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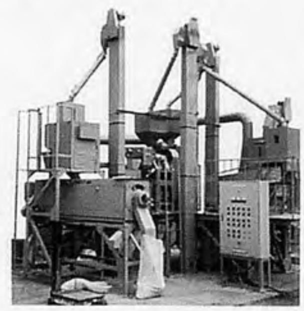

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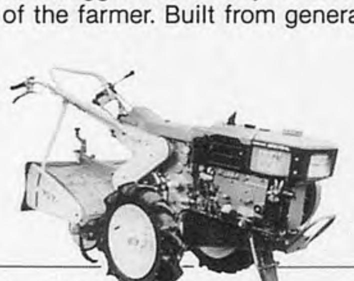

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EDITORIAL

Precision Agriculture Technology

Precision agriculture technology is not only a new word in the lexicon of mechanized farming but implies also the ultimate in agriculture research attempts. Already the terminology is now creating some noise in the development and trials of a crop yield monitor that is attached to a combine, which purports to show the attainment of predetermined, yield level in a certain crop based on flat yield map. Quite naturally, this news presages an inspiration to farmers and makers of yield monitor.

Howsoever, this exciting news needs to be taken with a grain of salt precisely because it is premature to rejoice about it, considering that a growth model of actual crop performance id still imperfect. Farming, being a dynamic activity, has many unknowns, vulnerabilities and variables. It is subject to the vagaries of weather that are not easy to control nor regulate by man.

For instance, the writer had an opportunity recently to visit with a farm household in the U.S. that has been using a field monitor for four years that has not obtained a yield map no matter the adjustments in the rate of fertilizer application. The frustration of the household stopped the use of the flat yield map. It is true that this single observation is rather isolated as to reflect the real trend which is why researchers are still splitting hairs trying to zero in on acceptable findings that deserve to be publicized for the benefit of farmers.

The preceding observations need not dampen the interests of researchers and scientists even as they are not looking forward to discovering a very precise technology such as those used in the war in Iraq that hit and destroy targets. It is simply the writer's personal interest to keep abreast of ongoing research and development, through the AMA, so that farm mechanization efficiency might be enhanced in order to increase agricultural productivity and ensure food availability.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
April 2003

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Relationship of Specific Draft with Soil and Operating Parameters for M. B. Plough

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Abstract

The draft of tillage tools plays a vital role in the design of tillage implements and has a significant influence on the type of mechanical power required for its operation. The compaction level, moisture content of soil and forward velocity of tool affect the pull and specific draft of a mould board plough bottom. An experiment was carried out in laboratory conditions in a soil bin at the Department of Agricultural and Food Engineering, IIT, Kharagpur, in order to determine the effects of soil compaction level, soil moisture content and tool forward velocity on pull and specific draft of a 15 cm mould board plough bottom model. The forces acting on the plough bottom were sensed using an octagonal ring transducer and the horizontal and vertical forces were recorded using a two-channel RS-Dynograph model recorder. The compaction level, moisture content and velocity were varied at three levels each and the data were analyzed statistically. The effects of all the three independent variables were significant at 1% level on the pull and specific draft. The interaction of compaction level with moisture content was also significant at 1 per cent level. The interaction of compaction level with velocity was significant at 5 per cent level in the case of pull, but non-significant in case of specific draft. Empirical equations were fitted for pull and specific draft separately. An attempt has also been made in this study to determine the coefficients of ASAE equation for local conditions and it was found that moisture content and cone index have significant effects on coefficients (A, B and C) of the ASAE equation. The cone index was used in the present investigation as an index for soil compaction level.

Acknowledgement

The authors gratefully acknowledge the support and facility provided by Department of Agricultural and Food Engineering, IIT, Kharagpur. For this study the guidance and help extended by Late Prof. A. C. Datta is also gratefully acknowledged.

