and manual transplanting

Particulars	Tomato crop		Chilli crop	
	Mechanical	Manual	Mechanical	Manual
Plant mortality, %	4.94	9.40	5.65	8.08
Labour requirement, Man-h/ha	64.6	253.03	55.6	184.7
Cost of transplanting, US $/ha	52.4	57.5	45.7	42.0
Time requirement, h/ha	10.8	50.6	9.4	36.9

Design and Construction of the Airtight Ferrocement Bin for On-farm Storage of Paddy

by

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Abstract

A hermetically sealed ferrocement bin was conceived by application of a systematic design process. It consisted of a frustum of a cone with a conical bottom supported by three vertical columns with V-shaped cross-section. A labour and material saving model was developed to contain 2.5 tons of paddy. After detailed designing of the bin, it was constructed and the actual cost incurred was investigated before introducing to the farmer who requires this type of bin for on-farm storage of paddy.

Introduction

Production of paddy is highly seasonal and consumption of rice is almost uniform throughout the year. Therefore, the excess paddy has to be preserved for use in the off-season. At present, paddy is stored either in bags or in bulk. The 'Bissa', an indigenous storage bin, made of clay and reinforced with wooden sticks was the typical outdoor storage method used in the past (Palipane, 1978), but these bins are not in use at present due to shortage of raw material as well as difficulties in handling of paddy. Storing in jute bags, woven polypropylene sacks and wooden boxes are the most popular methods to store paddy at farm level. Since the grain is exposed to insects, pests, rodents, birds and highly moist environment, damage to paddy during storage is unavoidable.

Past studies showed that insects causes the major loss to the grain during storage, amounting up to over 6 % as storage loss (Sartaj and Ekanayake, 1991). Under tropical climatic conditions, where high temperature with high humidity is prevailing throughout the year, hermetically sealed storage has proven to be one of the most effective storage systems for our country as reported by De Lima, 1990. Although modern and efficient storage systems are available at the commercial level, there is a necessity to have cost effective efficient storage system for on-farm storage in order to enable the farmers to keep their paddy and sell it in the off-season at a higher price.

Considering various storage systems, an airtight ferrocement bin was conceptualised adopting a systematic design process (Adhikarinayake, 2005). The components of the paddy storage system are shown in **Fig. 1**. The storage bin is a frustum of a cone, joined to a conical hopper bottom and supported by three V-shaped vertical columns.

The conical bottom is provided with an outlet, having a threaded socket to enable complete discharge of the bin. A lid with a threaded socket is provided on the top to close the bin after filling in order to achieve complete air tightness. The upper cone is covered with a straw layer to protect the content from excessive heating over daytime and cooling during the night to prevent moisture migration and condensation of moisture. A metal cone is placed on the top of the bin with husk bags or straw to protect from rain.

Detailed designing of the storage bin is presented in the following sections.

Detailed Design of the Ferrocement Bin

Capacity and Basic Dimensions of the Bin

The average land area possessed by the farmer is one hectare (2.5 acres) and the average crop yield in paddy cultivation is 4.5 to 5 tons per hectare. In a season, a farmer gets 5 tons (250 bushels) of paddy under a favourable weather condition. Usually, half of the harvested paddy is available for sale and the rest is stored for home consumption as well as to meet future needs by selling some portion of it. Therefore, it is advisable to construct one stor-

age structure, having 2.5 tons (125 bushels) holding capacity for the saleable portion. Considering the bulk density of common varieties of paddy as 540 kg/m³, the required volume of the bin is 4.63 m³.

The bottom part of the container was selected as a conical shape for easy discharge. The outlet is to be 750 mm above the ground level in order to collect the paddy into a bag while unloading. The upper section was selected as a frustum of a cone. If it were a cylinder, the top of the cylinder would have to be covered by a strong dome and be designed to bear a load of at least two farmers and a few paddy bags. Therefore, the other components; cylinder, hopper, columns foundations, have to be designed accordingly. Therefore, the top section was made as a frustum of a cone so that the space on the top was sufficient only for one farmer for loading purpose.

An economic model was developed to select the basic dimensions of the bin.

Volume, V, of the bin is derived from the following equation.

$$V = \frac{\pi}{3}(R^3 \cdot Tan\ \theta + R^3 \cdot Tan\ \alpha - r^3 \cdot Tan\ \theta - d^3 \cdot Tan\ \alpha) \quad ....(1)$$

where,

R: Radius of the base of two cones

r: Radius of opening at the top

θ: Slop of upper cone to the horizon

α: Slop of bottom cone to the horizon
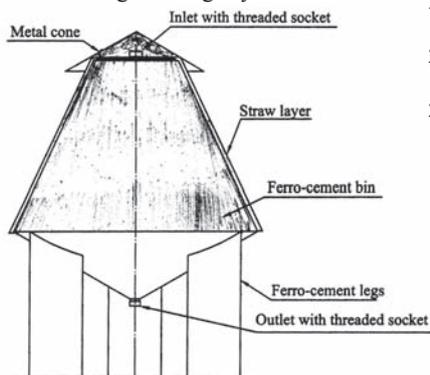
d: Radius of outlet

By modifying the above formula, Tan θ is derived from;

$$Tan\ \theta = \frac{3V - \pi \cdot Tan\ \alpha \cdot (R^3 - d^3)}{\pi \cdot (R^3 - r^3)} \quad ....(2)$$

Since the upper section of the bin is a conical shape, the intensity of pressure affecting to the wall is minimal and the major load is acting to the bottom cone. Therefore, both cones should be constructed, to bear the relevant loads.

Considering the construction cost of a unit area of the upper cone as C_t and the bottom cone as C_b, the cost of the bin excluding columns and foundation, can be derived from the following formula.

$$C = \frac{\pi \cdot C_t}{Cos\ \theta} \cdot (R^2 - r^2) + \frac{\pi \cdot C_b}{Cos\ \alpha} \cdot (R^2 - d^2) \quad ....(3)$$

Substituting Cos θ = $1/\sqrt{1 + Tan^2\ \theta}$) to equation (3), the cost equation is shown as follows.

$$C = \frac{\pi \cdot C_t}{\sqrt{1 + Tan^2\ \theta}} \cdot (R^2 - r^2) + \frac{\pi \cdot C_b}{Cos\ \alpha} \cdot (R^2 - d^2) \quad ....(4)$$

The following factors were considered in selecting parameters of the above equations.

Radius of inlet: r = 400 mm

- to facilitate a person to enter through the inlet into the bin for cleaning and repair

Slop of the bottom cone: α = 30°

- for easy flow of grains to the outlet

Bin outlet: d = 50 mm

- to discharge paddy with a controlling disk

Volume of the bin: V = 4. 65 m³

- volume of 2,500 kg of paddy

Since the National Engineering Research & Development Centre, where the research was conducted, has experience on the ferrocement technology the following values were considered for the study.

Cost of upper cone: C_t = 978 Rs./m²

-Min. thickness of ferrocement layer is 25 mm

Cost of bottom cone: C_b = 1470 Rs./m²

- Additional reinforcement is required

Substituting above values into equations (3) and (4), a function of the cost of the bin can be derived as a relationship of R, radius of the cone base. The relationship is valid at the range of inclination of the top cone of θ from 0° to 90°.

Fig. 2 shows the relationship of cost of the bin vs its radius of the cone base. At R = 1.15 m, the total cost of the bin reached its minimum value of Rs.16,265 (US$169.43). Therefore, the radius of the cone base was selected as 1.15 m from **Fig. 2**.

Fig. 3 shows the bin with basic

Fig. 1 Storage concept of the on-farm airtight storage system

Fig. 2 Relationship of cost of the bin to radius (♦) and to its height (●)
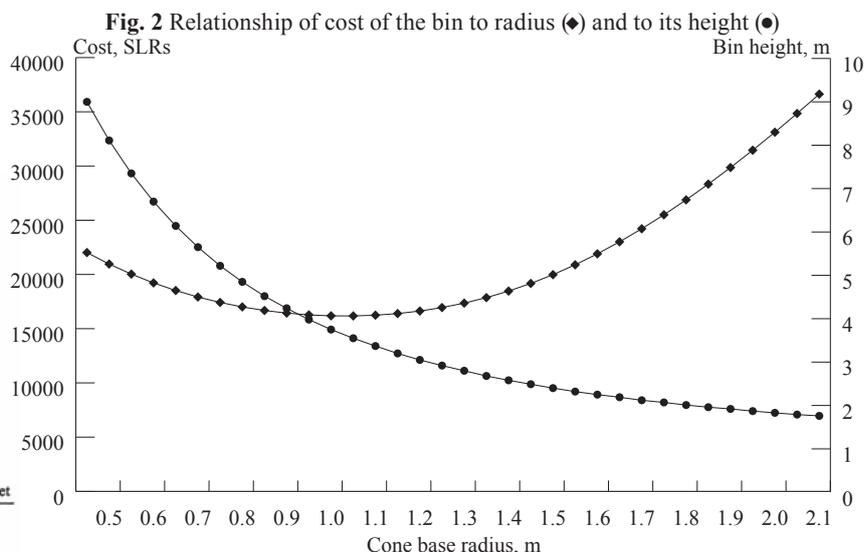
dimensions.

Intensity of pressure to the inclined wall

The pressure normal to the retaining surface wall can be expressed conveniently as a fraction of the equivalent fluid pressure (Reynolds and Steedman, 1981) which is expressed as;

$$q = k \cdot D \cdot h \cdot Sin^2 \beta + g_s \cdot Cos \beta$$
............................(5)

where,

D: the weight per unit volume of the grain, kN/m^3

h: the depth below the free surface, m

β: inclination of the wall

g_s: weight per unit area of the container, kN/m^2

k: measure of fluidity of the retained material and determined by;

$$k = \left[\frac{Sin\,(\beta - \gamma)}{(\alpha + 1) \cdot Sin \beta} \right]^2 \cdot$$

$$\frac{Cos\,\mu}{Sin(\mu + \beta) \cdot Sin \beta}$$

$$a = \sqrt{\frac{Sin(\gamma + \mu) \cdot Sin(\gamma - \square)}{Sin(\mu + \beta) \cdot Sin(\beta - \square)}}$$

where,

γ: Angle of internal friction of material

β: Inclination of the wall

$\square$: Angle of slop of retained material

μ: Angle of friction between material and wall

Rankin reported that the friction between the wall and the material is usually neglected, resulting in a higher calculated normal pressure, which is safe.

If friction is neglected and level filling of the paddy in the bin is assumed, the factors k and a are simplified to following.

$$k = \left[\frac{Sin(\beta - \gamma)}{(a + 1) \cdot Sin \beta} \right]^2 \cdot Sec^2\beta \ .....(6)$$

$$a = \frac{Sin\,\gamma}{Sin\,\beta} \ ....(7)$$

Intensity of Pressure to the Upper Cone: Considering D as 5.29 kN/m^3, β as 65º, γ as 34º, h as 1.61 m and g_s

as 0.89 N/m^2, and substituting into the formulae (6) and (7), the values for *a* is 0.6170 and *k* is 0.1504. Then the intensity of pressure acting on the upper wall qu according to the equation (5) is 1.94 kN/m^2.

Intensity of Pressure to the Bottom Cone: Similarly, considering the values for γ as 34º, β as 150º , h as 2.245 m and g_s as 0.89 kN/m^2, the values for factors *a* is 1.118 and *k* is 2.881. Substituting into equation (5), the intensity of pressure acting on the bottom cone is 9.33 kN/m^2.

Selection of Mesh - Mortar Ratio

According to the studies of Tricka et al., 1985, two layers of hexagonal galvanized woven wire mesh of 0.48 mm diameter reinforced with 5 mm diameter mild steel bars is able to absorb up to 12 kN/m^2 of live and dead load. The recommended cement-sand ratio is 1: 3 with a water-cement ratio of 0.45 at a thickness of 25 mm. Nimityongskul and Koentjoro, 1985, reported

Fig. 3 Basic dimensions of the bin
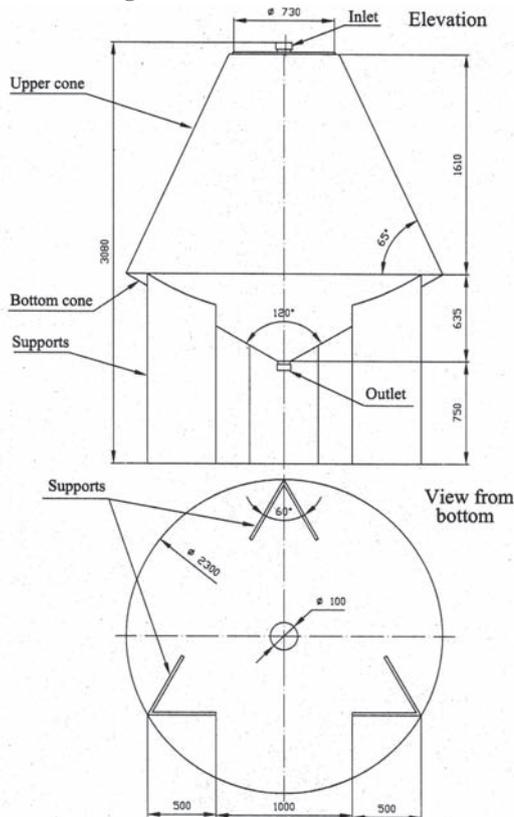
Fig. 4 Skeleton of upper cone and completed lower section of the bin
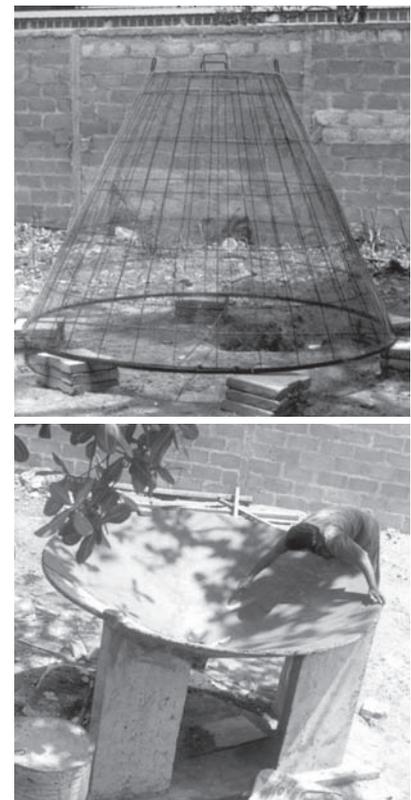
that the coefficient of permeability becomes higher when the thickness of the plastering mortar is increased. This phenomenon is contrary to that observed in concrete and is mainly caused by the manual plastering applied in the construction of ferrocement. It is more difficult to obtain a proper compaction of thicker section than a thinner section during its application through the wire mesh. The coefficient of permeability of a wall with two layers of wire mesh is 0.701×10^{-9} mm/sec. For that reason, a sealant has to be applied to make the surface airtight to prevent gas exchange through the wall.

Design of Columns

The total dead load and imposed load on the columns are as follows.

Fig. 5 Pictorial view of the bin after construction at the NERD Centre

· Surface area of the upper cone is 8.3 m² and bottom cone is 4.8 m². Considering the thickness of cones as 25 mm and the density of ferrocement with double hexagonal wire mesh and 5 mm MS rod skeleton structure as 35.11 kN/m³, the total weight of the both cones is 11.50 kN.
· Weight of the lid having diameter of 750 mm and thickness of 25 mm is 0.78 kN.
· Imposed load due to weight of paddy is 24.79 kN.
· Imposed load due to weight of a worker in feeding the bin is 0.64 kN.

The total designed load acting to the columns is 37.71 kN. Since there are three columns to support the structure, each column has to bear 12.57 kN.

Total stress of Δ enforced to one column is defined by:

$$\Delta = \frac{P}{A} + \frac{M}{Z}$$

where,

P: axial load,
A: Cross section,
M: Momentum around the common axis,
Z: Sectional module of the column.

Substituting A as 50 mm • 500 mm • 2 slabs, M as 12570N • 1130 mm and Z as 50 • 500³ mm³ / (12 • 250) mm:

$$\Delta = \frac{12570}{50 \cdot 500 \cdot 2} + \frac{12570 \cdot 1130}{(50 \cdot 500^3) / (12 \cdot 250)} = 7.07 \frac{kN}{mm^2}$$

Total stress is lower than the allowable stress, $\Delta_{allowable}$ of 11.25 N/mm² which is defined by;

$$\Delta_{allowable} = 0.45 \cdot f_{cu}$$

where f_{cu}, - compressive strength of concrete is 25 N/mm².

Design of the Base

The total weight of the three columns is 4.248 kN considering volume of each column as 0.177 m³ and density of concrete as 24 kN/m³.

The total service load including the bin, material, farmer and the three columns is 41.96 kN. Then, the expected load to the base is 45.32 kN; (41.96 kN • 1.08). Considering the allowable bearing pressure of the soil as 50 kN/m²; the required area for the base is 0.9 m².

Table 1 Cost of production of a ferrocement bin in SLRs (1 US$ = SLRs 97)

Inputs	Quantity	Cost (in SLRs)	
Material			
10 mm dia. MS rod	33.54 m	900.00	
5 mm dia. MS rod	109.75 m	675.00	
10 mm dia. for steel	36.60 m	855.00	
Chicken wire mesh	0.75 roll	1,950.00	
50 mm × 50 mm GI wire mesh	78 m²	1,350.00	
100 mm GI pipe	0.15 m	260.00	
100 mm GI socket	2 Nos.	600.00	
Gauge 26 binding wire	0.5 kg	40.00	
Welding rods	0.5 kg	75.00	
Gauge 22 aluminium sheet	9.75 m²	750.00	
Cement	600 kg	4,800.00	
Sand	0.85 m³	1,050.00	
Aggregate	0.27 m³	380.00	
Sealant	1 kg	400.00	14,472.00
Weather shield paint	1 lit	380.00	
Labour			
Welder @ Rs.400.00	4 man-days	1,600.00	10,100.00
Mason @ Rs.400.00	10 man-days	4,000.00	
Helper @ Rs.400.00	15 man-days	4,500.00	
Total		**SLRs**	**24,575.00**
		US $	**253.35**

The three columns were placed together by a 100 mm thick concrete plinth leaving a gap of 500 mm between each column for convenient discharge of paddy into sacks. The total area of the plinth is selected as 1.465 m^2.

Preliminary Check of the Effective Depth of the Concrete

Considering the density of concrete as 24 kN/m^3, the weight of the entire structure including the base is 46.2 kN. The overall depth of the concrete plinth is checked by:

$d > 10 \cdot (N)^{0.5}$ where, d is the effective depth and N is the ultimate load which is considered as 1.4 times the service load.

Then $d = 10 \cdot (1.4 \cdot 46.2)^{0.5} = 80.42$ mm which is less than the selected thickness of the base of 100 mm. Therefore, the design calculations conformed to the safety standards.

Construction of the Bin

Pictorial views of the construction of the bin at different stages are shown in **Figs. 4** and **5**.

The structure of the upper cone was made of two rings of 800 mm and 2,300 mm diameter using 10 mm dia mild steel iron rods, connected by welding 24-5 mm dia mild steel iron rods. Height of the cone frustum was 1,610 mm. The bottom cone was fabricated similar to the upper cone, but the height was 635 mm. Additional two rings made of 10 mm dia mild steel iron rods were attached to the bottom cone between the base and the outlet of the cone to bear the imposed load. Two layers of chicken wire mesh were attached to each cone externally and internally using binding wires.

The V-shaped column was cast in two stages. Reinforced steel frame was prepared for the both sides. One side was cast using a mould to a thickness of 50 mm keeping it on a flat floor. After curing, the other side was cast keeping an angle of 60º in between the two slabs. The top of the column provided a curvature to fit to the bottom cone. Similarly, three columns were cast.

After aligning the three vertical columns in an equal triangle, the base was made with concrete to a thickness of 150 mm leaving about 50 mm above the ground level. For aligning of the three columns, an equal triangle frame, made from 50 × 50 × 5 mm angle iron was used. The top outer tips of the columns were tighten to the bottom cone skeleton maintaining the base of the cone horizontally to the water-sprit level. The cone was plastered with a sand-cement mortar mixture prepared to the ratio of 1:3. After two days, the top cone skeleton was placed over the bottom cone and tighten using binding wires. Similarly, the top cone also was plastered as the bottom cone. An L-shaped grove of 25 × 25 mm was provided at the rim of the top cone for the lid. The lid was made with ferrocement to a thickness of 25 mm and a steel tube of 100 mm diameter was embedded at the center to close the bin using a treaded socket. A sealant material based on the rubber latex dissolved in cement slurry was applied to the wall of the bin on both sides to make the wall airtight. After drying the plaster, wall was painted with white weather shield paint.

Production Cost of a Ferrocement Paddy Bin

Table 1 shows the expenditure incurred in construction of the ferrocement paddy bin.