Introduction

The design of soil working implements is largely dependent upon the magnitude of soil forces apart from the operating conditions and type of power source used. Information on soil forces acting on the implement has not only helped the designers of machineries rather it has also helped the designers of power source such as tractor. Among various farm operations, tillage has been regarded as the most energy intensive operation, which results in high magnitude of forces that loads the tractor tremendously. Therefore, the soil forces acting on plough bottom has been an area of interest for researchers. The amount of soil forces acting on a plough bottom depends on various soil and operating parameters. Kepner, *et al* (1978) quoted that Clyde (1944), Getzelaff (1953) and O'Callaghan, *et al* (1965) had reported that useful soil reaction forces vary widely and is influenced by soil type, soil condition and edge shape and sharpness ratio of tool.

Based on the tests carried out in the soil bin the ratio of vertical to horizontal soil reaction forces were reported to be in the range of 0.5 to 0.6 for sand and 0.35 to 0.45 in other soils. Various other researchers who carried out studies in the same area later reported that the useful soil draft is mainly dependent upon the soil strength, operating parameters and some design features of the implement. Oskui, *et al.*, (1982) made an attempt to establish empirical relationship of plough specific draft with cone index as an indicator of soil strength, moisture content of soil, plow speed and mould board tail angle. Anon (1997) adopted an empirical equation as a standard for estimating the useful draft in terms of operating velocity and some coefficients which represent the soil conditions. The soil conditions were largely isolated in three groups and a weightage was assigned accordingly. The soil conditions varied not only with soil texture and structure but also with other soil parameters such as moisture content and strength. Therefore, a study was undertaken to determine empirically the relationship for specific draft and pull with soil-tool parameters.

Materials and Methods

An experimental investigation was carried out in order to study the effects of moisture content and cone index (representing compaction level) of soil and forward velocity of tool on specific draft and pull of a 15 cm mould board plough bottom in laboratory conditions. The independent variables and their levels are listed in **Table 1**.

Three replications were made. The dependent variables were specific draft and pull. The description of other parameters were: a. soil type, sandy loam soil of Kharagpur; b. depth of operation, 7.5 cm; and c. width of operation, 15 cm.

Experimental Set-up

The experimental set-up consisted of an indoor soil bin with tool mounting arrangements and transducers for measurement of vertical and horizontal forces on the tool. The moisture content of the soil was determined using the oven dry method. The cone index was determined using an ASAE standard cone penetrometer with 3.225 cm^2 base area and 30^0 cone apex angle. The mean of the penetration resistance up to 15 cm depth is reported. The forward velocity of the tool was determined by noting the time taken to travel a known distance. A description of the soil bin, tool mounting frame and force transducer are given below.

Soil Bin and Tool Mounting Frame

The soil bin is 15.6 m long, 1.17 m wide and 0.90 m deep and was constructed of brick and mortar. The experimental soil was filled in the bin to a depth of 75 cm. There were two rails, one on each side of the bin which were used for supporting a soil processing trolley and a tool trolley. The soil processing trolley is used for tilling, compacting and mixing of the soil and for adding water to the soil. The tool trolley has a frame of adjustable height on which a tillage tool could be mounted. Using this frame the mould board plough bottom could be kept at any depth of operation. The tool trolley is moved on the rails with the help of a rope wound over two drums, one at each end of the bin. A motor through a gear reduction unit drives one of the drums. Different speeds of travel were obtained by choosing different gears in the gear reduction unit.

Transducers for Measurement of Vertical and Horizontal Forces

An extended octagonal ring transducer was used for measurement of vertical and horizontal forces acting on the plough bottom consisting of an extended octagonal ring made of mild steel and eight strain gauges mounted on this ring. The vertical and horizontal forces were sensed independent of each other. The transducer was mounted between the plough bottom and frame of the tool trolley. The outputs from the strain gauges were recorded using a two-channel chart recorder model Dynograph of RS-Beckman.