The cost of material to construct a bin was US $149 (SLRs.14472.00) and the labour cost was US $104 (SLRs.10,100.00). The total cost was US $253.35 (SLRs.24,575.00). However, the total cost can be reduced by making appropriate jigs and fixtures and also constructing the bin in large scale, thereby, some materials can be saved. Since the technology was new to the welder and the mason, the cost of labour can be reduced further once they have become acquainted with the technology.

Conclusions

The economic model developed can be used to design a ferrocement bin of different capacities required by the farmer.

The basic structure, which consists of welded or bound mild steel iron rods and chicken mesh to form the shape, can be fabricated in a small workshop or at the site where the bin is constructed. Therefore, the paddy bin can be constructed by the village artisans and skill masons using materials available in the vicinity. Since theses bins are required for the farmers in the paddy growing regions, construction of the bin will be a new self-employment opportunity for the rural sector.

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The Situation of Agricultural Mechanization in Sarab City - Iran

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Abstract

In order to evaluate the existing situation of agricultural mechanization and to recommend some guidelines for its development, this study was conducted in Sarab County with 66,674 hectares of farming land. In this study, number of tractors, types of machines, mechanization level, degree, and capacity were calculated. Management of machines, operators' skills and degree of depreciation were also evaluated and the results were analyzed. The study showed that 33 % of universal tractors (Romania) were obsolete. The mean mechanization level was 0.85 hp/ha; although this number was higher than the national level (of Iran), mechanization degree was very low in most farming operations. Management of machines and operators' skills were also very low. It was estimated that, to reach the mechanization level of 1.5 hp/ha, 771 tractors are required. Productivity coefficient of machinery is 62 %, which shows that the machinery is not used ideally. In this study some overall guidelines for improving mechanization and increasing farm production were also presented.

Introduction

To make a reliable plan to develop the agriculture of a region, it is important to gain a precise knowledge of the existing situation and problems facing the development of agriculture. Otherwise all long-, middle-, and short-term plans will be ineffective and finally problematic and they will lead to waste of capital and time. This is of crucial importance in developing and undeveloped countries because of limited capital and economic depression. However there are many fields with potential for development in these countries.

One of the main reasons, and probably the most important one, for this kind of social structure is the dependence of these countries on traditional agricultural systems with low efficiency. Therefore, attempts to find a rudimentary solution to enhance the effectiveness of agriculture in the economy of these countries as one of the main goals must be taken into consideration. In this light, "the mechanization of agriculture to enhance per capita production of workers, to reduce production costs, to increase the profitability of products, and to extend the agricultural area" and "utilization of scientific resources and researches in the field of appropriate application of potential facilities of water and soil and increase in production per unit area" are two main ways to evolve the traditional agriculture systems. In most cases, these two ways are used simultaneously (Ranjbar, 1989).

By definition, the mechanization of agriculture is "application of mechanical implements or as a whole, the application of the state-of-the-art technologies in agriculture to increase productivity and to reach sustainable agriculture". There are three specific indices including mechanization degree, level, and capacity for the study and evaluation of mechanization in different regions.

Although the developmental patterns for a region can be provided after investigation into the facilities and limitations of that region, it must be noted that we can never offer a certain pattern of agricultural development alike for all regions, since they are different culturally, geographically, economically and socially. So, each part of the world has its own characteristics and needs a specific pattern of development (Shahbazi, 1989).

This investigation was carried out in Sarab City in the province of East Azarbayjan in Iran in 2003-04 to study the situation of mechanization in the region and to analyze the relevant qualitative and quantitative issues.

Methodology

Sarab City in the east of East

Azarbayjan Province stands between the latitudes of 37º 45′ and 38º 00′ N. and longitudes of 47º 30′ and 47º 45′ E. According to the census of 2001, the population of the city was about 161,741 and the population of working men of this city in the agriculture sector was about 24,911 (Anonymous, 2001). The total area of the city was more than 3,560 km^2 of which 100,740 hectares are arable, 66,674 hectares for irrigated and non-irrigated and the rest for fallow.

In terms of Emberget classification, the climate of the region is semiarid and cold. The mean annual temperature is 0-10 ºC and mean annual precipitation of low and high lands is 300 and 600 mm, respectively. The city whose altitude is 1900-m is under the aquifer realm of Oroumiyeh Lake and Adji-Chai River (Anonymous, 2001).

Methods of Study

In this research, we used a field study as the cornerstone of reviewing the gathered data and, besides, extensive and intensive methods were used. Inquiry and observation constituted the tools of the research. Field observation (which is done in the heart of the society unlike the in vitro observation) is the base of this method, which is used for studying different social, human, vegetative and animal-related phenomena (Sarokhani, 1994).

The extensive method is an important method in large-scale social and regional investigations. In this objective method, questions with low depth are considered (Louimi, 2000). This method is required because it enables generalizability of results and finally unmasks the general properties and existing norms (Sarokhani, 1994).

The aim of the intensive method is to the analyze phenomena and account for. This method includes a wide spectrum and is considered more rigorous for the extensive method (Sarokhani, 1994).

In view of the definition of field study and the description of the intensive and extensive methods as subsets of the field study, it was attempted to use both methods in this experiment. A region was selected as a sample and this sample was studied intensively and thoroughly, for the following reasons:

1. inaccessibility to all villages around the city;
2. infeasibility of studying such factors as degree of mechanization in every village;
3. this region being roughly agrozone as regards the elevation temperature and general climatic condition;
4. farmers being of similar social and cultural conditions and facing similar constraints.

In statistical analyses, random samples were selected from the villages under the service of public agencies and questionnaires were filled in these sample villages and eventually the results of this survey were generalized to the whole region.

Methods of Data Gathering

In this study, methods that are used for gathering data were questionnaire, interview, observation, gathering formal statistics, and finally library study.

Evaluation Indices

The indices and qualitative and quantitative criteria by which the status of mechanization were evaluated were as follows:

The mechanization degree is one of the quantitative indices (Almasi et al., 2000) by which the mechanization degree of different operations in a limit can be assessed. In other words, mechanization degree is used for determining the extent of different operations done by machinery (versus operation done by human, animal or noncompliance of them). In this study, wheat, barley and potato were selected as dominant and strategic crops (in terms of their productivity to farmers) for extensive investigation. Then the mechanization degree of different operations on these crops was intensively examined in the sample region (Sharabian Region) and the ratio of accomplished mechanization operation to the required one was determined.

The level of mechanization which was calculated by the following formula (Almasi et al., 2000):

Total powers of existing tractors (hp) = Average nominal power of one tractor × Number of working tractors

Total real power of tractors = Total power of existing tractors × Conversion coefficient ....(1)

According to the recommendations of the reference (Almasi et al., 2000), the conversion coefficient is 0.75, so

Mechanization level (hp/ha) = Total power / Cultivated area ....(2)

The executive power of the region: to calculate this capacity, it was essential to calculate the real period of time which experiences the highest operational density in terms of agricultural calendar of the region and the table of time limitations of the application of the machinery as well as the required period of time to carry out the desired operations per hectare (Louimi, 2000).

Existing executive power = (Existing period of time × Existing number of tractor) / Required time period for preparing of field per hectare ....(3)

Productivity coefficient: this is calculated by the executive power (Louimi, 2000).

Productivity coefficient (%) = (Necessary executive capacity / Existing executive capacity) × 100 ....(4)

In fact, the necessary executive power is the area that may be completed in the real period of time.

The mechanization capacity or consumed horse power - hour through energy resources (including animal, human and mechanical).

Animal energy: to calculate the animal power, the energy produced by an animal during a working day[*] is equal to (Iran Consulting, 2000):

Annual functional hours = Number of functional days × Mean functional hours during a day

Total existing animal power (hp) = Produced power of animal × Number of animals

Animal energy (hp-hr) = Total existing animal power × Annual functional hours

Human energy: the procedure for calculating human energy is similar to the previous one, but it should be taken into consideration that firstly to calculate the number of working population in agriculture sector, all people of the region including farmers and supporting people who play a role in crop production should be involved; secondly a normal person can meanly produce on average about 0.12 hp during a working day (Iran Consulting, 2000).

Mechanical energy: to calculate the mechanical energy, the first instruction has to be followed, the number of days machinery is used during a year should be noted according to the calendar, as well as the limitations of using machinery on some days. And the mean daily functional hours of machines are separately calculated according to existing resources and field studies. Besides calculating the energy of machines, all existing machines should be considered, whether stationary or mobile, which are producing power for cropping work.

Calculation of number of tractors, combines and required implements:

To calculate the number of required tractors we follow the inverse procedure as that for calculating mechanization level. Therefore having a certain mechanization level, the required number of tractors can be calculated as following: ....(5)

Necessary tractor power = Determined mechanization level[**] × Cultivated area (ha) / Conversion coefficient (0.75)

Required tractor power = Necessary tractor power − Existing tractor power

Required number of tractors = Required tractor power / Nominal power of an appropriate tractor

To calculate the required number of combines, the steps must be followed:

Performance of each combine in workable period = Number of workable days × Feasible capacity of combine (ha/day)

Necessary number of combines = Existing harvestable area / Performance of each combine in workable period

Required number of combines = Necessary number of combines − Existing active combines

To predict the required implements for cropping operations, we take the following steps:

Effective area capacity (ha/hr) = (Working width (m) × Speed (km/hr) × Efficiency (%)) / 10

Working area of implement = Area capacity of implement × Number of working days × Mean daily working hours

Necessary number of implements = Total working area of required operation / Working sur-

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[*]The power corresponding to each one (hp): Horse = 1, Donkey = 0.5, Mule = 0.8, Working cow = 0.8, Bull = 0.8.

[**]The mechanization level which is predicted in Third Development Program of the country.

Table 1 Mechanization degree (MD) of prevalent mechanical operations of potato

Type of operation	MD for concerned operation areally, %	Comments
Initial soil tillage		
Mouldboard plow	97 and more	Nowadays all cultivated fields are usually plowed at least once.
Heavy disk	negligible	It is not prevalent in the region and farmers do not know this kind of operation.
Chisel plough	14 and less	Some farmers use it for gathering vegetative remnants after harvesting potato.
Secondary soil tillage		
Disking	35	It is used for breaking the clods.
Harrow	23	It is used for collecting the vegetative remnants and simple furrow-making.
Planting		
Potato planter	12	Its application has not extended because of ignorance of ramers and the problems facing fields leveling.
Furrower	78	In recent years, the application of this method has increased because it is simple and time saving.
Protection		
Sprinkler	6 and less	This method is not used widely because of restricted spread of that.
Tractor sprayer	57	In the protection stage, this is used widely for fighting against weeds and pests.
Knapstack sprayer	55	Farmers who do not have access to tractor spray use this implement eigher manually or mechanically.
Harvesting and postharvesting		
Potato digger	20	Fields cultivated by potato planters are usually harvested by potato diggers.
Transportation	100	Potato is transported to dtorehouses or market by vehicles.

face of an implement
Required number of implements = Necessary number of implements − Number of existing active implements

Results and Discussion

Investigation of Mechanization Degree, Level and Capacity

According to equation (1). Considering the extensive studies, the results were generalized to the entire region. The results for potato, wheat and barley (irrigated or non-irrigated) are summarized in **Tables 1** and **2**, respectively.

To investigate the mechanization level which was, in fact, per capita power in terms of hp per hectare. First of all it was necessary to determine the number of all kinds of active tractors in the region which were used as the resource of draft power. Therefore, the total power of all tractors (shown in **Table 3**) with respect to their trademarks were deduced from the results of the questionnaire and statistics for existing trademarks as well as the investigation into the life time of these about 33 % of the tractors made in Romania (type U650) were either amortized or did not play a role in agriculture sector. According to this table and equation, since the arable area of the region is 66,674 hectares, the mechanization level is 0.85 hp per hectare. Although this figure is desirable in comparison with the mechanization level of the country which is 0.6 hp per hectare (Kiani, 2000), it is not reasonable in comparison with the mechanization level of developed countries as well as the predictions of Third Development Program of the country in the agricultural sector in which the mechanization level has been determined as 1.5 hp per hectare. So, an appropriate solution ought to be sought.

In studying the mechanization capacity or consumed hp-hr in producing crop products via three energy resources (animal, human, mechanical), according to section (4), total consumed energy via these three resources were calculated and are summarized in **Table 4**. According to **Table 4**, total consumed energy in the region was 280,530,855 hp-hr. In fact, with regard to cultivated area i.e. 66,674 hectares, total consumed energy per hectare via these resources was 4,207.5 hp-hr. Naturally the greater the mechanization degree of a crop, the higher this figure would be and vice versa. According to the table, animal, human and mechanical energy comprised 1.28 % and 2.24 % and 96.48 % of the total consumed energy, respectively. This shows the vital

Table 2 Mechanization degree (MD) of prevalent mechanical operations of wheat, barley (irrigated and non-irrigated) in the region

Type of operation	MD for concerned operation areally, %	Comments
Initial soil tillage		
Mouldboard plow	97 and more	Nowadays all cultivated fields are usually plowed at least once.
Heavy disk	negligible	It is not prevalent in the region and farmers do not know of this kind of operation.
Chisel plough	8 and less	Chisel plough which is used for plowing non-irrigated firld is not prevalent because of ignorance of farmers.
Secondary soil tillage		
Disking	7 and less	It is used for breaking the clods.
Harrow	13 and less	It is used for collecting the weeds and vegitative remnants.
Planting		
Drill seeder	7 and less	Seeding with drill seed is not quite prevalent in the region.
Seeder	35	Sowing by seeder in non-irrigated fields is developing.
Top-dressing	12	Farmers do not extensively use mechanical sprinklers because of inaccessibility.
Disking	94 and more	Almost all fields which were manually seeding are disked to cover seeds.
Protection		
Ditcher and border	78	Ditcher and single beam plow perform the relevant activities.
Tractor sprayer	30	To fight against weeds and pest.
Knapstack sprayer	42	To fight against weeds and pest.
Sprinkler	7 and less	This method is not used widely because of its restricted spread.
Harvesting		
Combine	90	This is widely used for harvesting in irrigated and non-irrigated fields where combine application is not problematic.
Mower	8	Inclined fields which used to been harvested manually are now harvested by mower.
Post-harvesting		
Bailer	8 and more	Packaging of hay by bailer is on the rise in recent years.
Thresher	95 and more	Almost all barley and wheat which are mowed manually or by mower are threshed by thresher and then barley and wheat are separated from hay by traditional methods.
Transportation	92 and more	

importance of mechanical resources in crop production.

Required Number of Tractors, Combines and Other Implements

To calculate the required number of tractors, the instructions given in section (5) must be followed. In this study, the certain mechanization level was determined with respect to the predicted mechanization level in the Third Development Program, which proposes an average of 1.5 hp per hectare. The calculation showed that the necessary tractor power was 133,348 hp of which 75,564 hp exists and so 57,784 hp was required. According to the studies and referring to the resources and researches, the appropriate tractors for the region are commonly middle-power ones (Iran Consulting, 2000). In this study, the MF285 with nominal power of 75 hp that is both middle-power and made-in Iran and easy-to-access were the basis of research. Finally 771 tractors of the same brand were estimated to meet the requirements of the region.

To calculate the number of combines required, considering equation (5) and the results shown in **Table 1**, which indicate that the mechanization degree for harvesting by combine is 90 % and total area of wheat and barley is 35,294 hectares in the region, altogether a 31,765 hectare area will be harvestable by combine. According to the agricultural schedule of the region and limitation in using machinery from July 10 through August 20, which are forming the harvest season, allotted time (or workable days) for to harvest is 32 days in the region. Extensive studies show that mean performance of combines is 10 hectare per day. So, 100 combines are needed of which just 35 combines exist. Now it may be asked whether the remaining 65 combines are necessary to procure. If necessary, how have farmers met their needs as yet? The answer is that Azarbayjan is a region with various climates, therefore harvest of wheat starts from the northern part, i.e. Moghan Plateau, and with increase in temperature in the first months of summer it extends to western and southern parts of the region. So annually, combine owners in Ardebil and Moghan Regions are dispatched to this city after completion of harvesting the wheat of their own regions and, thus, the need for combins in Sarab is met. On the other hand, since the purchase and maintenance costs of combins are high and it is annually applied just in a short period of time, it seems that the procurement of this number of combines is not economical. However, it must be noted that the lack of service and maintenance centers for combins in the region is a severe problem that prevents owners from repairing their combines that leads to a waste of harvest time (due to protracting of repairing and replacing accessories). Furthermore, since drivers are not skillful and do not know how to adjust their combines, seeds break and are scattered in different parts. All of these problems incur a high costs for farmers.

To predict the required number of implements, the instructions given in section should be followed. The results of this prediction have been summarized in **Table 5**. Allotted time has been calculated according to the agricultural calendar of the region. Besides, the real period of time for using these tools has been calculated according to the limitations of applying the implements (Iran Consulting, 2000). As shown in the table, the number of existing implements such as mouldboard plow, disk and chisel plough are excessive and superabundant. Although this is a positive point, with respect to the mechanization degree, it is clear that these implements are being misused. Conversely there is a severe shortage of some other implements such as seeder, potato planter and potato digger which needs to be resolved and calls for investments.

Situation of Productivity of Agriculture Machinery

To study the conditions of productivity of agricultural machinery various factors can be used such as the ratio of final yield of crops to their final (potential) efficiency or qualitative factors such as the status of training and skills of users of machinery. In this study according to the agricultural calendar of

Table 3 The total power and number of all kinds of active tractors in the region

Type	Mean nominal power, hp	No. of active tractors	Conversion coefficient	Total power, hp
Romania (30-60)	40	6	0.75	180
Romania (60-80)	65	664	0.75	32,370
MF (30-60)	45	7	0.75	236
MF (60-80)	75	380	0.75	21,375
MF (80-110)	110	10	0.75	825
John Deer (80-110)	105	18	0.75	1,417
Others (30-60)	40	9	0.75	270
Total	-	1,094	-	56,673

Table 4 Consumed energy in terms of energy resources (including animal, human and mechanical)

Type	Consumed hp-hr	Consumed hp-hr per hectare	Share of each resouce, %
Animal energy	3,600,192	54	1.28
Human energy	6,283,140	94	2.24
Mechanical energy	270,647,253	4,059.5	96.48
Total	280,530,855	4,207.5	100.0

the region, preparation of the field involves the maximum density of operations and is the most energy-consuming part of cropping operation. This part is carried out in 50 days (second 10-days of September through the last 10-days of October). This number of days and limitation of machinery during this period of time indicates that about 30 days of this period are workable and during this limited time all operations related to cultivation of irrigated and non-irrigated wheat have to be finished. Besides, if appropriate precipitation occurs during this period, even the operations concerning the cultivation of irrigated barley and non-irrigated cereals are carried out whose total operational area is about 31,800 hectares. This amount of area is known as the required executive power of the region. Now according to equation (3), with a workable period of 30 days as well as 1,094 active tractors (**Table 3**) and mean efficient workday of 7.28 hours based on extensive studies, the current executive power of the region will be 51,449 hectares.

Therefore, according to equation (3), productivity coefficient of machinery is 62 %, which shows that the machinery is not used ideally. That is, at the present the mechanization level of 0.85 which is in itself low, farmers do not use the current machinery effectively because of the lack of knowledge in using them correctly. This intensifies the obstacles to the mechanization development in the region. It must be noted that in the calculation of productivity coefficient, the limited period of time has been used but farmers usually proceed with preparation operations of the field without paying attention to the agricultural calendar, which leads to the prolongation of the current period of time and reduces the real productivity coefficient.

Conclusion

The main obstacles to development of the mechanization of the region are as follows:
  i. the problems of farmers and providers of machinery services due to different factors, e.g. the absence of service stations and after-sale services, the area of fields which are not large enough to apply the machinery, etc.;
  ii. the lack of sufficient training, and promotion of knowledge and even applied research in the field of mechanization;
  iii. the poverty of operations technologically (mechanization degree);
  iv. low efficiency coefficient of agriculture machinery;
  v. disproportion of existing mechanical technology with requirements of the region.

However it must be noted that there are other restrictions in water, soil and human (experts) resources and particularly investments on infrastructure, e.g. construction of dams and machinery supply which are together responsible for the poor mechanization.

According to the extensive studies, the following solutions are recommended:
  i. Long-term planning for integrating fields via reform of inheritance laws. Although this program needs large-scale decision-making and national will, it should be noted that for transition from traditional structure of agriculture to developed structure, legal and financial supports of first level management are needed.
  ii. Establishment of specialized committees involving graduates in the field of agronomy and their recruitment to villages and agricultural centers for training and promotion of information to farmers. This can help to solve the problems of farmers and employment of graduates.
  iii. The precise conduct of training classes and demonstration of suitable and examined patterns to the farmers, because it seems that the main reason for low efficiency coefficient is the ignorance of the users of the machines.
  iv. The establishment of central service stations at least in central villages and provision of after-sales services of machines and accessories in these stations.
  v. To enhance the mechanization degree and specially the mechanization level from 0.83 to 1.5 hp per hectare, it is essential to provide 771 middle-power tractors as well as the required

Table 5 The number of required implements to carry out the prevalent operations
(with the assumption that mechanization degree is 100 %)

Implement	Existing number	Working area, ha	Allotted time of operation, day	Real time, day	Area capacity, ha/hr	Implement performance in real time, ha	Required number
Mouldboard plow	1,271	44,051	40	20	0.31	45	979
Chisel plough	439	22,623	40	20	0.86	125	181
Disk	480	66,674	40	20	1.05	153	436
Seeder	73	14,322	50	24	0.67	117	125
Potato planter	5	5,150	50	21	0.29	45	115
Potato digger	18	5,150	60	40	0.47	137	38

implements, e.g. 52 seeders, 110 potato planters, and 20 potato diggers.