Procedure

The soil bin was filled with sandy loam soil of Kharagpur, India. On the adjustable frame of the tool trolley an octagonal ring transducer was fitted. The strain gauge circuits were then connected to the two-channel recorder. The mouldboard plough bottom was fitted to this octagonal ring. The transducers were calibrated by applying known loads in vertical and horizontal directions at the approximate location of centre of resistance of the bottom. The required volume of water was added to the soil. The soil was tilled and mixed with a rotavator, leveled with a leveler and compacted with a roller, all mounted on the processing trolley. Using a cone penetrometer the cone index of the soil up to a depth of 15 cm was determined at different places. The average value was reported.

The tool trolley was ready for operation. The depth of operation of the plough bottom was set by adjusting the mounting frame. A suitable gear of the gear reduction unit was selected and set. For the purpose of measuring the forward speed of travel a distance of 5 m was marked on the rails of the soil bin. The motor was put on. The two-channel recorder was also operated. The time required to travel the distance marked above was noted and the speed of travel was calculated. The motor and recorder were put off. The vertical and horizontal forces recorded in the chart paper of the recorder were read and the mean values were calculated. After completing the test run the tool was raised on the frame and the tool trolley was brought back to the starting position.

Different cone index values were obtained by adjusting the compacting roller as per requirement. Higher levels of compaction were obtained by running the roller more number of times. Also, adding the required volume of water could increase the soil moisture level. The selection of different gears in the gear reduction unit made it possible

Table 1. Number of Levels and Values of Independent and Dependent Variables

Name of Independent variable	Symbol	Number of levels	Values
Moisture content, per cent (db)	M	3	8.86, 9.8, 11.98
Cone index of soil, Kg/cm^2	CI	3	(1.82 - 5.73 range)
Forward velocity, m/sec	S	3	0.77, 0.90, 1.14

Table 2. ANOVA for Specific Draft and Pull at Different Levels of Cone Index, Moisture Content and Forward Velocity

Source of variation	Specific draft			Pull			Tabular F	
	Degree of freedom	Mean sum of square	Observed F	Degree of freedom	Mean sum of square	Observed F	1%	5%
Replication	2	0.000248		2	0.16			
Moisture content (M)	2	0.1455	3101.5**	2	1867.88	1277.377**	18.00	6.94
Error(a)	4	9.387E-5		4	2.92			
Velocity (V)	2	0.007559	869.84**	2	214.35	5281.564**	18.00	6.94
Error(b)	4	1.738E-5		4	0.081			
M × V	4	5.714E-5	0.0083	4	1.123	0.0096	6.63	3.69
Error(c)	8	0.0068		8	117.14			
Cone index(CI)	2	0.02315	164.45**	2	486.70	239.86**	5.25	3.26
M × CI	4	0.006195	49.53**	4	102.38	50.43**	3.89	2.63
V × CI	4	0.000179	1.430	4	5.80	2.857*	3.89	2.63
M × V × CI	8	7.89E-5	0.662	8	4.25	2.106	3.04	2.21
Error(d)	36	12.50E-5		36	2.03			
Error(total)	80			80				

* significant at 5 % level, ** significant at 1% level

to vary the forward speed. The test runs were repeated after varying the moisture content, compaction level and forward speed. Thus 81 test runs were carried out. The data were analyzed.

Results and Discussion

The effects of moisture content, cone index and forward speed on specific draft and pull were analyzed statistically. The detailed analysis of variance was carried out and the F-values are quoted in **Table 2**. All the three independent variables viz., moisture content, cone index and velocity were significant in both cases at 1 per cent level. Also, the interaction of cone index with moisture content was significant in both cases at 1 per cent level and the interaction of the cone index with velocity was not significant with the specific draft but significant at 5 per cent level with the pull. An empirical equation was developed between the specific draft as the dependent variable and moisture content, cone index and velocity as the independent variables as shown in **Equation (1)**.

The overall regression coefficient in the above case was 0.961. The observed values and values predicted using the Eq (1) are presented in **Fig. 1**.