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Development and Performance Evaluation of a Mat Type Nursery Raising Device

the manual method. Thus, there was a saving of Rs.1,009/- over the manual method of raising mat type nursery for one hectare.

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Development and Performance Evaluation of a Mat Type Nursery Raising Device

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Abstract

In the Tarai region the rice transplanting is accomplished mainly by the manual method. Manual transplanting is a labour intensive operation comprising of nursery raising, uprooting of the seedlings, transporting and transplanting them in the main field, with a total labour requirement of about 280-350 man-h/ha. High labour demand during peak transplanting period adversely affects the timeliness of this operation, thereby reducing the crop yield. To correct the problem, mechanical transplanting could be considered as the most promising option. The major constraint in the adoption of mechanical transplanters is the complex and labour intensive technique of raising mat type nursery in frames on perforated plastic sheets. Another constraint is unevenness of plant population in the mats. With a view to reduce the drudgery in raising mat-type nursery, a mat-type nursery raising device was developed and tested. The developed device performed satisfactorily and gave the desired density of 80-100 g seed per mat with three passes of the device at 1.03 mm sprout length. The thickness of the soil layer could be also maintained to 20 mm, as required in a single pass, through out the length of the mat. It saved both time and labour of 72.02 and 33.33 percent, respectively, over the manual method. The cost of raising mat type nursery for one hectare (400 mats) was Rs.299.5, compared to Rs.1,608.75 with manual method.

Introduction

Rice and wheat are the two major crops grown in the country and constitute as a major share of the Indian diet. The food grain production of 209.2 million tonnes was shared by 89.4 million tonnes production of rice from an area of 43.6 million ha during the year 2002. The efforts are required to extend the quantum of rice production to 120 million tonnes by 2020 AD from its present value for sharing the national food grain production basket to meet out the requirement of the burgeoning population of the country (Anonymous, 2002). Looking at the total scenario of rice crop production during the current and last year, the situation has been backward this year rather than forward to achieve the target, as nature has not favoured the rice growers through desired fall of precipitation and temperature.

Therefore, sharpening of our technological tools, or fine tuning of technology, is required so that the trend of increasing productivity may be achieved. The various methods being practiced to grow rice are direct drilling/broadcasting of dry rice in a well prepared seed bed, broadcasting/line sowing of pregerminated seeds in puddled bed and the widely adopted method of rice transplanting either manually or by using a manual/mechanical rice transplanter. The problem associated with direct seeding is that of weed control (Jayasuriya and Price, 1979), whereas uniformity of plant population is sacrificed in the broadcasting method. The rice transplanting method gives the desired result but the labour requirement is very high. It involves labour intensive operations like nursery raising, uprooting of the seedlings, transporting and transplanting them in the main field requiring about 280-350 man-h/ha (Anonymous, 1999). High labour demand during the peak transplanting period adversely affects the timeliness of this operation, thereby, reducing the crop yield. In the Tarai region of Uttaranchal rice transplanting is mostly done through manual labour on a contractual basis. These labourers do not transplant the required number of hills per square meter for want of

covering more area within the short period contributing to lower yield.

Mechanical transplanting is considered as the most promising option as it reduces labour requirement by 90 percent, minimizes stress and drudgery, ensures timely rice transplanting and provides optimum plant population contributing to higher productivity. The major constraint encountered in the adoption of mechanical transplanting is complex and labour intensive technique of raising mat type nursery in frames on perforated plastic sheet. Unevenness of plant population in the mat is another problem. To eleviate the associated problem with the manual method of raising mat type nursery, Chiu et al. (1998) conducted study on a simulation model for the seeding operation of rice nursery in Taiwan. The developed model could be used as a tool to help managers of rice seedling centers optimize their seedling operations in terms of worker allocation, speed of seedling line and size of hoppers. Also, the potential delay in the seeding system could clearly be detected through the result of simulation. Garg and Dixit (2003) studied the design, development and evaluation of a mat type nursery sowing seeder. The nursery seeder was calibrated in the laboratory using pre-germinated paddy seeds having different sprout lengths, viz 1-2 mm, 3-5 mm and 6-10 mm. The manual dropping of seeds took about 10 minutes but the seeder saved 70-80 % of the time over the manual method.

Keeping the above points in view and with limited work in Indian conditions, a mat type nursery-raising device was developed and tested in the department of Farm Machinery and Power Engineering, College of Technology at G. B. Pant University of Agriculture & Technology, Pantnagar. The performance of the developed device was also compared with the manual method of raising mat-type nursery with its economics.

Materials and Methods

Development of a Nursery Raising Device

The nursery raising device developed in the department of Farm Machinery and Power Engg, College of Technology of this university consists of two major units, first a soil spreading device and second a seed spreading device. The detailed description of both the devices is given below:

Details of seed and soil spreading device

A seed-spreading device was developed to drop the pre-germinated sprouted rice seeds evenly on the soil-filled frames of size 220 × 500 mm. The various components of the device are frame, handle, ground wheel, hopper with adjustable control plate, sieve and power transmission unit (**Fig. 1**).

Frame: The frame of the seeding device was made of 40 × 40 mm mild steel angle iron. The overall length and width of the frame were 615 and 530 mm, respectively. The seed hopper, along with agitating unit was mounted on the frame. Four mild steel ground wheels 215 mm in diameter were provided to support the weight of various components of the device and also to keep the device in a level and stable position. The power from the ground wheel was transmitted to the

Fig. 1 Schematics of seed spreading device

seed agitating unit through a shaft. A handle of size 1,015 mm in length with adjustable height was provided to operate the device manually.

Hopper: A hopper made of mild steel sheet, 1.4 mm thick, was provided for storing the sprouted seed. The hopper was trapezoidal in cross-section 530 mm long, 200 mm wide and 375 mm high. The side wall of the hopper was inclined, in accordance with the angle of repose, for easy flow of the sprouted seeds. In order to regulate the flow of sprouted seed from the hopper to the seed-agitating unit, an adjustable control plate was provided in the hopper. The control plate had slots to adjust the opening of the hopper to regulate the quantity of flowing seed.

Soil agitating unit: The seed-agitating unit consisted of a rectangular frame, sieve and power transmission unit. Provision was made to agitate the seed dropping from the hopper in order to get uniform distribution over the entire width of nursery frame. The frame of the agitating unit was fabricated using 25 × 25 mm mild steel angle iron 520 × 300 mm long. The size of the frame was designed to cover the entire width of the nursery frame. A sieve with rectangular slotted openings 20 mm long and 5 mm wide was fitted in the frame of the agitating unit. The openings provided in the sieve were 2 holes per square inch.

Power transmitting unit: The power to operate the seed agitating unit was transmitted from ground wheel to sieve through a chain-sprocket drive. A sprocket with 30 teeth was fitted on the ground wheel shaft of 16 mm in diameter. Another sprocket with 10 teeth was fitted on another shaft of the same diameter and 300 mm long. The power from the ground wheel shaft was transmitted to a smaller shaft through a roller chain with 16 mm pitch and 448 mm long. The speed ratio between these two shafts was 1:3. At one end of the smaller shaft a crank

mechanism was provided that transmitted power to the sieve in the centre for agitating the seeds dropping on it from the hopper. Provision was made in the crank mechanism to increase or decrease the amplitude (stroke length) of the agitating sieve as per the requirement. The stroke length of the agitating sieve was 20 mm.

Discription of soil spreading device

A soil spreading device was developed for spreading a layer of soil of desired thickness over the nursery frame uniformly (**Fig. 2**). All components of the soil spreading device were almost similar to the seed spreading device except that it did not have an agitating unit. Instead a scraper blade was provided. In order to avoid bridging of the soil, an agitator, made of iron pieces welded opposite to each other on a hollow mild steel pipe, has been provided in the soil hopper. The power to drive the agitator was obtained from the ground wheel shaft

through a chain and sprocket drive. The transmission ratio between the ground wheel and the agitator was kept at 1:3.87.

A scrapper blade was provided just under the soil hopper. The scraper blade was fabricated with mild steel sheet of 1.4 mm thickness. The size of the scrapper blade was 520 × 170 mm. The size was selected to cover the entire width of the nursery frame. The scrapper blade was hinged at one end using mild a steel rod 560 mm long and 5 mm diameter. The height of other end of the blade was adjustable to obtain a desired thickness of the soil to be layed in the nursery frame.

Methodology

In order to test the performance of the device in the laboratory as well as in the field, the following methodology was adopted to determine the various related parameters.

Weight of seed per mat

The sprouted the seed hopper

Fig. 2 Schematics of soil spreading device

1. Frame
2. Ground wheel
3. Handle
4. Soil hopper
5. Soil agitator
6. Scraper blade

PLAN

ELEVATION
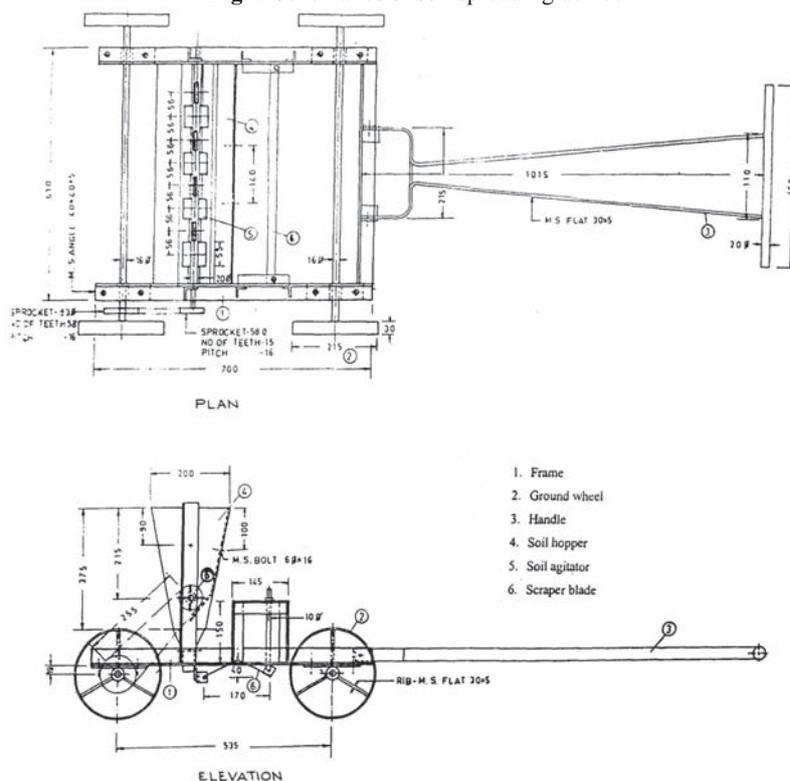
was filled and the seed spreading device was moved over the nursery frame that had sections of size 220 × 500 mm in order to determine the amount of seed dropped per mat. Thereafter, the seed dropped in each section of the nursery frame were collected and weighed. This was done to calibrate the device for proper seed rate. The same procedure was adopted for determination of weight of seed dropped per mat for different passes of the device, viz 1, 2, 3, 4 and 5 passes. For each pass the procedure was repeated thrice.

Uniformity of seed and soil

To determine uniformity in seed distribution per mat the device was operated over a test run of 1.0 meter length. The test run was divided in to three equal segments along the width. Three square containers of size 50 × 50 mm were placed randomly in each segment along the length of the test run. The device filled with sprouted seed was moved over the test run. The seed dropped in each container were collected, averaged out for each segment, counted and weighed. In a similar way, the uniformity of soil placement was determined.

Mechanical seed damage

The mechanical seed damage of sprouted seed was determined by taking a known quantity of sample from the seeds received from the seed spreading device and the damaged seeds were separated manually from the sample and weighed. The percentage of mechanical seed damage was calculated using the following equation:

Mechanical seed damage (%) = (Weight of damaged seed in the sample / Total weight of the sample) × 100 ....(1)

Thickness of soil layer

The soil spreading device was moved over a test run of 1.0 in length after filing the hopper with soil. The soil from the hopper was allowed to flow under gravity. When the soil dropped from the hopper the excess soil was scraped off by the scraper blade to get the desired thickness of soil layer. Thereafter, water was applied through a water sprinkler for settlement of the soil. The thickness of the soil dropped on to the nursery frame was measured at different locations from the test run with a vernier caliper.

Experimental variables

The following parameters were considered for the performance evaluation of the seed spreading device in the laboratory.

Sprout length of rice seed: 4 levels (1.03, 3.48, 4.64, 9.47 mm)

Number of pass of device: 5 levels (1, 2, 3, 4 and 5 pass)

Comparative performance evaluation in actual field condition

The performance of the developed device was compared with manual method of raising mat type nursery

Table 1 Amount of seed dropped per mat in different passes of the machine at different sprout length

Number of passes	Replications	Amount of seed dropped per mat length, g			
		Sprout length, mm			
		1.03	3.48	4.64	9.47
1 Pass	1	25.9	19.3	15.9	19.0
	2	26.3	20.5	16.3	23.0
	3	24.9	21.3	14.7	18.0
	Average	25.7	20.3	15.63	20.00
2 Passes	1	53.0	39.5	28.9	28.0
	2	50.0	38.9	29.7	31.0
	3	49.5	39.0	31.5	32.0
	Average	50.83	39.13	20.03	30.33
3 Passes	1	77.0	57.5	44.9	64.0
	2	78.0	59.3	45.8	58.0
	3	82.0	59.7	46.3	59.0
	Average	79.0	58.83	45.67	60.33
4 Passes	1	101.5	78.0	61.0	68.0
	2	105.0	83.0	63.5	84.0
	3	99.3	81.0	62.9	68.0
	Average	101.83	80.67	62.47	73.33
5 Passes	1	128.5	104.0	79.5	90.0
	2	131.5	100.0	77.5	88.0
	3	128.5	107.67	81.5	83.0
	Average	129.00	103.67	79.63	87.00

Table 2 Visible mechanical seed damage of sprouted rice seed

Replications	Weight of seed sample, g	Weight of damaged seed, g	Average seed damage, %
1	50	0.00	0.00
2	50	0.00	0.00
3	50	0.00	0.00
4	50	0.00	0.00
5	50	0.00	0.00
Average	50	0.00	0.00

Table 3 Thickness of soil layer obtained by soil spreading device

Replications	Thickness required, mm	Thickness obtained, mm	Variation
1	20	20	0.00
2	20	20	0.00
3	20	20	0.00
4	20	20	0.00
5	20	20	0.00
Average	20	20	0.00

in actual field conditions. The time and labour required in unit operations of raising mat type nursery in both the systems were recorded. After 8 days of raising the nursery, the mat thickness and other seedling characteristics like mat density, plant height, leaf stage and stem thickness were determined. Later on, economic analysis was also performed for both the methods of raising mat type nursery.

Results and Discussion

Performance Evaluation of the Device in the Laboratory

The performance of the seed and soil-spreading device was evaluated in the laboratory. The results are discussed below:

Weight of seed per mat

The weight of seed dropped per mat have been presented in Table 1 for different passes of the device and different sprout length of the seed. At 1.03 mm sprout length, the average weight of seed dropped per mat was 25.70, 50.83, 79.00, 101.83 and 129.00 g for 1, 2, 3, 4 and 5 passes of the device, respectively. When the device was tested for increased sprout length of 3.48 mm, the average weight of seed dropped decreased to 20.30 g for 1 pass, 39.13 g for 2 passes, 58.83 g for 3 passes, 80.67 g for 4 passes and 103.67 g for 5 passes of the device. When the sprout length increased further to 4.64 mm the average seed dropped per mat was 15.63 g, 20.03 g, 45.67 g, 62.47 g and 79.63 g for 1, 2, 3, 4 and 5 passes, respectively. At the highest sprout length of 9.47 mm, the average weight of the seed dropped per mat increased from 20.00 g for 1 pass to 30.33 g for 2 passes, 60.33 g for 3 passes, 73.33 g for 4 passes and 87.00 g for 5 passes of the device. The relationship between sprout length and seed dropped per mat in different passes has been presented in **Fig. 1**, which

shows an increase in weight of seed dropped per mat with the increase in number of passes of the device for all the sprout lengths of the seed. This was because, in every pass, some quantity of seed was being added to the seed dropped in the previous pass.

The weight of seed dropped for smaller lengths of sprout for a given pass was more than the weight of seed dropped at higher sprout length. This was because with the increase in sprout length the free flowing and sliding characteristics of the germinated seed upon itself decreases.

Fig. 3 shows that there was an increase in weight of seed dropped per mat beyond 4.64 mm sprout length from its previous values for all the

passes. This was because the hopper opening was increased from 12.5 to 18.0 mm in order to make the seeds flow from the seed hopper after a sprout length of 4.64 mm. The theoretical requirement of the seed per mat was determined as 80.00 g. From the **Table 1** it is clear that this requirement could be achieved in 3 passes, 4 passes, 5 passes and 3 passes of the seed spreading device for a sprout length of 1.03, 3.48, 4.64 and 9.47 mm at 12.5 and 18.0 mm hopper opening.

Uniformity of seed

The uniformity of seed placement in one-meter length of test run was determined and the results have been presented in **Fig. 4**. For one pass of the device, at 1.03 mm

Table 4 Weight of soil obtained by soil spreading device in 50 × 50 mm

Replications	Weight of soil required, g	Weight of soil dropped, g	Variation, g
1	58.93	62.36	3.43
2	58.93	68.26	9.33
3	58.93	67.40	8.47
4	58.93	62.10	3.17
5	58.93	75.20	16.27
6	58.93	64.26	5.33
7	58.93	61.06	2.13
8	58.93	65.13	6.20
9	58.93	60.06	1.13
10	58.93	61.17	2.24
Average	58.93	64.70	5.77

Fig. 3 Effect of sprout length and number of passes on amount of seed dropped per mat
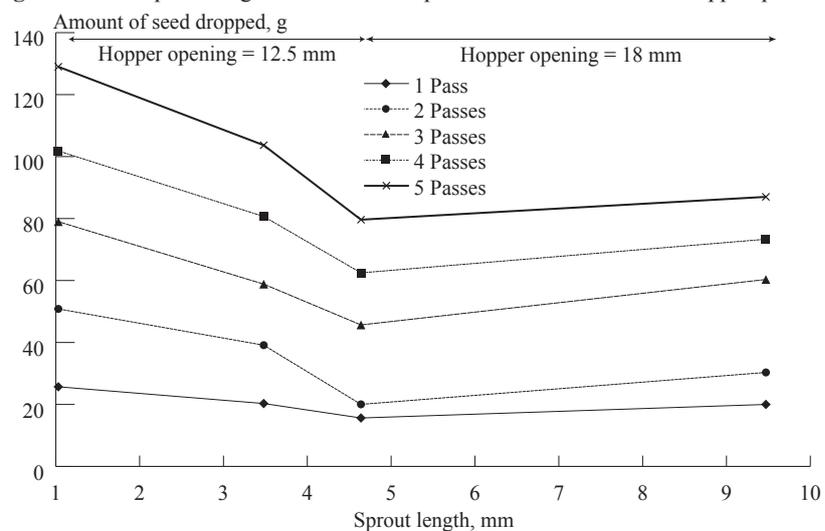
sprout length, the average number of seed dropped in each segment was 16 seeds. When the number of passes was increased from 1 to 2, the average number of seeds dropped in each segment was 35 seeds, which shows that the machine is able to drop the seeds uniformly over the entire test run. The number of seeds dropped in each segment in all the passes and sprout lengths was almost same with very small variation.

Mechanical seed damage

A sample size of 50 g was taken from the sample received after passing through the machine in order to determine visible mechanical damage. The broken seeds were separated from this sample and the result has been presented in **Table 2**. There was not any visible damage either to the seed or to the sprout of

the rice seed. Thus, it can be said that the machine spread the seeds uniformly over the nursery frame without any visible mechanical damage to seed or its sprout.

Thickness of soil layer

The thickness of soil layer after spreading it by the soil spreading device and watering was measured with a steel scale. The thickness of soil dropped has been presented in **Table 3**. The thickness of the soil layer measured at different locations was 2 cm. This indicated that uniform thickness of soil layer could be obtained with the help of the soil spreading device.

Uniformity of soil placement

The uniformity of soil placement in a one meter length of test run was determined and the results have been presented in **Table 4**. The aver-

age amount of soil dropped in each segment of size 50 × 50 mm varied between 61.06 and 75.20 g with an average of 64.70 g which quite close to the theoretical value of about 59 g. The average variation was 5.77 percent. Thus, the results indicated that the device gave uniform thickness of soil layer through out the test run.

Comparative Performance and Economic Assessment

Comparative performance evaluation of the developed device with conventional (manual) method of raising mat type nursery was done in actual field conditions at the university farm. The time and labour requirement was noted for each unit operation involved in raising mat type nursery and the data have been presented in **Table 5**. The total time required to raise 24 mats of nursery

Fig. 4 Effect of number of passes on number of seed dropped in 50 × 50 mm at different sprout length
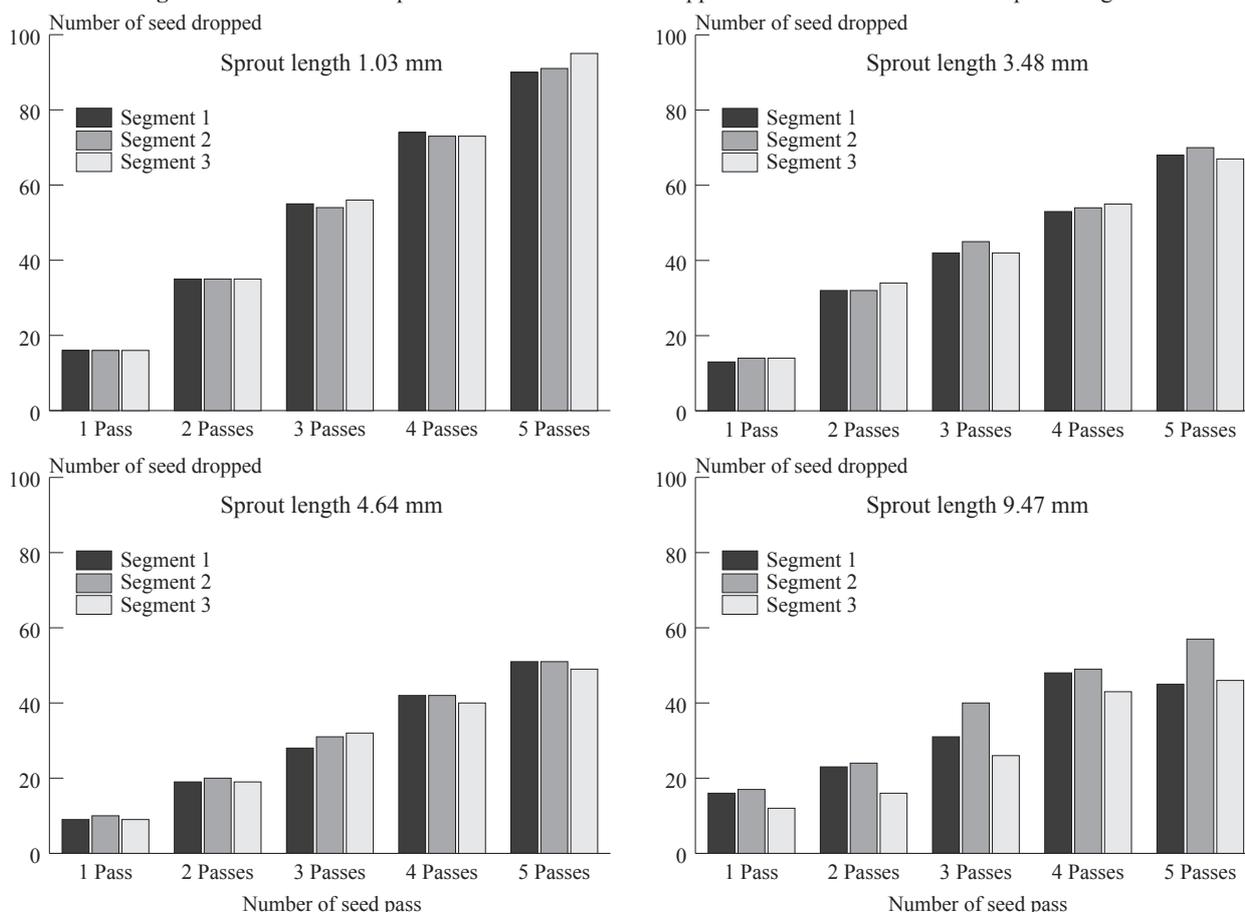
of size 220 × 500 mm was 2,574 seconds in manual method whereas it was only 718.8 seconds with the developed device. The total time saving in comparison to the manual method was 1,855.2 seconds. The time required in filling, levelling and compaction of soil in the nursery frame was 687, 420 and 84 seconds, respectively, whereas all these unit operations could be done with the device in 48 seconds only. The total time required in seed spreading with manual technique was 441 seconds whereas it was only 16.8 seconds with seed spreading device. Thus, the time saved with the developed device over the manual method was 72.07 percent. The labour requirement for various unit operations in raising 24 mat type nursery is also presented in **Table 5**. Eighteen labours were required for the manual method of raising mat type nursery whereas only 12 persons were required, along with the developed device, for raising the same quantity of mats. Thus, the labour saved with the developed device over the manual method was 33.33 percent. The saving in cost of raising mat type nursery for one hectare (about 400 mats) was Rs. 1,009/- over the manual method.

The characteristics of mat type nursery were also noted on 8th day in both the methods and the data have been presented in **Table 6**. The number of seedlings per cm^2 varied between 3 and 5 for manually raised nursery, whereas it was 2 to 5 for the developed device with almost the same number of seedlings per cm^2 in both methods. The stem thickness and leaf stage was 1.0 and 2.0 mm for the seedlings raised by both methods. The seedling height was a little less, 56.67 mm, for manually raised seedlings as compared to 65.0 mm for mechanically raised nursery. The average mat thickness was 20.0 mm, which is as per the requirement for mechanically raised nursery, whereas for manually raised nursery it was only 15.0 mm,

which is less than the required mat thickness. Thus, the results of seedling characteristics raised by the developed device were at par with the manually raised mat type nursery.

Conclusions

Based on the experimental results it could be concluded that the developed device can be used successfully for raising mat type nursery provided the length of the sprout is at the initiation stage. At this stage of sprout length the device gave good results especially with respect to uniformity of seed placement over the nursery frames. The recommended quantity of seed per mat (80-100 g) could be achieved in 3 passes of the device when sprout length was 1.03 mm. At 3.48 and 4.64 mm sprout length, the recommended quantity of seed per mat could be achieved in 4 and 5 passes of the device, respectively. The device saved time and labour of 72.02 and 33.33 percent respectively over

Table 5 Time taken in different unit operations of mat type nursery raising with manual and developed device for 24 mats

Name of the unit operations	Method of nursery raising			
	Manual		Mechanical	
	Time required, min(s)	Labour requirement, no.	Time required, min(s)	Labour requirement, no.
Spreading of polythene sheet over the ground surface	60	2	60	2
Laying of frame over the polythene sheet	120	1	120	1
Making perforation in plastic sheet	78	2	78	2
Filling of soil in nursey frame/filling of soil in hopper and operating of the machine	687	2		
Levelling of soil in nursery frame	420	2	48	2
Compaction of soil in nursery frame	84	2		
Sprinkling of water over the soil in nursery frame	300	1	300	1
Spreading of pre-germinated seeds over the soil in nursery frame/filling of seed in the seed hopper and operating the machine	441	2	16.8	1
Spreading of soil layer (2-3 mm) over the pre-germinated seed in nursery frame	315	2	15	1
Covering of the mat with residue/straw	69	2	69	2
Time loss	-	-	12	0.00
Total	2,574	18	718.8	12

Net saving in time requirement = 72.07 %; Net saving in labour requirement = 33.33 %; Labour charge @ Rs.60 per day; Net labour charge in manual method for raising 400 mats = Rs.1,609.20; Labour charge in mechanical method for raising 400 mats = Rs.299.50; Operational cost of the developed device for raising 400 mats = Rs.300.97; Net cost involved in raising mat type nursery by device, Rs./ha = 600.47; Net saving = Rs.1,009/-

Table 6 Seedling characteristics of mat type nursery raised by both the techniques

Parameter	Nursery raising method	
	Manual	Mechanical
Variety	Pusa Basmati	Pusa Basmati
Seed rate, kg/ha	32-36	32-36
Number of seedling/cm^2	3-5	2-5
Height of seedling, mm	56.67	65
Stem thickness, mm	1.00	1.00
Leaf stage	2	2
Mat thickness, cm	1.50	2.00

Development of a Prototype Dehuller for Pretreated Chickpea

by

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Abstract

A prototype machine was developed for dehulling of pretreated pulse grain. The dehulling unit consists of an abrasive roller and a stationery concentric perforated mesh drum over it. The separation of hull and splitting of chickpea grain was effected by abrasive action and shear forces caused on the grain when the roller rotates in the drum. The machine was tested using conventional and improved grain pretreatment methods. A dehulling index of 0.93 and dhal recovery of 78 percent were obtained with improved pretreatment method.

Introduction

Pulses are among the ancient food crops with evidence of their cultivation for over 8000 years. Besides being a rich and the cheapest source of dietary protein and a valuable animal feed, they also play a key role in improving and sustaining soil productivity. About 15 percent of the dietary protein is met from pulses in India as compared to 9 percent in Asia, and 7 percent in the world. They not only add to the quantity of protein in the diet but also improve its quality by balancing the essential amino acid pattern in the mixed diets. Chickpea is the most important pulse crop of the Indian subcontinent, accounting 47 percent of the total pulse production from 33 percent of the total pulse area. Generally, chickpea is consumed in the form of dehusked splits (dhal) or besan obtained from the dhal. Removal of the seed coat reduces roughage, improves storability and palatability for consumption in various forms. It also improves soaking, cooking quality and digestibility.

The dehulling of chickpea has emerged as a large scale value addition commercial operation, from a small scale traditional process. It is estimated that about 50 percent of the chickpea dehulling is still carried out on a cottage industry level by the farmers and small retailers either traditionally using stone chakki or mechanically using dehullers. Several small millers process 100 to 500 kg of grain per day either for trade purpose or custom hiring basis as a home scale operation.

The traditional stone chakki method is a slow and very laborious process. The dehulling technology of chickpea, at the small scale commercial level involves two basic operations, i.e. loosening of the husk by soaking the grain 5-6 hours followed by sun drying that splits the grain into cotyledons using emery coated disks and rollers. Abrasive dehulling is much faster and less tedious, but it causes excessive breakage losses of cotyledons in the hull fraction, yielding a low quality end product with more losses. Prolonged soaking of the chickpea grain in water also causes cup formation in cotyledons resulting in poor quality dhal. Hence, there is a great demand from the traditional pulse processors to upgrade their existing milling machinery and improve pretreatment procedures.

Chickpea can be dehulled with less loss and higher quality dhal than is possible with current mechanical dehullers if proper pretreatment methods and dehulling equipment could be developed. Pretreatment such as wet or dry conditioning have been used for centuries in pigeonpea dehulling with great success in the traditional dehulling system to facilitate the removal of seed coat and splitting of cotyledons. The pretreatments followed in pigeonpea should not be followed as it is, because, it is considered hard to mill grain compared with chickpea. Hence, incorporation of some of the underlying principles commonly used in traditional dehulling system using mechanical dehulling machinery could lead to less breakage of chickpea during the dehulling process due to loosening of seed

coat from the cotyledons.

Attempts have been made to develop small scale dehullers (capacity ranging 100-150 kg/hour) for pretreated pulse grain but with little success so far. Lal et al. (2004) developed a small capacity dhal chakki for pretreated pulses. Their mill consisted of two 15 cm diameter cast steel disks. One is stationery and the other is rotates within an 18 cm diameter housing. The grain was passed in between the plates by adjusting the gap between them. Dehulling and splitting was accomplished by the shear and frictional action on the grain, which took place between the stationery and rotating disks. The hull and the fine powdery materials were separated from the dhal by a cyclone separator. Anonymous (2003) described a method for dehulling chickpea grain for dhal making use of a roller type dehuller. The process improved the recovery and quality of dhal. In order to substitute the traditional village level processing, CFTRI has developed an integrated small scale pulse processing unit- mini dhal mill. This consisted of a dehusking unit, aspirator and a reciprocating sieve, all run by a one horse power motor (Annual report, 1990, CF-TRI).

Materials and Methods

Construction of the Dehuller

An abrasive roller type small capacity chickpea dehuller was developed at CRIDA. The main part of the dehuller consisted of an abrasive coated truncated cone roller (30 to 25 cm diameter, 60 cm length) and a concentric mesh drum, which was made from 1.5 mm thick, 2 mm diameter mesh holes mild steel sheet rolled into a cylinder. To develop the roller, two 2.5 cm thick, 27.5 and 22.5 cm diameter cast iron plates were selected and joined together using 1 cm uniform thickness and 60 cm length, good quality wooden

flats to form a cylinder structure. To ensue a proper rough surface over the cylinder, medium grit size B-type carborundum abrasive material was plastered uniformly over the wooden surface to a thickness of 1.5 cm (**Fig. 2**). This abrasive surface was durable and easy to repair in case of wear during operation. The annular space between the mild steel drum and abrasive roller was kept at 1.5 cm. In operation, the abrasive surface inter-locked with the grain mass forcing grain to move along the peripheral surface of the roller; but the movement was restricted by the surrounding grain layer, which was confined by the stationery drum surface. As a result, the abrasive action; grain against grain, grain against abrasive roller surface and grain against drum surface was created, thus, increasing the dehulling efficiency.

The drum was fixed to a 95 × 64 cm rectangular frame made of 75 mm angle iron. A drive shaft 50 mm in diameter ran through the axis of the drum carrying the abrasive roller bolted on each side of the shaft (**Fig. 1**). The drive shaft was mounted on pedestal bearings and

fitted to a pulley driven through a V-belt by a 3-horsepower electric motor. For loading and unloading of the grain in the machine, an inlet hopper was provided on upper topside of the drum and an outlet at the lower end of the drum cover plate. The dhal delivered at the outlet by the dehuller contained considerable amount of husk. To separate these hulls, an aspirator containing four numbers of 75 × 62 mm size blades inside, was fitted to the machine. The product outlet duct of the dehuller was connected to the aspirator through a 5.5 cm diameter flexible hose pipe. The fan was driven from an auxiliary 2.5 cm diameter shaft, which was driven by the motor through a V-belt and pulley.

Grain Pretreatment Procedure

As shown in **Fig. 2** in the present study the cleaned grain was passed through the roller machine with lighter force, which caused a mild abrasion (tempering operation). This tempering caused slight scratches on the seeds and enhances their water absorbing efficiency, leading to the loosening of the seed coat. The grain material was then treated with

Fig. 1 Chickpea dehuller

Front view

Side view
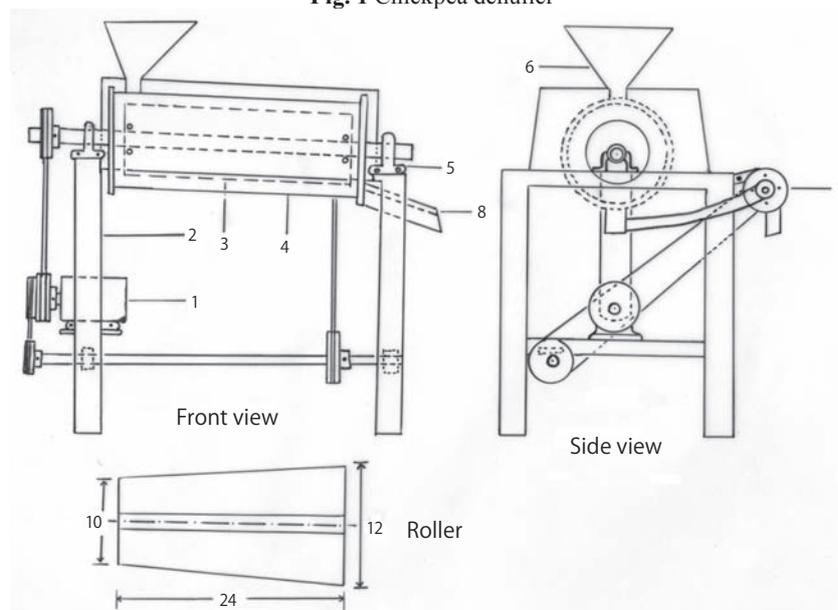
Roller

1: Motor with plat form, 2: Main frame, 3: Abrasive roller, 4: Enclosed mesh drum, 5: Pedestal with bearing, 6: Grain hopper, 7: Suction fan, 8: Outlet

water and heaped for a period of 4 hours to allow the surface moisture to be absorbed into the grain (conditioning). The conditioned material was spread on the drying floor to dry under the sun. If necessary the material was stirred occasionally. After sun drying, the grain was fed into the dehuller (**Fig. 3**).

Milling Tests

The chickpea grain produced in the local village was used to prepare the pretreated samples for the milling tests under a frontline demonstration of improved machinery for pulse crop production programme. The initial moisture content of the grain was 9 percent (dry basis). Moisture content of the cleaned grain was determined using a digital moisture meter. Thousand-grain weight was measured using an electronic balance. Dimensions of 50 grains were measured using a dial gauge type grain vernier. The shape of the grain was expressed in terms of sphericity calculated by the following expression.

Sphericity =

$$\frac{\text{Geometric mean diameter}}{\text{Major diameter}}$$

In which, Geometric mean diameter = $(L \times W \times T)^{1/3}$ mm

Where,

L = Length, mm

B = Breadth, mm

T = Thickness, mm

Bulk density was measured by weighing the sample of known volume. The theoretical hull content of the grain was measured, by removing the husk of 100 g sample manually using sharp nails.

The milling tests were conducted with the newly developed dehuller using carefully treated samples. In each treatment, four replications were made and a 25 kg grain sample was used for each replication. The abrasive roller speed was nearly 900 revolutions per minute, which was found optimum in preliminary tests. The following four treatments were selected for the study.

T_1 = Raw grain milling

T_2 = Soaking of raw grain in water for 5 hours and 24 hours sun drying

T_3 = Raw grain milling to obtain splits + Edible oil application at 0.3 % for 48 hours and 24 hours Sun drying + Milling

T_4 = Tempering + Water application at 10 % for 4 hours and 8 hours sun drying followed by milling

The milled fractions were separated using a mechanical sieve set. The dehulling index and dhal recovery were calculated by the expressions,

Dehulling Index =

$$\frac{(M_c + M_h) - (M_{uh} + M_f)}{M_t}$$

Where,

M_c = Mass of cotyledons and broken cotyledons

M_h = Mass of removed hulls

M_{uh} = Mass of grain that remained unhulled

M_f = Mass of fines in the final product

M_t = Total mass of sample fed into the dehuller

Dhal recovery = $\dfrac{F_p}{M_t} \times 100$

Where,

F_p = Mass of dehulled cotyledons and dehulled grain

Results and Discussion

Table 1 shows the important

Fig. 2 Pretreatment process of chickpea

```
        Chickpea
           │
           ▼
        Cleaning
           │
           ▼
        Piting
      (Tempering)
           │
           ▼
       Aspiration ──────────▶ Husk
           │
           ▼
   Water application ◀──────┐
        @ 10%               │
           │                │
           ▼                │
      Conditioning          │
       (4 hours)            │
           │                │
           ▼                │
        Drying              │
      (16 hours)            │
           │                │
           ▼                │
        Milling             │
           │                │
           ▼                │
Brokens ◀─ Separation ─▶ Rounds ─┘
           │
           ▼
       Clean dhal
```

Fig. 3 Chickpea dehuller - front view

physical properties of chickpea grain used in the milling tests. The knowledge of geometric mean diameter and sphericity helped in deciding the clearance between two abrasive surfaces for dehusking and splitting. It will also help in designing the cleaner and separator. Gravimetric properties such as bulk density and thousand grain weights are necessary in design and analysis of separation, design of hoppers and blowers, which are essential parts of a dhal milling equipment.

The results of the analysis of variance for the brokens, dhal recovery and dehulling index calculated during the milling tests are shown in **Table 2**. The F value was significant at 1 percent level of probability for brokens, dhal recovery and dehulling index for all the treatments. This indicates that each treatment performed differently while dehulling. The performance results of brokens, dhal recovery and dehulling index obtained in all the four treatments is shown in **Fig. 4**. The treatment T_4 recorded the highest dal recovery of 78.3 percent and lowest broken (4 percent), where as, treatment T3 registered the height broken of 11.25 percent with 66 percent dhal recovery. In treatment T_2, the dehulling index was highest 0.95; slightly higher than T_4. This could be explained by the fact that soaking of the grain in water for a longer

period usually caused cotyledons to swell and subsequent drying shrink the cotyledons by pulling away from the gummy layer (reduces tightness of the husk over the cotyledons) making it easy to remove husk during the milling process. In soaked grain, due to drying, the absorbed moisture defused out slowly leaving a considerable hollow space between the cotyledons. Consequently, the cotyledons became cup shaped from the original semi spherical shape. During milling the edges were broken away, increasing broken percent and powdering losses in milling. As a result, the over all dhal recovery was reduced to 70 percent, even though highest dehulling index of 0.95 was recorded (**Table 3**). The dhal obtained in the treatment T_2 was considered to be inferior in quality by the farmers and traders. Since there were no other options, farmers were resorting to this practice, which was more amenable to

conventional milling units.