Similarly, an empirical equation as shown in **Equation (2)** was fitted to the data on pull. This had an overall regression coefficient of 0.951. The observed and predicted values agreed closely as shown in **Fig. 2**.

The specific draft and pull of a tillage tool were known to vary with the square of forward velocity. However, they were found to vary linearly in the above empirical equations because the range of forward velocity of 0.7 to 1.1 m/s is very small.

ASAE Equation and its Coefficients

The ASAE proposed the following equation in1997 for estimating the draft of plough in terms of forward velocity as:

$D = F_j (A + B S + C S^2) w \times d$...(3)

where,

D= Draft, N

F_j, A, B and C are coefficients; F_j depends on soil condition with j = 1 for coarse soil, j = 2 for medium soil and j = 3 for fine soil

w=width of cut, m

d= depth of operation, cm

Rewriting the above equation,

$D = (A' + B'S + C'S^2) w \times d$ ..... (4)

For each combination of moisture content and cone index an equation of the above type was fit-

Equations

$$d_U = 0.05017 + 0.06789S + 0.06618M + 0.03596CI + 0.01729S \times CI - 0.00443M^2 - 0.00251M \times CI \quad (1)$$

where, d_U= Specific draft offered by the soil, kg/cm^2

M = Moisture content of soil, per cent (dry basis)

S = Forward velocity, m/s

CI = Cone index of soil, kg/cm^2

$$P = 48.900 + 1.195CI + 0.6376M \times S + 4.1950S \times CI - 0.1724M^2 - 0.0821M \times CI \quad (2)$$

where, P = Total pull of m.b. plough, kg

$$Z = a + b M + c/(CI^2) + d/(CI^3) + e/(CI^4) + f/(CI^5) \quad (6)$$

where, Z = Dependent parameter (A, B or C)

a, b, c, d, e and f are empirical coefficients.

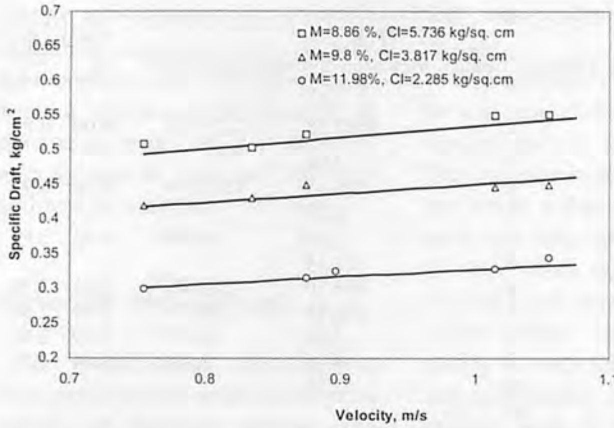

Fig. 1 Variation of specific draft of a 15 cm m.b. plough model with forward velocity.

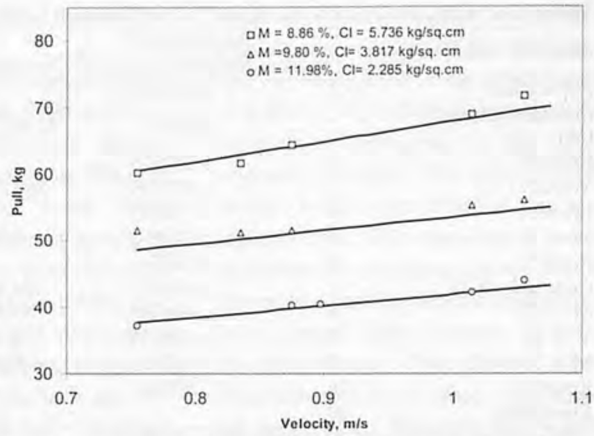

Fig. 2 Variation of pull of a 15 cm m.b. plough model with forward velocity.