Comparison of the results obtained with the dehuller in treatment T_3, in which the chickpea was first split using a huller, then treated with oil and finally fed to the machine to remove the seed coat, showed that the prototype was able to achieve an improvement in dhal recovery of approximately 9 percent when compared with traditional small scale units of 57 percent mean recovery (Singh and Jambunathan, 1990) for the same treatment. This indicated that the prototype was more efficient than the traditional processing unit in splitting the grain kernels during the milling and dehulling. The index is more or less equal to that obtained in the traditional process.

Study of the results obtained with the untreated grain (T_1) showed that, the prototype was not able to achieve dehulling efficiently, i.e. most of the hull fraction remained with the splits, hence the dehulling

Table 1 Physical properties of chickpea used in the study

Sl No.	Length, mm	Breadth, mm	Thickness, mm	Size, mm	Spherecity, mm	Bulk density, g/cm³	1000 grain weight, g	Husk content, %
1	8.57	6.24	5.96	6.83	0.81	0.76	191.02	13.50
2	8.69	6.32	6.05	6.93	0.80	0.79	185.00	12.80
3	8.32	6.15	5.51	6.56	0.78	0.73	199.05	15.00
4	9.06	6.79	6.37	7.31	0.82	0.75	193.90	14.00
5	8.96	6.80	6.20	7.23	0.80	0.78	190.50	12.20
Mean	8.72	6.46	6.018	6.972	0.802	0.762	191.89	13.50
SDm	0.298	0.3117	0.3238	0.3051	0.0148	0.0238	5.135	1.081

Fig. 4 Effect of different treatments on brokens, dehulling index and dhal recovery of chickpea
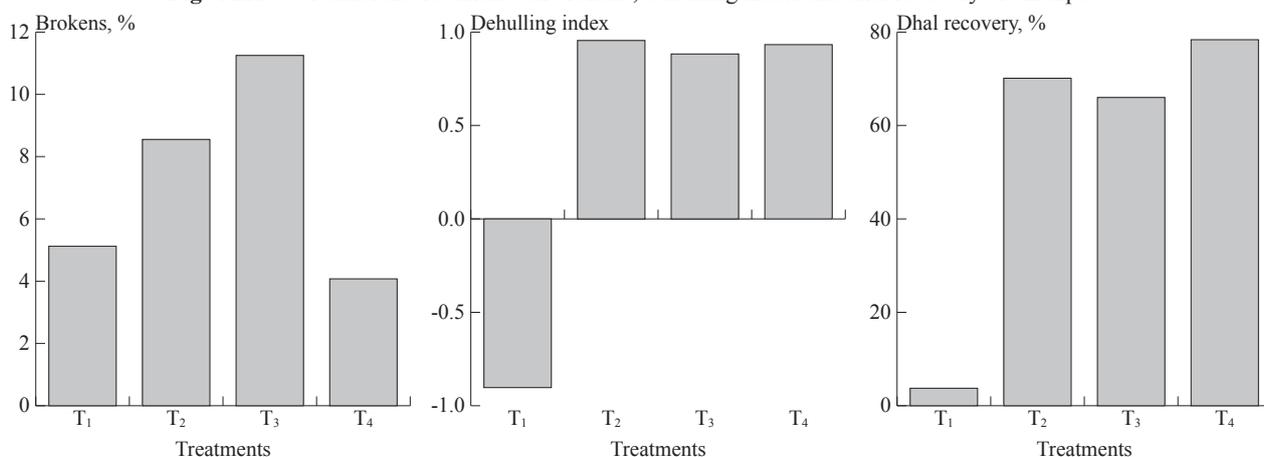
index was found to be negative. The over all results obtained in these experiment indicated that there was a substantial improvement of the dehulling index by milling tempered and conditioned grain (T_4) using the prototype compared to dehulling of T_2 and T_3 treatments which were conventionally used. The dhal recovery levels from the prototype dehuller were also substantially higher compared to conventional milling units. In addition, the yields obtained were comparable with large scale commercial milling units where the yields varies between 70-80 percent (Singh and Jambunathan, 1990).

Conclusions

A small capacity prototype dehuller for pretreated chickpea incorporating basic principles from both traditional and mechanical dehulling systems was developed. The performance of the prototype was evaluated using four treatments consisting of both traditional and improved pretreatment methods. The grain scratched and moistened to 18 percent moisture content for 4 hours followed by sun drying16 hours yielded a dehulling index of 0.93. This indicated that most of the grain was fractionated into hulls and cotyledons. The dehulling index of the unconditioned control sample was -0.90 indicating that most of the grain sample was either broken or remained unhulled.

Comparison of the results obtained from the conventional treatments revealed that an average of 9 and 13 percent improvement in dhal recovery was achieved using the abrasive dehuller. The over all results indicated that it was possible to obtain higher recovery levels and higher dehulling index with the newly developed prototype dehuller than conventional milling units.

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■■

Table 2 Analysis of variance for brokens, dehulling index and dhal recovery

Source	df	SS	MS	F
Brokens				
Replications	3	7.755	2.585	
Treatments	3	129.145	43.048	7.03**
Error	9	55.140	6.127	
Total	15	192.040		
Dehulling index				
Replications	3	0.008	0.003	
Treatments	3	10.012	3.337	2,280.68**
Error	9	0.013	0.001	
Total	15	10.033		
Dhal recovery				
Replications	3	75.563	25.188	
Treatments	3	14,087.810	4,695.938	270.81**
Error	9	156.063	17.340	
Total	15	14,319.440		

** = Significant at 1 % level

Table 3 Table of means for brokens, dehulling index and dhal recovery

Sl. No.	Item	T_1	T_2	T_3	T_4	Mean
1	Rank	3	2	1	4	
	Brokens, %	5.125	8.550	11.250	4.075	7.250
2	Rank	1	4	2	3	
	Dehulling index	-0.903	0.955	0.883	0.933	0.467
3	Rank	1	3	2	4	
	Dhal recovery, %	3.75	70.125	66.00	78.375	54.562

Study on Intelligent Measurement and Analysis System of Soil Electric Conductivity

by

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Abstract

A Virtual Instrumentation (VI) based instrument capable of fast acquiring and real-time measuring soil EC was designed. This VI system consisted of a DAQ card 6024E, an EC sensor, a temperature sensor, and signal conditioning modules. Compared with traditional instrument, VI is different in system development and design due to the application of common graphical language LabVIEW. So the critical technologies VI and software design was analyzed and discussed. Considering the influence factor of soil temperature, the temperature correction method was proposed to eliminate measurement errors automatically. So the instrument could measure soil EC at various temperature immediately. In addition, functions, such as data display, data storage, data print and network transmitting, were also realized. The precision tests of three KCl standard solutions (different concentration) have been done and the results showed the instrument had high accuracy and strong stability. This study provides a convenient method for valid measurements of multi-parameters.

Introduction

With the development of agricul-tural information technique and precision farming, the soil EC measurements have been increasingly gaining attention. In terms of dielectric physics, the soil EC measurements belong to the field of theory and methodology research of dielectric wastage measurements. In recent years, the research of agrology shows that soil EC contains abundant information about soil characteristics and physical properties, which include soil salinity, water content, temperature, organic matter content and texture. In developed countries, it is a hotspot of precision farming research to evaluate the growth condition of a crop by measuring soil EC.

However, at present, there are few instruments for measuring soil EC and most of them can not reach fast and accuracy requirements in the agricultural information acquiring process because of the main defect, most of the traditional instruments use hardware entirely, which results in difficulties to realize temperature compensation that can calibrate the measurement bias. Besides, it is too complicated to use a mathematical model (e.g., four-electrode measurement method) for its excessive involvement of physical and mathematical methods, although its accuracy is high (Yurui and Maohua, 2001). In order to overcome the drawback mentioned above, the major task is to develop an application program that can efficiently collect data and timely process them to replace the traditional instruments. To this purpose, we have designed the virtual instrument to acquire and measure the soil EC. This instrument was designed to synchronously gain real-time soil EC and soil temperature from sensors, and exteriorly calibrate soil EC via temperature correction.

Development Tool

Current software for data acquisition (DA) is increasingly using the virtual instrument (VI) concept, which is a software emulation of a physical instrument. Virtual instrumentation enables developers to design custom instruments with functionality defined by the user and suited for particular application. Unlike other types of DA software, a VI combines ease of use and flexibility, with the possibility of re-use

Fig. 1 Graphical user interface panel of a LabVIEW program taken from the sample library
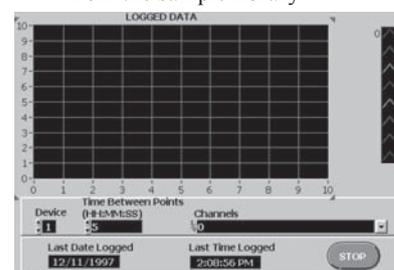
of developed modules for new application. The graphical programming language LabVIEW by National Instruments was used to create a soil EC measurement system on the windows PC platform. It was designed for programming data acquisition, data handling and data display (Kodosky et al., 1991). "The software is the instrument" is not just an advertisement but describes the aim of the software package. It allows creating sub-programs referred to as 'virtual instruments' that operate the same way as real instruments-0. A VI consists of two windows, the front panel (**Fig. 1**) and the block diagram (**Fig. 2**). The front panel (with knobs, switches, graphs, and so on) is the graphical user interface. The block diagram, which is the executable code, consists of icons that operate on data connected by wires that pass data between them. Standard blocks are available from extensive instrument libraries; these deal with data acquisition, signal generation, instrument control as well as data analysis and presentation. Advanced data processing and visualization is accomplished in a separate VI, which receives previously stored data. The program is quite flexible since it can be modified, according to particular needs, at any time by the operators.

Measurement and Design

Hardware Design

The measurement instrument mainly consists of an EC sensor, a temperature sensor, a signal conditioning module and a data acquisi-

tion card, hosted by a personal computer. The hardware structure of the instrument is shown in **Fig. 3**.

1. Two sensors. The EC sensor was used to acquire soil EC voltage signal, and the temperature sensor acquired its corresponding temperature voltage signal. These constituted signal sources of the measurement system.
2. Signal conditioning module. Not all sensors produced a perfect voltage for a DAQ device to measure, since the signal could be too noisy, too small, or too large for the range of the DAQ device. This module altered the signals before the DAQ card could reliably and accurately acquired them.
3. DAQ card. This was a plug-in device providing the capability to digitize the conditioned analog signal. The computer can then analyze and present the digitized and conditioned signal.
4. PC. It was regarded as a control and processing unit, and provided a service platform on which we could perform operations such as measure, save, display and etc.

Measurement Methods

Generally, EC sensors are adopted for soil EC measurements, considering artificial compensation needs to be made for the bias of temperature and distributing capacitance if using traditional EC meters. Concretely, select the conductance electrode type SDL-1, made by Wuhan neng-

shi chemistry Ltd., as soil EC information receiver. The measurement method of resistance allotting voltage was used (**Fig. 4**).

In the **Fig. 4**, R_x was conductance electrode and R_m was exterior resistance with value 100 kΩ. Instead of DC, an AC signal source was utilized in the circuit to avoid appearing polarization phenomena that would probably result in influencing the measurement precision. The voltage range of signal source was 6-10 V and frequency was 50 Hz. In addition, a high frequency should be adopted in case of high EC values. A temperature sensor whose type was LM35/34 was used to acquire soil temperature information. It was noticeable that the sensor should be calibrated with ice water before using it (Jun and Fuhai, 2000).

The voltage of signal power U_0 and electrode U_1 were acquired, then the conductance value of electrode could be worked out according to **Fig. 4**. The expression is (Wentong, 1995):

$$G = \frac{U_0 - U_1}{R_m U_1} \quad \text{................................(1)}$$

In succession, the EC value of solution being analyzed can be calculated utilizing the expression:

$$S = G \cdot K \quad \text{.....................................(2)}$$

Where G represented the conductance of the solution, S was the EC value and K was the EC cell constant.

There is a relationship between solution EC and its temperature. The ionization capability of the so-

Fig. 2 The program code of the application of Fig. 1 in the "diagram" window
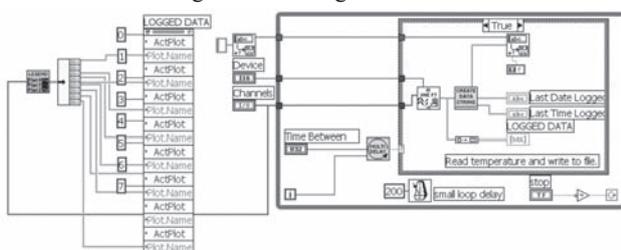
Fig. 3 Hardware structure of the measurement instrument
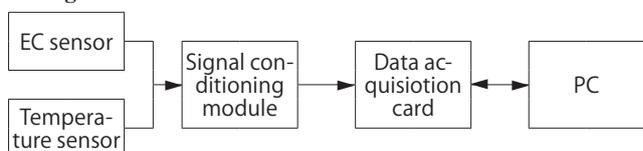
Fig. 4 The measureing circuit of the EC sensor
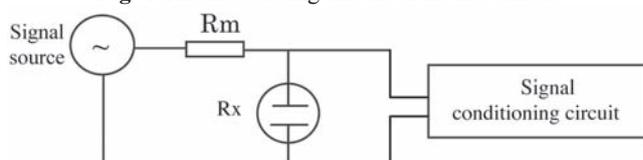
lution increases when temperature rises and then the EC is expected to increase. Therefore, considerable attention must be paid to it and the measurement error caused should be eliminated or minimized. In the process of measuring, the temperature should be kept as close as possible to 25 ºC and be held steady, otherwise the temperature correction should be made if the temperature is out of the limits of 25 ±0.5 ºC.

Referring to the relationship mentioned above, the EC at any temperature could be converted into the values at 25 ºC. The well-known expression of GB6908-86 is (Yonghui and Guangming, 1997):

$$S_{25} = \frac{S_t \cdot k}{1 + \beta(t - 25)} \quad ....(3)$$

where, S_t is the signal to be transformed, S_{25} is the conjugate of the St and β is the temperature correction coefficient. The formula (3) could be applied to correct measurement results.

Some preprocessing, including low-pass filtering and difference magnification should be done to the DC signals from the temperature sensor before converting it into digital signals, while an application program was adopted to process the AC signals from the EC sensor because its value was high.

Every DAQ card operated within LabVIEW requires a special driver. Consequently it was decided to use a data acquisition card manufactured by National Instruments (DAQ 6024E). The card is installed and can be tested by a utility called "NI-DAQ"; the installation of LabVIEW which runs automatically. LabVIEW is still very stable without any noticeable change after the automatic installation procedure. The card is the core of hardware that is completely "plug and play" for PCI bus computers and features 12-bit ADCs with 16 analog inputs and 200 KHz maximum sampling rate. It can be easily software-configured and calibrated (KrauB et al., 1999).

Software Solutions

The front panel (**Fig. 5**) of the VI is developed using the LabVIEW (Zebao and Linfeng, 1999; LabVIEW, 2000; Wells and Travis, 1997). The acquired signal is displayed as soon as new samples are available. Some controls allow the user to choose the sampling frequency, the number of points displayed and the analog channel to which the input signal is routed. The values assigned to these controls are inputs for the different blocks that constitute the diagram, shown in **Fig. 4**, for managing the acquisition process.

The VI program, if running, starts the samples acquiring, and allows display of the time-domain shape of the temperature and the voltage along with the value of its amplitude (**Fig. 6**). Once the samples are acquired, the expressions aforementioned are applied to the displayed samples through which leads to on-line processing, while, the results such as soil EC and soil temperature

Fig. 5 Front panel of measuring program of soil EC
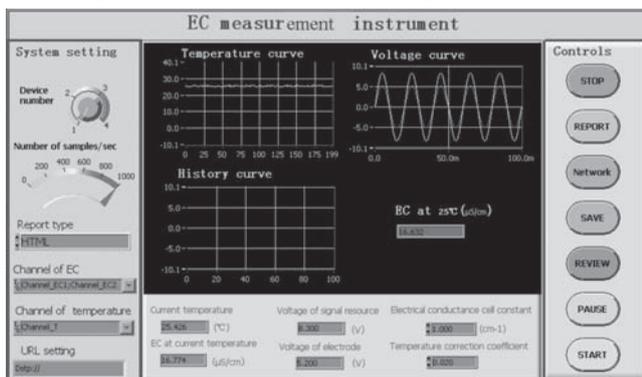
Fig. 6 Block diagram of data collection program of the measuring instrument for soil EC
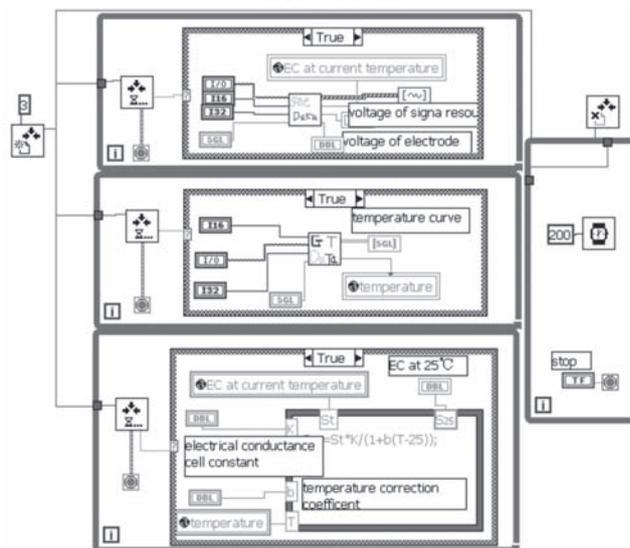
Fig. 7 The distribution map of soil EC at testing field

Table 1 Comparison of test results and standard velues

Materials	Test values, μ S/cm	Standard values, μ S/cm	Relative errors
KCl (1 mol/L)	111,850	111,342	0.46 %
KCl (0.1 mol/L)	12,935	12,856	0.61 %
KCl (0.01 mol/L)	1,390	1,408.8	-1.33 %

are displayed on the panel. The last samples displayed are then saved as an Excel file, or graph saved as a BMP file if "SAVE" button is pressed. Pressing the "REPORT" button causes the report forms to print that have existed, and the "REVIEW" button causes the data in the memory to be retrieved and displayed. Each press of the "STOP" button causes the acquisition process to stop, and the "PAUSE" button causes a pause in the same way.

In order to accomplish network functions, the modules such as telnet, ftp and email provided by Lab-VIEW software package are utilized to carry out remote logging in, mail sending, data transmitting and web publishing. Moreover, the graphics can be spread on real time due to using Datasocket tool.

Performance Verification and Experimental Results

The verification test of the measurement VI has been performed by measuring the KCl standard solutions, which are usually applied to calibration nicety of EC measurement instrument, by the reason of those EC values are stable at various temperatures and concentrations. During the verification, above all, the specific demands on experimentation were met according to national standard. Successively, three KCl standard solutions of various concentrations were collocated, which were 1 mol/L, 0.1 mol/L and 0.01 mol/L. Finally, the EC values were obtained by using this measurement VI. The comparison of the test results at 25 ºC with their standard values are illustrated in **Table 1**. It shows that the test results approach to their standard values, and the relative errors are small to some extent.

To obtain soil EC in a scientific way, a measurement experiment was performed in a typical farm field of Zhejiang province. The area

of the test field was about 33 acres, and the hypsography of the field was relatively low in the west and north sections while high in other sections. The map of soil EC of the testing field was determined using the following procedures:

· Soil samples were respectively taken at depth 20 cm for each 50 m on the testing field, then 63 samples were put together.
· The samples were dried in an oven, and then diluted with water in the weight ratio of 3 to 1 (soil: water).
· The EC values of the samples were obtained using this virtual measurement instrument.
· The distance inverse ratio method and software Arc View were used to analyze the obtained values.

A distribution map of soil EC was eventually obtained as descried in **Fig. 7**. From the figure, the EC values were relatively great in the west section of the filed while small in other sections.

Conclusion

Aimed at drawbacks in traditional instrumentation of soil EC such as coarseness and low-accuracy, a new measurement VI (Virtual Instrumentation) for automatically measuring soil EC, was developed.

Aimed at improving the measurement accuracy of the new instrument, a suitable method of temperature correction based on a software program was applied to automatically eliminate measurement errors.

Aimed at testing the performance of the new VI, an experiment focusing on soil EC was carried out. After analyzing the results of the experiment, it was shown that the VI was fast and accurate in acquiring soil EC information.

Due to the application of software, the measurement VI had a friendly interface and was powerful

with its functions like data display, data storage, data print and network transmitting; it had qualities of real-time, convenience and flexibility.

The study of soil EC measurement has provided a methodology for validity measurements of multi-variations, and could be widely used in other fields.