Table 3. Coefficients of ASAE Equation at Different Values of Moisture Content and Cone Index

Moisture Content	Cone Index	A	B	C	R^2
8.86	5.73	533.19	-227.26	247.79	0.921
8.86	2.60	496.32	-313.74	274.96	0.961
8.86	2.16	306.44	145.51	-22.94	0.934
9.8	4.68	251.47	289.56	-52.50	0.945
9.8	3.82	365.35	45.85	41.42	0.934
9.8	2.41	478.43	-263.70	20.8.68	0.976
11.98	2.28	237.72	77.58	24.34	0.902
11.98	2.16	341.75	-118.55	103.94	0.981
11.98	1.82	449.10	-390.32	261.77	0.932

Table 4. Coefficients of Equation (6) for Best-fit Curves

Item	a	b	c	d	e	f	R^2
A	9844.5	-22.45	-11980.5	551740.1	-1069145.6	741480.3	0.788
B	-21480	1547	278770.9	-1287700.6	2499423.2	-1734295.7	0.833
C	12936.9	3.872	-167653.9	772094.45	-149140.9	1036657.7	0.876

ted. For example, at 8.86 per cent moisture content and 5.736 kg/cm^2 cone index, the equation would be:

$$D = (533.19 - 227.26S + 247.79S^2)wd \quad .... (5)$$

The above coefficients are shown in **Table 3** where similar equations were fitted at all combinations of moisture content and cone index and are listed.

It can be seen that these coefficients themselves vary with moisture content and cone index. Thus, each of these coefficients can, in turn, be expressed as empirical functions of M and CI. An empirical function of the form was found to fit for A, B and C (**Equation (6)**). Values of a, b, c, d, e and f of the equation fitted to A, B and C values given in **Table 3** are given in **Table 4**. Overall regression coefficients for A, B and C were 0.788, 0.853 and 0.876, respectively.

Conclusion

The empirical functions for specific draft and pull of a 15 cm mould board plough bottom model in Kharagpur sandy clay loam soil was non-linear in moisture content, cone index and velocity. The interaction between these variables plays a very significant role in comparison to their individual effects. The coefficients of ASAE equation were also depended on soil moisture content and cone index.

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Influence of Seedling Mat Characteristics and Machine Parameters on Performance of Self-propelled Rice Transplanter

by

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Abstract

An 8-row self propelled rice transplanter using mat type seedling was evaluated to optimise the seedlings as well as transplanter parameters in the laboratory. The laboratory investigations were carried out on the concrete floor with four seed rates, i.e., 80, 100, 120 and 140 g/ mat, three ages of seedling of 20, 25, 30 days, three cutting finger lengths of 7, 12, 17 mm, two operating speeds 1.40, 1.80 km/h and two types of soils used for raising nursery, i.e., silty clay loam and sandy loam. In the study, the number of seedlings per hill, missing hills, and hill percentage with mechanically damaged seedlings were determined with respect to each seedling density, ages, cutting finger length and operating speed. The mat requirement was also calculated according to different seedling density with respect to cutting finger length of the transplanter.

In order to achieve the recommended 2-3 number of seedlings per hill and minimum missing of hills, the density of seedling mat found to be in between 2.0 and 3.0, 1.25 and 2.00 and less than 1.25 seedlings per cm^2 corresponding to 7, 12 and 17 mm cutting finger length, respectively. And in order to minimize mechanical damage to seedlings, 30-day old seedlings were observed to be better. The number of mats of size52 × 22 cm for transplanting one hectare area would be required as 400, 700 and 1000 corresponding to densities of 2 to 3, 2 to 1.25 and less than 1.25 seedlings/cm^2 for cutting finger length of 7, 12 and 17 mm, respectively.

The missing hills were noticed from 0 to 14.10 per cent which were mainly due to the non-uniformity of the seedlings in the mat. However, the percentage of missing hills decreased with increasing the density and cutting finger length. The hill percentage with mechanically damaged seedlings varied from 0.92 to 8.40 per cent which was greater at greater cutting finger length, operating speed and lower age of seedling.

Introduction

Rice is one of the most important crops and staple food of millions of people which is grown in many countries of the world. The total area planted to the rice crop in India is 42.20 million hectares, which is the largest in the world against total area of 148.40 million hectares. The total rice production of the world was 527 million tonnes out of which 84.74 million tonnes were produced in India (Survey of Indian Agriculture, 2000).

Rice is largely grown by transplanting the seedlings in puddled field conditions. Transplanting rice gives a more uniform crop stand with higher yield than direct seeding (Khan and Gunkel, 1989). Transplanting work is backbreaking and involves enormous drudgery and human stress in sweltering weather. The work consumes about 250-300 man-h per ha which is roughly 25 per cent of the total labour requirement of the crop (Singh *et al.*, 1984).

Rice transplanting has emerged as a big problem in the whole rice region due to the acute shortage of labour. Optimum plant density and timeliness in operation in rice has been considered essential for optimizing rice yield. Hence, since long, mechanical transplanting has been observed to be the most promising option as it saves labour, minimizes stress and drudgery, ensures timely transplanting and attains optimum plant density contributing to higher productivity.

The main constraint in the popularization of the self-propelled transplanters is the raising of mat type rice seedlings. It has been estimated that the transplanting of rice seedlings by the self-propelled transplanter reduces the labour requirement by 90 percent compared to the manual transplanting. Information on optimum parameters of seedling mat such as density of seedling, age of seedling and soil type for nursery raising for self-propelled rice transplanter is not available for Indian conditions. The machine parameters such as cutting finger length and transplanting speed are also not specified for better transplanting performance. Therefore, the present study was carried out to find the effect of seedling mat as well as transplanter parameters on the performance of transplanter using mat type nursery and to identify the optimum seedling mat conditions for efficient operation of a self propelled rice transplanter.

Materials and Methods

The laboratory experiment was conducted in order to investigate the effect of the mat parameters such as density of seedlings, age of seedling and transplanter parameters as cutting finger length and operating speeds on number of seedlings per hill, missing hills and hill percentage with mechanically damaged seedlings corresponding to two soil types for nursery raising. The experiment was conducted at the concrete floor of the laboratory.

In order to determine the effect of seedling characteristics of mat type seedling on the transplanter performance, the seedlings were grown by using two types of soil, i.e., heavy (silty clay loam) and light (sandy loam soil) with different seedling densities. The influence of seedling age, density and finger length were studied by operating machine at two speeds viz., 1.40 and 1.80 km/h on number of seedlings per hill, missing hills and hill percentage with mechanically damaged seedlings so as to optimize the seedling parameters for satisfactory performance of the transplanter. Four seed rates of 80, 100, 120 and 140 g/mat and three seedling ages of 20, 25 and 30 days were used in the laboratory experiment. Three cutting finger lengths were chosen for investigation viz. 7, 12 and 17 mm so as to accommodate low, medium and high densities of seedling corresponding to 120-140, 100-120 and 80-100 g/mat seed rate.

The study was planned in four factors C.R.D with three replications. The observations were taken for each age, density, cutting finger length, operating speed for two soil types of mats to calculate the average number of seedlings per hill, missing hills and hill percentage with mechanically damaged seedlings. The self-propelled rice transplanter (Model : 2 ZT-238-8) and its operation on concrete floor are shown in **Figs.1** and **2**.

Results and Discussion

The data related to different seedling characteristics such as density, height, root length, stem thickness and number of leaves are presented in the **Table 1**. The table indicates that densities of 2.71, 3.32, 4.37 and 5.46 seedlings/cm^2 when nursery was grown by using silty clay loam soil and 2.71, 3.62, 4.79 and 5.57 seedlings/cm^2 with sandy loam soil were found corresponding to seed rates of 80, 100, 120 and 140 g/mat, respectively. It was observed that there was not much difference in seedling densities in both types of soils.