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■■

Design and Development of a Machine for Aonla Seed Removal

by

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Abstract

A hand-operated machine for the removal of seed from the fresh aonla fruit was designed and developed. The machine consisted of fruit seat, fruit punching rod, handle and frame to hold all the parts. The machine had a capacity of 16.66 kg/h or 530 fruits/h. The waste that included the pulp and juice was recorded to be 10 percent. The cost of the machine calculated was Rs.650, in which only the seat and the punching rod were made of stainless steel and all others parts were of mild steel. The cost of operation, including the labor cost and depreciation was Rs.10.20 per h. The aonla fruit after removal of seed by the machine was used for the production of intermediate moisture food by osmotic dehydration which had a good consumer acceptance.

Introduction

Aonla (Emblica Officinalis) an edible fruit indigenous to tropical India and South East Asia, is a rich source of vitamin C, Pectins and tannins apart from pharmaceutical properties. Because of its unique nutritive and therapeutic qualities aonla is considered as "Wonder fruit for health", and it has extensive adoptability to grow in diverse climatic and soil conditions. The embolic fruit is spherical, smooth and has six ridges extending from the base to the apex that divide it into six months (Barthakur and Arnold, 1990). Aonla fruits are astringent, cooling, anodyne, carminative, digestive, stomachic, etc. and its medicinal and tanning properties have been reported by Rao and Siddique, 1964; Giri and Banerjee, 1986. The nutritional quality, ease of long distance transportation and Vitamin C stability are properties of the fruit that makes it of interest for commercial exploitation. In India, the area under Aonla has increased from just 3,000 hectares in the 1980's to 50,000 hectares in 2002 (Singh, 2003). Aonla fruit is available only for a short period (October to January), is highly perishable, and it is not consumed as fresh fruit due to its high acidic and astringent taste. Hence, it's processing and storage is essential. A number of processed products like aonla pulp, RTS, Nectar squash, candy, pickle, sauce, fruit toffee and dehydrated shreds are prepared from aonla fruits to improve their acceptability and exploit nutritional qualities, besides its use in ayurvedic formulations.

Seed are required to be removed from the fruit for most of preparations and fruits in full shape or sliced form are needed after seed removal for the development of value added products from Aonla.

The shredding and removal of seed from Aonla done are done manually due to non availability of suitable machines. Therefore, a hand-operated machine for removal of seed from Aonla fruit has been developed and its features and performances are reported in this paper.

Materials and Methods

The developed hand operated seed removing machine consisted of a fruit-punching rod, fruit resting seat, handle with extension and the frame to hold all the important movable parts. The parts of the machine coming in contact with fruit were made of stainless steel (food grade) and all other parts were made of mild steel. The whole machine was electroplated to avoid rusting of parts when it comes in contact with ascorbic acid present in the fruit. The hand-operated seed removing machine for Aonla is given in **Fig. 1**.

The fruit to be destoned is kept on the fruit seat on the platform, which has a hole at the centre of the seat. The solid rod connected to the handle punches the fruit with a shock load, which makes the seed portion of the fruit move down through the hole provided at the centre of the seat. After each punching, the seed will be removed and the fruit will have a hole at the center.

Fruit Platform and Seat

The fruit platform holds the fruit for punching. It is made with stainless steel plate, which is bent at different places to get the required

Fig. 1 Schematic diagram of Aonla destoning/seed removing equipment

Dimensions in mm

1	FRUIT PUNCHING ROD
2	GUIDER
3	FRUIT PLATFORM
4	BASE PLATE
5	FRAME
6	HANDLE
7	HANDLE EXTENSION

shape. A hole is made at the center of the platform which is surrounded with depression, which helps the fruit rest comfortably without any movement during punching. The dimensions are designed based on the physical properties of the aonla fruit.

The platform is made with a stainless steel plate of 2 mm thick, 60 mm width and 220 mm length. This plate is bent every 60 mm along the length to have the designed dimensions and bolting arrangements as shown in **Fig. 1**.

Maximum width of the fruit: 50 mm
Allowance on all sides: 10 mm
Size of the platform: 60 × 60 mm
The diameter of the hole is based on the maximum size of the aonla seed.
Maximum diameter of aonla seed: 17 mm
Diameter of the hole provided: 18 mm

For self-alignment of the fruit over the platform, a semicircular depression called the fruit seat is provided around the hole to a depth of 5 mm at the centre.

The platform is provided at certain height above the base plate so for collection of fruit core with seed.

Height of the fruit core: 45 mm
Clearance above and below the core: 15 mm
Height of the platform above base plate: 60 mm

Punching Plunger

Fruit punching plunger is a solid rod made of stainless steel hinged with the stand, which penetrates the fruit through a guider and removes

Table 1 Design specifications of the developed Aonla seed removing equipment

Parts	Dimensions, mm
Platform size	60 × 60
Seater hole	18
Punching plunger	
Diameter	12
Length	200
Length of handle	550
Frame plate	250 × 150
Height of frame	300

the fruit core with seed when the handle is moved down. The diameter was selected based on the standard diameter of the plunger available in the market. The diameter was selected as 12 mm.

The length was designed based on the length of stroke and link arrangements as

Stroke length of plunger: 60 mm
Length of the guider: 40 mm
Extension below guide: 10 mm
Distance between plunger hinge point and guide: 90 mm
Total length of plunger = 60 + 40 + 10 + 90 = 200 mm

Handle

The handle is an important component of the machine which works on the principle of lever mechanism and is used for transmitting the force required for punching the fruit.

Calculated force required for cutting the fruit (F_1): 16 kg
Assumption
Average force that a man can exert freely with hand (F_2): 3 kg
The position of the cutting point from hinge point - (L_1): 100 mm
Length of handle = ($F_1 \times L_2$) / F_2 = (16 × 100) / 3 = 533.33 mm
Length of handle = 550 mm
The movement of the handle will be an arc due to hinging at one end.
Stroke length: 50 mm
Vertical movement of handle at the cutting point based on the similar triangles: 500 × 50 = 100 × N
Movement of the handle (N) = (500 × 50) / 100 = 250 mm

Frame

The frame consists of base plate and vertical pipe, to which a handle, plunger and fruit seater are attached. The vertical pipe is welded to the base plate.

The frame consists of
Base plate: 250 × 150 mm
Height of frame: 300 mm

The base plate is provided with four holes on the corners to fix the machine onto the working table.

Performance Evaluation of the Machine

The performance of the developed Aonla fruit seed removing machine was evaluated based on its capacity, efficiency, percent pulp waste, per cent juice waste and percent pulp recovery. The capacity of the machine was determined by calculating time of operation and weight of the aonla fruits used for seed removal. The capacity was also calculated in terms of number of fruits, since the time required for deseeding a small or large fruit is almost the same. The efficiency of the pulping was calculated based on the amount of pulp that could be obtained by the machine from the total amount of pulp present in the fruit.

Efficiency of Pulping = Amount of pulp out put along with de-seeded fruit / Total amount of pulp present fruit

The recovery percent indicates the capacity of the mechanism to recover the fruit pulp with respect to the total weight of the fruit including seed.

Recovery percentage = Weight of the pulp recovered / Total weight of the fruit

The economics of the developed machine was estimated by considering the cost of the raw materials, overhead charges and labor charges. The cost of operation was calculated by estimating the fixed cost and variable cost.

Results and Discussion

The specifications of the developed hand operated destoner/seed removing machine is given in the **Table 1**.

Performance Evaluation of the Machine

The capacity of the machine was found to be 16.66 kg/h and 530 fruits/h. The capacity of the machine was also determined on per day basis, which was 128 kg/day and 4,240 fruits/day, which a single labor can operate. Manual removal of seed is very laborious because of the hardy nature of the fruit; hence, the fruit needs prior blanching to remove the seed, which causes the loss of valuable nutrients. The developed machine would be useful to remove the seeds from the fresh fruits and the deseeded fruits could be used for juice extraction without any loss of nutrients. The fresh fruit after the removal of seed could also be used for the preparation of value added products and intermediate moisture foods. The fresh Aonla fruit and fruit after removal of seed is shown in **Figs. 2** and **3**.

The mean value for efficiency of pulping was 90.65 percent. The 10 percent loss was due to adherence of hard fibers along with some pulp attached to the seed and draining of juice during the punching operation. It was found that 7.75 percent of pulp and 2.1 percent of juice was going as waste along with seed. The loss of pulp might be due to structural arrangement of the seed present almost at the center of the fruit, which was also removed while punching with a solid rod and the loss of juice might be due to shock load application. The recovery percent of the developed mechanism was was 86.3.

Cost Economics

The cost of the newly developed machine was Rs.650. The cost of operation calculated was Rs.10.2 per hour.

Fig. 2 Three varities of fresh Aonla fruit
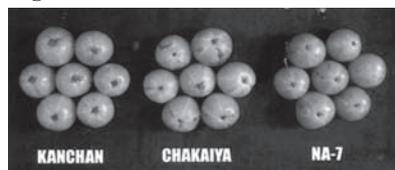
Fig. 3 Aonla fruit after seed removal
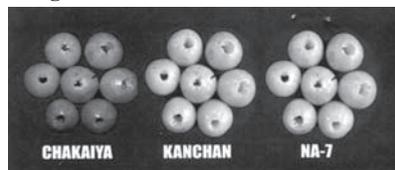
Conclusions

A hand operated machine for the removal of the seed from Aonla fruit was designed and developed. The developed machine had a capacity of 16.66 kg/h and 530 fruits/h. The waste that included the pulp and juice during seed removal was 10 percent. The efficiency of pulping was 90.65 percent. The cost of the machine was Rs.650, in which the fruit platform and the punching rod were made of stainless steel and all others parts were of mild steel, which was electroplated. The cost of operation including the labor cost, depreciation and interest was Rs.10.2 per h. The developed machine could be used to remove seed from the fresh Aonla fruit and the deseeded Aonla fruit could be used in full shape for further value addition.

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Fig. 4 Aonla seed removing equipment

Agricultural Mechanization in Bangladesh

by

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Abstract

In Bangladesh about 52 percent of the work force are engaged in the agriculture sector, which contributes about 21 percent to the gross domestic product. This indicates a very low labour productivity. It can be enhanced through increased use of agricultural machinery. High yielding varieties cover more than 80 percent of the production of rice, wheat, maize and potatoes. Use of fertilizers and agrochemicals are increasing every year. Water pumping for irrigation was first mechanized and, at the present time, 55 percent of the cultivable area is under irrigation, mainly by pumped groundwater. The next operation that has been mechanized is the tillage operation mainly done by power tillers (single axle hand tractor) as the average farm size is very small. At present about 80 percent of the land preparation is by power tillers and tractors. The next operation that is being rapidly mechanized is threshing. Farm power availability was only 0.24 kW/ha in 1960, which has increased to 1.05 kW/ha in 2006. It is expected that the power will continue to increase further at a faster rate as there are many important agricultural operations that are yet to be mechanized. Due to various reasons, the degree of mechanization as well as contribution of agriculture to gross domestic product varied in different regions. With the increase of farm power availability and fertilizers, the
yield of crops continued to increase. Engines of shallow tubewell pumps are also widely used to power country boats, small three wheelers, rice mills, etc. Power tillers are used to some extent for haulage, but tractors are mainly used for this purpose.

Introduction

Bangladesh is a big delta plain formed by the three great rivers Ganges, Brahmaputra and Meghna (GBM). A total of 700 rivers flow throughout the country having a total length of 22,155 km (BBS, 2002) covering the country like veins and arteries of a human body, and flowing down to the Bay of Bengal. Out of these rivers, 57 originate from India and Mayanmar (Zaman, 2000). The country is bordered by India on the east, west and north and by the Bay of Bengal on the south. There is also a small strip of border with Mayanmar on the southeastern edge (**Fig. 1**). The country is situated in the northeastern part of South Asia, between 20º34′ and 26º38′ North latitude and 88º01′ and 92º41′ East longitude.

Area, Climate, Soils, Rainfall Pattern and Agricultural Resources

Bangladesh has an area of 147,570 sq. km, i.e. 14.75 mha of which 8.29 mha is cultivable land. Of the cultivable land 7.19 mha, i.e. 87 percent is cultivated. It has a tropical and sub-tropical monsoon climate.

Sweltering heat and high humidity prevail for major part of the year. Though the country has six seasons - summer, rainy, autumn, late autumn, winter and spring, four seasons are quite distinct. They are summer, rainy, autumn and winter. Monsoon starts in June and continues up to August. Rainfall during this period varies from 1,600 to 2,000 mm in the west, 2,000 to 4,000 mm in the southeast and 2,500 to 4,000 mm in the northeast. On an average, 61 percent of annual rainfall occurs during this period and only 3.5 percent during November to March (Rabi season) (Manalo, 1980). The country on an average receives about 2,030 mm rainfall annually ranging from 1,033 mm (in the northwest) to 5,412 mm (in the northeast). The country faces drainage problem during the rainy season, which in some years turns into heavy flood inundating as high as two-thirds of the country. **Fig. 2** shows the average monthly rainfall and evaporation of Dhaka, which is a typical representation of many areas of the country. It is conspicuous from the figure that during the Rabi season, crop production suffers if irrigation is not applied.

The winter, from December to February, is quite pleasant. The average minimum temperature ranges from 7.2 to 12.7 ºC and the maximum from 23.9 to 31.1 ºC. The mean temperature during the coolest month (January) ranges from 17 to 19 ºC with December and February 1 to 2 degrees hotter.

The soils of Bangladesh were developed mainly by the silt deposition of the major rivers. Major soils vary in both their nature and potential for agriculture. These are classified into three broad categories - floodplain soils, hill soils and terrace soils. The flood plain soils comprising fourteen different soil types include 79 percent of the total land area (BBS, 2002).

The floodplains of the GBM and smaller rivers occupy an area of smooth, very gently undulating relief comprising broad and narrow ridges and depressions. Differences in elevation between adjacent ridges and depressions range from about 1 meter on tidal plains (near the coast), 2 to 4 m (on Ganges and Brahmaputra river floodplains) and 5 to 6 m in the Northeast. In the extreme northwest, elevation exceeds 20 m above mean sea level (GOB and FAO, 1988). Except the depression sites and highly permeable soils, the floodplain soils are suitable for cultivation of most of the crops. The hill soils comprise 12.7 percent of the total land area and include a wide range of soils developed over consolidated and unconsolidated sandstones, siltstones and shales which underline the northern and eastern hills. Most of hill soils are not suitable for agricultural production due to its steep slopes and soil erosion during the monsoon. Fruit and timber production are the main use of this soil (GOB and FAO, 1988).

The terrace soils have an area of 8.3 percent and have formed over Madhupur clay on uplifted fault block which mainly stands a few meters above flood levels on adjoining floodplains. The agricultural potential of these soils is only moderate to low.

In Bangladesh sunlight, sufficient rainfall and reserved soil moisture favour year round crop growth. During monsoon, most of the cultivable lands remain submerged, thereby rice, jute and sugarcane are the main

crops in the water logged situation (Ahmed and Meisner, 1996).

Rice occupies 77 percent of the total cropped area of about 13.9 mha (Bhuiyan et al., 2002) and uses 82 percent of the irrigated water (BBS, 2002). Of the total water used for irrigation, boro rice (grown during the Rabi season) alone consumes 72 percent of the irrigation water. Aman rice covers about 51 percent of the total rice area, followed by boro rice that covers 39 percent and aus rice 10 percent. The other major summer crop is jute. Wheat, potatoes, pulses (lentil, grass pea, chickpea, etc.), oilseeds (mustard, rapeseed, groundnut, etc.) and winter vegetables are the main crops of the winter season.

Bangladesh has a population of about 146 million making it the most densely populated country in the world excluding city or island states. It is an agricultural county where 52 percent work forces are engaged in agriculture. Agricultural sector contributed 21 percent to the gross domestic product of which crop sub-sector contributed 12 percent. Sixty six per cent of the families are engaged in agriculture. It was a food deficit country until 1999 when the country became self-sufficient in cereal grains. This was possible due to expansion of irrigated area to 4 mha out of cultivated area of 7.2 mha, i.e. presently about 55 percent of the cultivated area is under irrigation. Irrigation of Bangladesh is heavily dependent on groundwater

irrigation. In 1971, during the year of independence, the contribution of groundwater to irrigation was only 3 percent. At present its contribution has increased to 80 percent.

The area, cropped area, population, population in agriculture, average farm holding size and contribution of agriculture to GDP are shown in **Table 1**. As population census was done every 10 years beginning from 1951, population shown in 1950, 1960 so on are that of 1951, 1961 so on. During 1971 it was not done due to the war of liberation. The first census after the liberation was done in 1974, then in 1981 and so on. The population of 2006 is the estimated figure based on the population census of 2001 assuming 1.54 percent population growth. Agricultural census is not done every year and was done in only1983-84 and in 1996, therefore, average farm holding size of only those two years are given.

Agricultural Production, Irrigated Area, HYV, Fertilizer and Pesticides
Agricultural Production

Table 2 shows the area, production and yield of major crops. From the table, it is seen that the area, production and yield of rice have increased steadily. This is an indication of government's priority on attaining self-sufficiency in cereal production, especially the staple food rice. The area, production and yield of wheat have grown steadily up to 2,000, and

Table 1 Area, population, farm holding size and contribution of agriculture to GDP

Year	Net cropped area, mha	Total cropped area, mha	Population, million[a]	Population in agriculture, %	Ave. farm holding size, ha	Contr. of agr. to GDP, %
1950	8.13	n.a.	41.93	n.a.	n.a.	n.a.
1960	8.33	n.a.	50.84	85[d]	n.a.	n.a.
1970	8.81	13.29	71.48[b]	79[e]	n.a.	59.4[c]
1980	8.45	12.94	87.12	57[f]	0.91[i]	54.10
1990	8.35	14.06	111.46	66[g]	n.a.	36.85
2000	8.13	14.27	123.15	62[h]	0.68[j]	25.58
2006	8.03	15.05	145.90	51.7	n.a.	21.17

n.a.= not available, [a]= Population of 1951, 1961 so on, [b]= Population of 1974, [c]= Data of 1973, [d]= Data of 1961, [e]= Data of 1974, [f]= Data of 1985-86, [g]= Data of 1990-91, [h]= Data of 1999-2000, [i]= Data of 1984, [j]= Data of 1996

then declined due to weather hazard, low price and competition with rice, maize, potato and vegetables. On the other hand, the area, production and yield of maize are steadily increasing due to high price of grain, less problem with weather hazards and good marketing facilities. Usually traders buy maize cobs or grain from the farmers' field or home. Introduction of hybrid varieties almost doubled the yield; therefore, farmers are getting much better yield and price. It may be mentioned here that, with the tremendous growth of poultry industries throughout the country, the demand of maize grain has increased tremendously and the present production of 0.78 million ton can only satisfy about 52 percent of the demand.

Almost all the grains are shelled by power operated maize sheller developed by the Bangladesh Agricul-

tural Research Institute (BARI) and a small portion by BARI-developed hand maize sheller.

With the advancement of plastic industries, jute cannot compete with plastic materials in the world market; therefore, its production is decreasing. However, the price of jute during the last three years (2004-2006) was high, therefore, farmers are increasing its cultivation. A few entrepreneurs are exporting diversified jute products that created a good demand for jute. Though, with the population growth, the demand for sugar is increasing, its production is not increasing because of competition with high value crops like vegetables, spices and fruits. At present, only about 10 percent of the demand (1.2 million ton) is satisfied by local production. Similarly the production of pulses and oilseeds are not increasing with the popula-

tion growth, again due to competition with rice and other high value crops. Though rice is not a high value crop, farmers want to grow it because of food security.

Irrigated Area

Table 3 shows the irrigated area of Bangladesh starting from 1962 as that was the year when mechanized irrigation started in Bangladesh (then East Pakistan) by Bangladesh Agricultural Development Corporation (BADC) to irrigate high yield variety (HYV) boro rice (rice grown during November-December to April-May). Power operated centrifugal pumps are used to lift water from surface sources like rivers, canals, ponds, extended marshy lands, road-side ditches, etc. As its suction head is low, it is called low-lift pump (LLP) or power pump. Six different sizes (14, 21, 28, 56, 84

Table 2 Area, production and yield of major crops of Bangladesh

Year	Rice			Wheat			Maize			Jute		
	Area, mha	Prod., mt	Yield, t/ha	Area, mha	Prod., mt	Yield, t/ha	Area, mha	Prod., mt	Yield, t/ha	Area, mha	Prod., mt	Yield, t/ha
1950	7.90	7.38	0.93	0.039	0.023	0.59	0.0049	0.003	0.61	0.63	0.61	0.96
1960	8.56	8.48	0.99	0.056	0.029	0.52	0.0028	0.002	0.71	0.56	0.99	1.77
1970	9.66	10.75	1.11	0.12	0.103	0.86	0.0032	0.003	0.94	0.93	1.19	1.28
1980	10.16	12.54	1.23	0.43	0.83	1.88	0.0020	0.001	0.50	0.76	1.08	1.41
1990	10.41	17.71	1.70	0.59	0.89	1.50	0.0035	0.003	1.00	0.54	0.84	1.50
2000	10.71	23.07	2.15	0.77	1.84	2.21	0.0220	0.120	5.35	0.41	0.71	1.73
2006	11.25	29.75	2.64	0.48	0.77	1.60	0.1300	0.780	5.72	0.40	0.75	1.88

Year	Sugarcane			Pulses			Oilseeds			Potato		
	Area, mha	Prod., mt	Yield, t/ha	Area, mha	Prod., mt	Yield, t/ha	Area, mha	Prod., mt	Yield, t/ha	Area, mha	Prod., mt	Yield, t/ha
1950	0.09	3.10	33.70	0.40	0.27	0.68	0.29	0.12	0.42	n.a.	n.a.	n.a.
1960	0.11	3.61	32.82	0.32	0.19	0.59	0.35	0.18	0.51	0.047	0.26	5.53
1970	0.16	7.51	36.04	0.35	0.26	0.74	0.34	0.31	0.91	0.850	0.85	10.00
1980	0.15	6.34	43.63	0.33	0.21	0.64	0.31	0.24	0.78	0.096	0.90	9.38
1990	0.19	7.40	39.80	0.74	0.51	0.69	0.57	0.43	0.77	0.110	1.07	9.15
2000	0.17	6.90	40.53	0.50	0.39	0.79	0.44	0.41	0.93	0.240	2.93	12.06
2006	0.08	3.59	44.88	0.63	0.59	0.94	0.58	0.63	1.08	0.370	5.37	14.51

Year	All vegetables			All fruits			All spices		
	Area, mha	Prod., mt	Yield, t/ha	Area, mha	Prod., mt	Yield, t/ha	Area, mha	Prod., mt	Yield, t/ha
1950	0.221	1.094	4.95	0.145	0.568	3.92	0.105	0.162	1.54
1960	0.119	0.569	4.78	0.055	0.277	5.04	0.111	0.225	2.03
1970	n.a.	1.749	n.a.	n.a.	n.a.	n.a.	0.164	0.378	2.30
1980	0.123	0.773	6.28	0.133	1.31	10.6	0.154	0.297	1.93
1990	0.163	1.058	6.49	0.151	1.39	8.6	0.148	0.330	2.23
2000	0.242	1.529	6.32	0.162	1.36	5.6	0.252	0.401	1.59
2006	0.650	7.787	11.52	0.385	4.60	11.95	0.450	1.693	3.76

and 120 lps) of pumps are used with 14, 28 and 56 lps being common. BADC stopped the LLP programme in 1990. Tubewell irrigation started with sinking of 380 deep tubewells (DTW) having 56 lps turbine pump by Bangladesh Water Development Board (BWDB) during 1961-66. BADC started sinking DTW in 1967-68 and continued up to 1992. After that DTW have been installed by private owners and others. Shallow tubewell (STW) irrigation started in early 1973 and in 2006 covered 67 percent of total irrigated area. These tubewells have a capacity of 10 to 21 lps.

Use of HYV

Table 4 shows the use of high yielding varieties (HYV) of rice. They were introduced in the 1960s. In the table production of local and HYV and the percentage of HYV are shown. In 1970, only 8 percent of rice production was HYV, it has increased to 77 percent in 2000 and to 87 percent in 2006. For wheat, potato and other crops, data on use of HYV are not available on a regular basis, therefore, are not given. At present, 100 percent of wheat production is of HYV. For potato, this figure is 80 percent. In recent years, farmers are planting mainly hybrid maize seeds, which are giving much higher yield than the composite varieties. Most of the important vegetables are of HYV, which has increased the vegetables production in recent years.

Fertilizer and Agro-chemicals

The use of chemical fertilizer in Bangladesh started in the 1960s.

With the introduction of high yielding varieties, their use became popular. Similarly, the use of agrochemicals (pesticides) became popular among farmers after the 1970s. Table 5 shows the use of fertilizers and agro-chemicals. Fertilizer use includes N, P_2O_5 and K_2O, not sulphur and zinc which have become very common. Agrochemicals include insecticides, fungicides, herbicides and rodenticides.

Farm Power Sources

Farm mechanization in Bangladesh started with the mechanization of water pumping for irrigation. Introduction of HYV rice triggered the rapid expansion of irrigated area. At present about 55 percent of cultivated area is under irrigation coverage. Next operation that has been mechanized is the tillage operation. Before mid 1960s, the entire land preparation work used to be done by bullock-drawn plough. After that a few large public sector farms and commercial establishment like tea estates started using tractors and power tillers. Because of the high initial cost of the equipment, cost of cultivation by these was not competitive with bullock-drawn plough. BADC had tried to introduce tractors among farmers on rental basis

during 1970s, but the programme could not succeed due to lack of spare parts and technicians, poor management, fragmented lands and various other reasons. In 1977-78, the public sector involvement in tillage operation was abandoned. A good number of power tillers (PT) were imported from Japan. The price was so high that only a few rich farmers bought them. Therefore, its use did not increase much.

In the beginning, extension of irrigation facilities was the responsibility of the BADC. Before marketing any farm machinery (mainly tractors, power tillers, pumps, engines for irrigation pumps and sprayers), these required certification by the "Agricultural Machinery Standardization Committee" of the Ministry of Agriculture. Though the system ensured high quality machinery, only a limited makes and models of machinery having relatively higher price were available in the market. Also the standardization procedure was time consuming. During the devastating flood of 1988, many draft animals died that created draft power shortage. The government abolished the standardization requirements in the same year and made the market open for import of agricultural machinery at a nominal

Table 3 Irrigated area with different mechanized irrigation devices

Year	Deep tubewell		Shallow tubewell		Low-lift pump		Total irrig. area, mha
	No.	Irrig. area, mha	No.	Irrig. area, mha	No.	Irri. area, mha	
1962	-	-	-	-	1,555	0.03	0.03
1970	940	0.01	-	-	17,846	0.26	0.27
1980	9,795	0.24	11,280	0.06	37,389	0.60	0.89
1990	22,412	0.45	252,500	1.13	56,500	0.49	2.06
2000	25,100	0.52	757,100	2.64	71,600	0.65	3.81
2006	28,289	0.70	1,182,525	3.12	119,135	0.80	4.62

Table 5 Use of fertilizer and pestcides

Year	Fertilizer use, kg/ha	Agro-chemicals use, kg/ha
1970	13	-
1980	37	0.25
1990	94	0.69
2000	137	1.92
2006	205	3.35

Table 4 Production of HYV rice

Year	Rice production, million ton			Percentage of HYV
	Local	HYV	Total	
1970	10.86	0.92	11.78	8
1980	8.12	4.42	12.54	35
1990	7.57	10.13	17.70	57
2000	5.35	17.72	23.07	77
2006	3.93	25.82	29.75	87

tariff. As a result, a large number of power tillers and small diesel engines started pouring into the country, mainly from China. The price of a Chinese power tillers is about US $ 800. This price is affordable to large and medium farmers. As a result, population of power tillers has increased rapidly in recent years and is still continuing. Even some small and landless farmers have bought these to provide custom services to farmers. It is estimated that at present about 300 thousand power tillers are in use in Bangladesh, which perform tillage operations in 80 percent of total cropped area.

The next operation that is rapidly being mechanized is threshing. Previously rice used to be threshed by bullock treading, hand beating and pedal thresher. With the reduction of cattle population and rapid increase in engines for irrigation pumps and power tillers, use of power threshers has increased in recent years. Table 6 shows the number of power sources in agriculture. Animal population of 1960, 1977, 1984, 1989 and 1996 are available. Therefore, farm power availability has been calculated for those years. Population in agriculture is not available for every year; therefore, it has been estimated for the year under consideration. Irrigation sector was developed by BADC. During 1990s, they with-

drew from the sector and private sector is doing the development of the sector. BADC now surveys and monitors the irrigation equipment every year, therefore, data on number of DTW, STW and LLPs are available. On the other hand, no organization has been given the responsibility of collecting data on the number of tractors, power tillers, threshers, shellers, sprayers, etc. Therefore, no reliable data are available on their numbers. The numbers shown are secondary data collected from importers, manufacturers and other sources. It is estimated that in 2006, about 12,500 tractors are in use in the country, but most of them are used for haulage. Only 3,000 are used for tillage operation.

In **Table 6**, two kinds of threshers are shown. The open drum thresher is the longer version of pedal thresher with engine of 3 to 4.7 kW fitted at one end. Three to four persons, including women, hold bundles of paddy at a time on the rotating drum. Closed drum thresher is the axial-flow type thresher operated by 6.5 to 7.8 kW engines. With the increase of maize production, the number of maize shellers is increasing. It is operated by 6.5 to 7.8 kW engines. Threshers and shellers are manufactured by a large number of manufacturers in different parts of the country. About 70 percent of the

threshers and shellers are operated by engines of irrigation pumps or power tillers. So while calculating farm power available in kW/ha, it is assumed that 30 percent of the threshers and shellers are operated by additional engines bought entirely for these operations. Power rating of each unit is shown in **Table 6**. Farm power availability was only 0.24 kW/ha in 1960, it has increased to 0.50 in 1989 and 1.05 kW/ha in 2006. The increase has been rapid in recent years and it is expected that this increase will continue further in future years.

Farm Implements and Equipment Used

In addition to the implement and equipment listed in Table 6, some other equipment are also used. At present about 250 power tiller operated seeders are used and it is expected that the next operation that will be mechanized is sowing. Both power tiller operated seeder for upland crop and manually operated plastic-made drum seeder for sowing rice in puddled field will be popularized. Manually operated weeders and sprayers are very widely used. The population of weeders is about 200,000 and sprayers is about one million. A few hundred pedal and power operated winnowers are also used.

Table 6 Population of different power sources in agriculture in different years

Source	Power rating, kW	Year					
		1960	1977	1984	1989	1996	2006
Animal (million)							
Bullock	0.180	6.7	7.61	7.69	8.26	8.34	8.30
Cow	0.135	2.82	3.32	2.13	3.30	3.42	3.70
Buffalo	0.746	0.23	0.24	0.34	0.34	0.24	0.24
Human (million)	0.074	14.04	17.01	17.41	32.57	34.53	31.82
Tractor	30	-	300	400	1,000	2,000	12,500
Power tiller	8	-	200	500	5,000	100,000	300,000
Deep tubewell	22	-	4,461	15,519	22,448	24,506	28,289
Shallow tubewell	6	-	3,045	67,103	223,588	325,360	1,182,525
Low lift pump	6	-	28,361	43,651	57,200	41,816	119,135
Thresher (open drum)	4	-	-	500	3,000	10,000	130,000
Thresher (closed drum)	7	-	-	100	1,000	5,000	45,000
Maize sheller	7	-	-	-	-	100	850
Farm power available, kW/ha		0.24	0.303	0.317	0.501	0.613	1.05

Mechanization in Different Regions

As discussed earlier, mechanization started with the mechanization of irrigation systems. Where irrigation is introduced, other operations like tillage, weeding, spraying, threshing and other operations are mechanized to some extent. As more crops are produced from irrigated lands, it is difficult to maintain the timeliness of different operations without mechanical means. As data on irrigation are available up to upazila (the smallest administrative unit) level throughout the country, for convenience the extent of irrigation has been evaluated for six administrative divisions like Dhaka, Chittagong, Rajshahi, Khulna, Barisal and Sylhet (**Fig. 1**) for the latest recorded year 2004.

Table 7 shows the irrigation equipment and irrigated area of six divisions for 2004. The Rajshahi division has the highest number of DTW and STW and also the highest percentage of irrigated area. The aquifers of this division are good for tubewell development, therefore, has the highest number of tubewells. Low-lift pumps are less in this division as the source of surface water is limited. As can be seen from **Fig. 1**, Barisal division is close to the Bay of Bengal, where fresh water is not available in STW or traditional DTW. Therefore, there is no tubewell in that division. Fresh water can be obtained if DTWs are dug very deep, which is not economically feasible. On the other hand the division has a lot of rivers. LLPs are used to pump water from these rivers. Chittagong and Sylhet divisions have a lot of hilly areas where tubewells can not be developed due to presence of rock in underground layers of adjacent agricultural lands. Therefore, numbers of both STWs and DTWs are low. So it can be concluded that due to various reasons mentioned, degree of mechanization varied in different regions.

Table 8 depicts the agricultural land area, gross domestic product (GDP) and rice production of six divisions for 1999-2000. Though rice production for later years was available, latest per capita and total GDP was available for 1999-2000. Therefore, the table shows data for that year. Both contributions to GDP and rice production have a direct relation with mechanization. Agricultural land area of Rajshahi division is 24.8 percent, whereas it contributes 26.5 percent to agriculture GDP and produces 31.1 percent of total rice production. Climate, soil, rainfall pattern and agriculture resources of the division are favourable for agricultural production. The main resource of the division is agriculture and not many industries have been set up. Though the division is rich in agriculture, people of the division, in general, are poorer than all other divisions as can be seen from per capita GDP ($302). In this division, there are not enough employment opportunities in other sectors. Though per capita GDP of Sylhet division is the lowest, the economic condition of people of Sylhet is, in general, better than that of other divisions due to receipt of lot of remittance from overseas (mainly U.K.). The area of Chittagong division is 21.7 percent, but its contribution to agriculture GDP and rice production are 18.9 and 15.4 percent, respectively. The division has hilly areas, which is about 10 percent of the whole area of the country. Tubewells cannot be installed in many agricultural lands adjacent to the hills due to presence of rock below ground surface. The

main seaport of the country (Chittagong) is in this division. There are many industries in this division. Though its contribution to agriculture GDP is relatively lower, the per capita GDP is the second highest (US $360). In comparison to the agricultural land area, the contributions to agriculture GDP and rice production are higher. As can be seen from **Table 6**, the number of DTW, STW and LLP of the division is higher than all other divisions except the Rajshahi division. As the capital of the country (Dhaka) is located in this division, it is the home of lot of industries; therefore, the overall economy is better and has the highest per capita GDP of US $443. The contribution of agriculture GDP and rice production of Khulna division is relatively lower than its area; its per capita GDP ($355) is the third highest. There are a lot of industries in the division and has the second sea port (Mongla) of the country. Majority of the fish exported are from this division.

Farm Power Availability and Fertilizer Input With Productivity

Table 9 depicts the relationship of farm power availability and fertilizer input with rice productivity, as it is the main crop of the country. Therefore, its productivity has been used to establish relationship. As explained earlier (**Table 6**, farm power sources), farm power availability of every 10 years could not be calculated. **Fig. 3** shows the relationship of farm power availability with rice yield. With the increase

Table 7 Number of irrigation equipment and irrigated area of six administrative divisions for 2004

Division	No. of DTW	No. of STW	No. of LLP	Total irrig. area, mha	% of irrig. area
Dhaka	6,452	227,428	18,122	1.14	28.25
Chittagong	2,225	30,683	25,246	0.49	12.01
Rajshahi	13,174	465,359	8,017	1.55	38.38
Khulna	2,794	199,348	6,967	0.49	12.01
Barisal	0	0	6,734	0.09	2.35
Sylhet	73	2,334	12,681	0.28	7.00
Total	24,718	925,152	79,850	4.04	100.0

of power availability, the yield of rice increased. From the graph it appears that if power availability is increased, yield would continue to increase, though not at the same rate. **Fig. 4** depicts the relationship of fertilizer input with farm productivity. It appears that, with more fertilizer input, the farm productivity will continue to increase. Of course, there is a limit of farm productivity beyond which even with the increase in farm power or fertilizer, yield would not increase.

Development of Agricultural Mechanization

Sequence of Agricultural Mechanization

Irrigation has been practiced for many centuries. Earlier human and animal operated indigenous equipment like 'don' and 'swing basket' were used. In 1961-62, mechanization of irrigation equipment started with the low-lift pump, which is ba-

sically a centrifugal pump operated by engine for lifting water from surface water bodies. The deep tubewell irrigation started from 1966-67 and the shallow tubewell irrigation from 1973-74. Water pumping was the first operation to be mechanized. After the introduction of high yielding varieties (HYV) of rice during nineteen sixties, Japanese type pedal thresher and manual weeders for wet lands were introduced to a limited area. With the increase of HYV rice, demands for pedal thresher increased. At the same time manually beating the panicle on hard surface like wood or fuel drum and bullock treading were in practice. The next agricultural operation that was mechanized was tillage operation. Though efforts were made by BADC to popularize the tractor first, then power tiller, it did not gain momentum. After the devastating flood of 1988, due to the shortage of draft animal and government policy of zero tax and tariff on agricultural machinery, the use of

power tiller increased tremendously through private initiative. Private companies imported cheap power tillers and rich farmers bought them for their own use as well as for custom hiring. Custom hiring became such a profitable business that an owner could get his money back within a year or two; therefore, the demand for power tillers continued to increase. With the mechanization of tillage operations, cropping intensity increased. At present, about 80 percent of the land preparation is done by 300 thousand power tillers, and only 3 thousand tractors.

Use of power threshers in Bangladesh is relatively new. No reliable statistics are available on the number of farm machines. It is estimated that the number of power tillers is 300 thousand and power threshers 45 thousand. Power threshers have been introduced mainly through private sector. There was not much extension work to popularize these like shallow tubewells. In the absence of power threshers, farmers were able to thresh paddy by traditional methods of bullock treading, manually beating and pedal threshing. Due to shortage of draft power, farmers could not cultivate their land. Therefore, tillage became mechanized before threshing, which is contrary to the usual case where threshing is mechanized before tillage. Maize shelling is almost fully mechanized, as the capacity of locally made hand operated sheller is only 35 kg/h against the power-operated sheller capacity of 3 ton/h.

Presently, R & D work on power tiller operated seeders is on going. Farmers are accepting this technology where demonstrations were given by research organizations. Country wide demonstrations of plastic-made drum seeders, developed by IRRI and made in Vietnam, have been going on for the last three years and it is expected that this seeder will be popular among farmers, as the labour shortage occurs during transplanting. It is expected

Fig. 1 Map of Bangladesh

that after irrigation, tillage, threshing and sowing will be mechanized. The next operation that is expected to be mechanized is harvesting of rice and wheat. R & D work on a locally made reaper is going on and it is expected that a good design will be available within a few years.

Change in Farming Systems

Before the introduction of mechanical devices, farmers could grow only one or two crops in a year. After their introduction, cropping intensity has increased by 180 percent. In many areas, growing three crops in a year has become very common. In the past, jute and sugarcane were the main cash crops. Now farmers have changed farming systems and introduced modern varieties of rice, potatoes, wheat, maize, vegetables, fruits, spices, etc. in their cropping sequence. Previously farmers used to grow rice for their own consumption. Now they consider it as a cash crop along with other crops.

Change in Mechanical System

As a first step of mechanization of tillage system, the government tried to introduce tractors during the 1970's. But, it was not successful and the programme was abandoned. Fragmented land was one of the reasons for failure of the programme. The power tiller was found suitable for the small size farm, therefore its use increased many fold. Almost all the power tillers are used on custom hiring basis and its ownership does not depend on farm size. As farm sizes are very small, power tiller owners have enough time to till neighbours land after tilling their own land. As the cost of hiring power tillers is lower than that of bullock, even very small farmers hire power tiller, not bullock. As tilling others lands by power tillers is a profitable business, many farmers, having a very small farm size, purchase a power tiller for earning money. This is also true for power thresher, which is used for custom hiring. Many poor and landless farmer purchase it for earning money. So it can be concluded that use of mechanical systems does not depend on farm size.

Nonlinear Adoption

Adoption of mechanical technologies in Bangladesh agriculture has followed a linear path, i.e. it occurred slowly and steadily without any sudden jump in adoption of mechanization in any agricultural operation. First water pumping was mechanized followed by tillage and threshing. Other agricultural operations like harvesting and transplanting require higher level of precision. Therefore, they are yet to be mechanized. Sowing requires an intermediate level of precision, therefore, its mechanization process has started to pickup.

Farm Equipment Supply

Difficulties Encountered in Sourcing

At present there is a great demand of reaper for rice and wheat. Though 52 percent of the population is engaged in agriculture, labour shortage occurs during transplanting and harvesting of rice and labour wage becomes very high. In order to re-duce the cost of transplanting and harvesting, appropriate equipment is necessary. Several engineering workshops have fabricated prototypes of a reaper. As manufacturing requires a little higher level of precision than other common farm machinery, the performance of prototypes is not up to the mark. Scientists and manufacturers are jointly working to develop a good reaper model. Reapers from Thailand, China and Japan have been tried; some of the models are good, but costly. Therefore, these cannot be used for commercial application.

The price of imported rice transplanters is very high, therefore, cannot be used commercially use. Research work has not been done seriously to adapt the machinery, at the present labour wage, the machine would not be able to compete with human labour.