Seedlings per Hill

The numbers of seedlings per hill obtained during the laboratory experiment under different conditions are given in **Table 2**. The number of seedlings per hill increased with an

Fig. 1 Self-propelled rice transplanter used in the experiment (front view).

Fig. 2 A view of the laboratory experiment.

Table 1. Seedling Characteristics under Different Seedling Age and Mat Density during Laboratory Experiment

(a) Silty clay loam soil

Age of seedling, days	Seed rate, g/mat	Mat density, seedlings /cm^2	Height, cm	Root length, cm	Stem thickness, mm	Number of leaves/ seedling
20	80	2.71	13.57	6.08	2.03	2.29
	100	3.32	13.08	6.66	2.00	2.38
	120	4.37	13.06	6.56	1.96	2.22
	140	5.46	12.72	7.36	1.94	2.56
25	80	2.71	16.14	7.67	2.21	3.09
	100	3.32	14.86	8.57	2.13	3.00
	120	4.37	14.75	8.75	2.08	2.86
	140	5.46	14.22	8.86	2.02	2.83
30	80	2.71	17.90	9.00	2.43	3.67
	100	3.32	16.90	8.40	2.50	3.50
	120	4.37	17.62	9.50	2.75	3.57
	140	5.46	16.83	11.8	2.43	3.50

(b) Sandy loam soil

Age of seedling, days	Seed rate, g/mat	Mat density, seedling /cm^2	Height, cm	Root length, cm	Stem thickness, mm	Number of leaves/ seedling
20	80	2.71	13.00	5.38	2.08	2.29
	100	3.62	12.93	6.75	1.83	2.43
	120	4.79	12.21	5.80	1.72	2.50
	140	5.57	12.08	7.33	1.58	2.40
25	80	2.71	18.20	7.14	2.58	2.86
	100	3.62	18.20	7.00	2.17	2.75
	120	4.79	16.29	6.50	2.10	2.71
	140	5.57	17.80	7.71	2.00	2.86
30	80	2.71	19.43	8.17	3.00	3.60
	100	3.62	18.92	7.86	2.94	3.60
	120	4.79	19.75	8.16	2.88	3.70
	140	5.57	18.17	8.00	2.83	3.60

increase in the cutting length of the transplanting finger as well as seedling density. The number of seedlings per hill varied from 2.20 to 9.70, 3.30 to 8.50, 3.90 to 9.80 and 5.33 to 11.87 for densities 2.71, 3.32, 4.37 and 5.46 per cm^2, respectively, with lowest being at 7 mm cutting finger length, 20-day old seedling, and 1.80 km/h operating speed and highest being at 17 mm cutting finger length, 25-day old seedling and 1.40 km/h operating speed in heavy soil nursery. Whereas in light soil nursery, the number of seedlings varied from 2.20 to 6.80, 3.50 to 8.11, 3.87 to 10.0 and 4.90 to 13.43 for densities 2.71, 3.62, 4.79 and 5.57 seedling per cm^2, respectively.

The number of seedlings per hill were at 7 mm cutting finger length for both the transplanting speeds and seedling densities of both heavy and light soil nurseries. It was also noticed that irrespective of cutting finger length and seedling density, the number of seedlings per hill increased with operating speed. However, the increase in number of seedlings per hill was more pronounced at higher cutting finger length. Seedling density, cutting finger length and age of seedling had significant effect on number of seedlings in both types of nurseries. However, the operating speed had no significant effect in heavy soil but affected significantly under light soil condition. The interaction of seedling density and cutting finger length had significant effect on seedlings per hill in both types of nurseries. At more cutting finger length, seedlings per hill were found to be higher due to greater cutting area of mat which contributed to greater number of seedlings. Seedlings per hill marginally decreased with few exceptions with respect to age of seedlings, i.e., 20 to 30 days due perhaps to an increase in stem thickness of seedlings with age which resulted a reduction in number of seedlings with corresponding finger length. It was further observed that the number of seedlings per hill was greater with respect to speed of transplanter in most of cases with few exceptions. This is because by increasing the operating speed, the transplanting finger speed also increased simultaneously which resulted in greater impact