There is a good demand for dryer during the rainy season for drying paddy and maize. Maize is especially vulnerable if it is not properly dried. A few private entrepreneurs started business in maize seed production and poultry feed industry based on maize. In the absence of any local dryer, some of them have imported dryers from abroad. In addition, some of the dryers have been fabricated locally. For paddy drying,

Fig. 2 Average monthly rainfall vs. evaporation at Dhaka
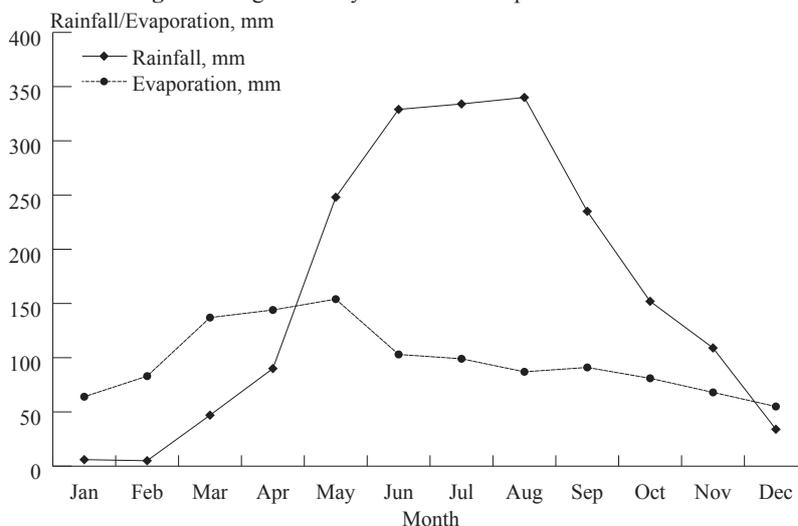
still the age old practice of sun drying is used at the farmers' home as well as at most rice mills. Automatic rice mills mainly use the LSU type dryer. With the economic development, urban affluent people are now ready to pay a premium price for quality products. Therefore, it is expected that more mechanical driers will be set up in order to have better quality rice.

In recent years, a power tiller-operated potato planter, potato digger, potato graders, and multi-crop seed drills have been developed by scientists. There is no government organization to extend and popularize these new farm machines to farmers. Department of Agricultural Extension mainly deals with crops, and not machinery. They set up hundreds of demonstrations on new crop varieties nationwide. On the other hand, scientists demonstrate a new machinery on a very limited scale. Cost of crop demonstrations is comparatively lower than farm machinery demonstrations. Typical cost of a small plot demonstration of crop variety is only a few US dollars, whereas that of farm machinery is a few hundred US dollars. Therefore, it may take many years to introduce appropriate equipment to meet farmers' demand.

Relationship of Retail Systems

As mentioned above, imported power tillers and engines are sold by importers to retailers of district towns. They also sell directly to farmers from their show rooms. Widely used locally made agricultural machines are pedal threshers and knapsack sprayers. Pedal threshers are manufactured by many small workshops and sold to farmers directly or through machinery shops. No dealership is given for these threshers. Knapsack sprayers are manufactured by a few manufacturers. They sell through dealer franchise mechanism as well as through machine shops. Recently a few manufacturers are have produced power operated threshers. Most of them sell directly to farmers. Only one or two big manufactures have developed dealer franchise mechanism for marketing their products. It is expected that other manufacturers will also follow the same path.

Linkages in the Supply Chains

A few businessmen import power tillers and small engines from China. They do not have dealers in district level towns; rather businessmen purchase PT and small engines from importers and sell to local farmers. Most of the running spare parts are locally made and are available throughout the country. Repair workshops are available in towns and some village markets.

Many farmers have learned to repair engines themselves. As low quality Chinese engines have frequent breakdowns, these need regular repair and maintenance. So, a large number of mechanical workshops have been established in the private sector. As a result of mechanization, skilled man power development has occurred in the rural areas. A few workshops are manufacturing spare parts of engines and exporting to neighbouring countries in addition to selling in the local markets.

Engineering Technology

During 1970's and 1980's, irrigation coverage to grow boro rice was expanding at a very fast rate. At that time, there were not many metalled road in rural areas. So supply of agricultural inputs like seeds, fertilizers, irrigation pumps and accessories, pesticides and farm machinery, was difficult, time consuming and costly. Due to poor roads, marketing of agricultural products was not easy. Bad transportation systems made the quality of products, especially fruits and vegetables, unacceptable to consumers. So producers could not get a good price. As a result commercial agriculture did not develop. At that time there was only a few rural areas with electricity. Farmers had to use diesel engines for pumping irrigation water. Toward the end of 1980s and 1990s,

Fig. 3 Relationship of farm power availability with yield

$R^2 = 0.98$
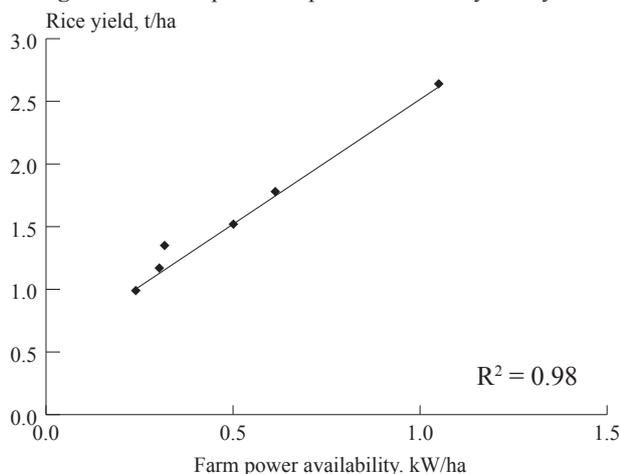
Fig. 4 Relationship of fertilizer input with yield

$R^2 = 0.99$
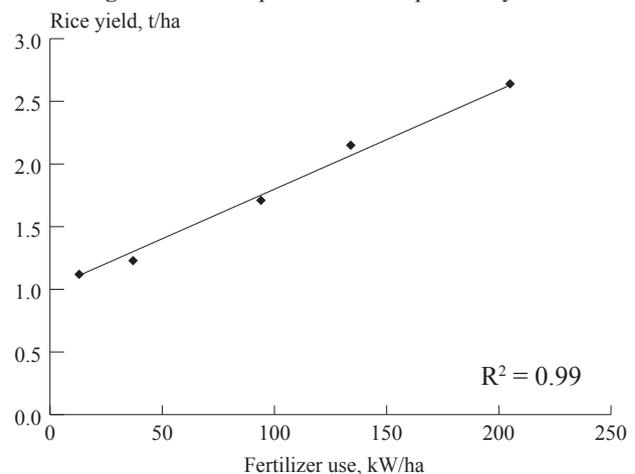
many rural roads were built. At the same time rural electrification gained momentum. Due to good communication, input supply became relatively easier, quicker and less costly. Use of electrical power for water pumping made the irrigation cheaper. Therefore, it can be inferred that both roads and electricity supported private/commercial agricultural input supply chains and service structures.

Off-farm Use of Agricultural Machinery

To popularize farm machinery, the government waived tax and duties on farm machinery. For irrigation, shallow tubewells have been installed in almost all the areas of the country. Most of these shallow tubewells, popularly known as 'shallow', are run by Chinese engines. These cheap engines have many uses. These are used to run small country boats and are popularly known as 'shallow boat' as shallow tubewell engines are used. This has created opportunity to move faster in river-dominant rural areas. Many people are using these engines for milling rice. Small hullers are fitted on tricycle vans and are moved door to door for milling rice. These small engines are also used to manufacture 3-wheeled vehicles for human haulage. In rural areas many people use engines for non-agricultural operations for income generation as well as poverty alleviation. Some power tillers are used in rural areas for haulage, in addition to tillage

operation. Owners of power tillers think that they can earn extra money during the off-season if they use them for transportation of both agricultural and non-agricultural items. A majority of the tractors in Bangladesh are used for haulage of bricks, sands, woods, etc. as the transportation cost is cheaper than that by trucks.

The Role of Policy

Until recently, only the public sector was involved in education, training and infrastructure development in mechanization. About a decade ago, the government allowed establishment of private universities. So far, 52 private universities have been established. But they mainly offer degrees in computer and business administration. In the public sector, besides universities giving a bachelor degree in engineering, polytechnic institutes offer a 3-year diploma (after secondary school examination) in different disciplines of engineering. Trade courses are also offered by vocational training institutes of public sectors. A few non-government organizations (NGO) are giving short-term training to

farmers and technicians on a very limited scale. Most of the technicians get on the job training in private engineering workshops. There are no standards and regulations to support or inhibit the development of technical capacity to support mechanization.

Economic, Business and Technical Factors

In general, economic condition of farmers of the country has improved in the recent years, mainly due to the adoption of various improved agricultural technologies. As the economic condition of farmers improved, they could afford to buy costly agricultural machinery and equipment like shallow tubewells, power pumps, power tillers, power threshers and power maize shellers. All these machinery and equipment are owned mostly by individual farmers, not by groups or cooperatives. As average farm size is small, almost all farmers use these machinery and equipment for giving services to neighbors in addition to their own use. Thus, farmers use the machinery for business and they are able to increase their income

Table 9 Relationship of farm power availability and fertilizer input with productivity

Year	Rice yield, t/ha	Farm power availability, kW/ha	Fertilizer input NPK, kg/ha
1960	0.99	0.240	-
1977	1.17	0.303	18.97
1984	1.35	0.317	36.55
1989	1.52	0.501	52.40
1996	1.78	0.613	88.36
2006	2.64	1.050	205.00

Table 8 Agricultural land area, GDP and rice production of six administrative divisions for 1999-2000

Division	Area, sq. km	% of total area	Contirubutes to total GDP, %	Contributes of agri. to GDP, %	Per capita GDP, US $	Rice production, mt	% of rice production
Dhaka	26,771.7	21.77	37.74	24.52	443	5.85	25.37
Chittagong	26,661.4	21.68	19.35	18.87	360	3.56	15.44
Rajshahi	30,474.5	24.79	20.36	26.54	302	7.18	31.14
Khulna	19,607.8	15.95	11.58	14.96	355	3.26	14.14
Barisal	8,509.0	6.92	5.79	8.84	306	1.54	6.67
Sylhet	10,930.6	8.89	5.18	6.27	296	1.67	7.24
Total	122,955	100.0	100.0	100.0	363 (Avg.)	23.06	100.0

and improve livelihood. If farmers did not use the machinery for business purpose, their use could not increase and agricultural mechanization could not materialize to the present level. With the advancement of agricultural mechanization, technical expertise has been developed entirely in the private sector in rural areas. Small workshops have been set up in rural areas to provide repair and maintenance service of engines, pumps, sprayers, threshers, power tillers and other agricultural machinery. If these technical services did not exist, farmers would have been reluctant to adopt farm machinery. Therefore, it can be concluded that the combination of economic, business and engineering technology factors greatly influenced the farm mechanization and enabled the changes in this field.

Structural and Technical Factors

To popularize agricultural mechanization among farmers, good quality machinery is essential. Many small workshop owners are manufacturing sub-standard quality machinery that creates negative impact among farmers. To improve the quality of manufacturing, technical people need to be trained. This may be done by government initiative. Small workshop owners, in general, do not use jigs and fixtures, so all machinery are not of the same standard. Therefore, special emphasis should be given to use jigs and fixtures for machine parts. Quality of raw materials, especially nuts and bolts, is poor. So the government should take necessary measures to ensure good quality raw materials in the market. Of course, when good quality materials would be used, the price of machinery will definitely increase. Initially farmers may be reluctant to pay extra money for good quality machinery, but in

the long run, use of better quality machinery is cheaper, so farmers would pay the extra amount for that. Medium and large manufacturers usually manufacture farm machinery. For them, establishing backward linkage is essential to reduce the cost of production. In order to provide repair and maintenance of farm machinery, establishment of small workshops in rural areas is essential. Without rural electrification, workshops can not be established. Operating cost of farm machinery can be reduced using electric motor. Therefore, the government needs to provide electricity in rural areas.

Transportation of machinery from urban to rural areas needs good road linkage. In addition, transportation of agriculture produce from field to farm house would be easier if power tiller operated trolleys could be used. Also, transportation loss can be reduced. Therefore, government should take measures to make farm roads.

Conclusions

Farm mechanization in Bangladesh is proceeding in the right direction. With economic development, more people will migrate to urban areas for better-paid jobs. Also in rural areas, more off-farm jobs will be available. As a result, shortages of agricultural labour will continue in the future. To overcome this problem, use of appropriate farm machinery is inevitable. For this, scientists and manufacturers need to work together closely. A few manufacturers have begun to produce farm machinery as per instruction of scientists. It is expected that this co-operation will increase further. Recently the government has instructed banks to finance farm machinery manufacturers and farmers. This will have a positive role in mechanization. In many rural areas metalled roads have been

constructed and electric connections have been provided. These two infrastructures play a very positive role in agricultural mechanization. The government has planned to construct more roads and electric lines that will further encourage mechanization of agriculture in Bangladesh. Research and development of appropriate farm machinery will enhance the mechanization process to a great extent.

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ABSTRACTS

The ABSTRACTS pages is to introduce the abstracts of the article which cannot be published in whole contents owing to the limited publication space and so many contributions to AMA. The readers who wish to know the contents of the article more in detail are kindly requested to contact the authors.

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Performance Evaluation of a Women Friendly Fertilizer Broadcaster With Reference to Ergonomics: D. Sirisha, Research Scholar, Dept. of Farm Machinery, Agricultural Engineering College & Research Institute, Tamil Nadu Agricultural University, Coimbatore - 641 003, India; **K. Kathirvel**, Professor & Head, Dept. of Farm Machinery, same; **R. Manian**, Dean, same.

Broadcasting of fertilizer is mostly done manually. This operation is generally done by farm women. Fertilizer broadcaster is used to broadcast palette and granular fertilizer to ensure the precise and uniform application. A commercially available fertilizer broadcaster was ergonomically evaluated for assessing its suitability to farm women labours. The unit consists of hopper, agitator, broadcasting disc, handle and straps. The unit consists of a hopper with plastic lid, an agitator, rotor plate with guide vanes, handle, feed control lever, gear and straps. The hopper has an opening at the bottom through which the material falls on the rotor plate. A feed control lever is provided at the bottom of the hopper for regulating the flow of fertilizers from the hopper to the rotor plate. When the fertilizer falls from the hopper on to the rotor plate it is scattered by the guide vanes. The unit is fixed to the front portion of body with shoulder belt provision. Ten women subjects were selected and screened for normal health for the investigation. The mean working heart rate and oxygen consumption were 140.10 beats min^{-1} and 0.648 l min^{-1} respectively. The energy expenditure for the broadcasting of fertilizer was computed as 13.55 kJ min^{-1} and classified as "very heavy". The mean energy cost of operation in terms of the maximum aerobic capacity was 45.28 % of VO_2 max, which was more that the Acceptable Work Load (AWL) of 35 % of VO_2 max. The work pulse value was 54.67 against the Limit for Continuous Performance (LCP) value of 40. The Overall Discomfort Rating (ODR) and Body Part Discomfort Score (BPDS) were found to be 7.55 and 62.11 respectively. Based on the evaluation and subjects feed back, the ergonomical design features viz. reduction in hopper capacity, reduction in length of crank handle, provision of cushion pad in between the hopper and subject and provision of transparent lid were incorporated. The fertilizer broadcaster with ergonomic design features enhanced the human comfort with improved physiological indices of 14.93 %, 24.53 %, 33.77 % and 32.69 % reduction in heart rate, oxygen consumption, ODR and BPDS respectively besides bringing the value of oxygen consumption rate (37.15 % VO_2 max) closer to AWL and work pulse (37.22) with in the LCP.

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Development and Performance Evaluation of Tractor Operated Cotton Stalk Shredder Cum Insitu Applicator: T. Senthilkumar, Asst. Prof., KVK, Vamban, Pudukkottai, India; **R. Manian**, Dean, AEC & RI, TNAU, Coinbatore, India; **K. Kathirvel**, Prof. & Head, same.

Incorporation of cotton stalks into the soil ensures rapid decomposition. The most rapid decomposition occurs when residue is placed 10 cm deep and shredding stalks as finely as possible also allows for rapid decomposition. The present migration of labour from rural sector to scholastic jobs in urban areas necessitates the need for mechanizing the faming operation of cotton stalk shredding and incorporation in the field. A tractor operated cotton stalk consisting of a shredder assembly, power transmission system with hydraulic motor, hitch frame and hydraulic lift was developed. The shredding unit consists of main shaft and two number of swing back type rotary blades. Lifting and lowering of the shredding unit is carried out by the hydraulic lift mounted in the front of the tractor. The power for the shredder is transmitted form the hydraulic motor and reduction gear box. The commercially available rotavator is used as insitu applicator for incorporation of shredded cotton stalks. The shredding cotton stalks was accomplished by the shredder in the front portion of the tractor and incorporation of the shredded cotton stalks was done by rotary tiller in the rear portion of the tractor. The unit was evaluated for its performance. Experiments were conducted with 4 treatments viz. disc ploughing with the standing cotton stalks, operation with cotton stalk shredder cum insitu applicator with 2.0, 2.5 and 3.0 km h^{-1} to find out the efficient method of cotton stalk shredding and insitu application. The influence of the selected treatments on soil physical and chemical properties was investigated. Operation with prototype cotton stalk shredder cum insitu application at 2 km h^{-1} forward speed is judged as the best among all the treatments as it records favorable increase in hydraulic conductivity (1.38 to 2.30 cm r^{1}), decrease in bulk density (1.33 to 1.25 Mg m^{-3}), increase available N (199.0 to 0.54 kg ha^{-1}), P (12.6 to 20.1 kg ha^{-1}), K (541.0 to 640.0 kg ha^{-1}) and organic carbon (0.36 to 0.54 kg ha^{-1}) of the soil.

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Evaluation of a Pad System for Cooling Poultry House in Iraq: Ali Mazin Abdul-Munaim, Dept. of Agricultural Mechanization, College of Agriculture, University of Baghdad, Baghdad, Iraq.

An experiment was undertaken to investigate of effect of using three kinds of pads (Aspen white excelsior, Lagonychium farctum and Alhagi maurorum) with three

different thicknesses of pad (5, 8, and 11 cm). This was to measure interior dry-bulb temperature, relative humidity, air velocity, cooling efficiency and static pressure in order to determine which one of them is better in evaporative cooling when used in poultry house. A factorial experiment with completely randomized design with three replicates was used. The pad, which was constructed of Alhagi maurorum with pad thickness 11 cm, gave interior dry bulb temperature 25.5 ºC, relative humidity 80 %, air velocity 1.36 ms^{-1}, cooling efficiency 87.2 % and static pressure 14.1 pa. Hence the pad made of Alhagi maurorum with 11 cm thick was recommended.

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Ergonomic Evaluation of Male and Female Operators during Weeding Operation: R. Yadav, Professor, College of Agricultural Engineering & Technology, Junagadh Agricultural University, Junagadh, India; **S. Pund**, Dy Manager, Mahindra & Mahindra (R & D), Nashik, India; **L. P. Gite**, Project Coodinator, CIAE, Nabi Bagh, Bhopal, India.

All the agricultural equipment are either operated or controlled by human workers and these equipments require skill, effort and correct speed. The estimated energy expended values can be used to define limits of human effort for various agricultural operations. The operator's performance in different field operations can be assessed on the basis of the physiological responses. The estimation of energy expenditure rate (EER) by measuring the OCR is fairly accurate and acceptable method. Using Morgan Oxylog II Apparatus recorded OCR during field operations. Oxylog can be easily mounted on the operator back and the oxygen consumed by operator during particular operation in the field can be recorded and data can be downloaded on PC for analysis and calculation.

In Saurashtra region weeding by sickle and with manual weeder is a common practice used by the farmers. In view of this 4 male and 4 female workers took part in this study. Subjects were acclimatized for the experimental protocol. Heart rate and oxygen consumption rate of male workers were measured. The physiological cost of male and female subjects was worked out on the basis of OCR and it was found to be 15.87, 15.87, 16.08 and 15.87 kJ min^{-1} and 8.14, 8.35, 8.35 and 8.35 kJ min^{-1} for subjects 1, 2, 3 and 4 respectively. Similarly physiological cost was worked out for female workers during weeding by manual weeder and it was found to be 13.57, 14.41, 14.20 and 14.41 kJ min^{-1} for subjects 1, 2, 3 and 4 respectively.

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Studies on the Application of Microwa Ves for Producing Banana Fruit Leather: T. Pandiarajan, Associate Professor, Agricultural Engineering College and Res. Institute, Kumulur - 621 712 Trichirappalli, Tamil Nadu, India; **Karpoora Sundara Pandian**, same.

Banana fruit leather is a well established product manufactured by dehydrating the fruit pulp into a leathery sheet. Conventionally hot air drying is employed to make banana fruit leather. In the present study an attempt was made to prepare banana fruit leather using microwaves. A domestic microwave oven at 90 W power level was used for the preparation of banana fruit leather. It was found that the time taken to prepare fruit leather using microwaves was only 90 min against 9 hours in case of conventional hot air oven. The quality characters like total soluble solids, colour texture and organoloptic characters were studies. It was found that banana fruit leather prepared using microwave was superior to the leather prepared using hot air oven.

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