Table 2. Effect of Seedling Mat Characteristics and Machine Parameters on Number of Seedlings per Hill during Laboratory Experiment

(a) Silty clay loam soil

Age of Seedling, days	Finger Length, mm	Seedlings per hill: Operating speed of 1.40 km/h, Density, number/ cm^2 (Seed rate, g /mat)				Operating speed of 1.80 km/h, Density, number/ cm^2 (Seed rate, g /mat)			
		2.71 (80)	3.32 (100)	4.37 (120)	5.46 (140)	2.71 (80)	3.32 (100)	4.37 (120)	5.46 (140)
20	7.00	2.40	3.30	3.90	5.33	2.20	3.67	4.70	6.60
	12.0	5.37	7.30	8.60	10.97	4.63	6.40	8.50	10.50
	17.0	6.40	7.90	9.80	11.83	5.40	7.60	8.90	11.30
25	7.00	2.83	3.10	3.33	4.12	2.80	3.00	3.83	4.30
	12.0	4.67	6.80	7.40	8.90	5.90	5.70	8.20	9.40
	17.0	5.30	8.50	8.70	11.87	6.10	6.10	8.50	11.50
30	7.00	2.40	3.80	5.33	6.47	3.40	4.10	4.90	4.90
	12.0	4.57	6.90	7.80	9.70	5.50	6.90	8.70	8.70
	17.0	5.50	7.80	8.77	10.70	9.70	6.90	9.10	10.57

(b) Sandy loam soil

Age of Seedling, days	Finger Length, mm	Seedlings per hill: Operating speed of 1.40 km/h, Density, number/ cm^2 (Seed rate, g /mat)				Operating speed of 1.80 km/h, Density, number/ cm^2 (Seed rate, g /mat)			
		2.71 (80)	3.62 (100)	4.79 (120)	5.57 (140)	2.71 (80)	3.62 (100)	4.79 (120)	5.57 (140)
20	7.00	2.20	3.50	3.87	4.90	3.06	4.40	4.90	7.00
	12.0	5.40	5.70	8.70	9.90	5.60	7.50	8.60	9.23
	17.0	6.30	7.14	8.80	12.5	5.90	7.70	9.50	10.60
25	7.00	1.74	3.02	4.30	4.40	1.90	2.39	3.21	4.67
	12.0	3.09	4.15	9.50	12.56	4.43	5.20	8.38	13.03
	17.0	6.80	4.80	10.0	13.33	6.50	7.20	10.10	13.10
30	7.00	2.17	3.34	3.80	4.60	3.20	4.50	5.03	5.80
	12.0	4.40	7.00	7.51	8.20	4.30	6.37	7.14	8.40
	17.0	6.40	8.11	8.50	8.90	5.70	7.90	9.57	11.27

force by the forks on the mats leading to more number of seedlings. Another reason for more seedlings per hill at higher speed might be due to greater vibrations of the tray which enhanced the downward movement of mats. These results are in agreement with the findings reported by Garg *et al.* (1982).

The agronomic requirement of number of seedlings is 2-3 per hill which may be obtained at density of 2.71 to 3.47 seedlings per cm^2 corresponding to seed rates of 80 to 100 g per mat with minimum transplanting finger length of 7 mm. If the seedlings density is less than 2.71 per cm^2 either due to damage by birds or scorching sun under moisture deficit condition, the number of seedlings may be increased by increasing the transplanter finger length more than 7 mm to obtain the required number of seedlings per hill. However, the mat consumption would be increased with an increase in the finger length.

The seedlings per hill were determined theoretically by taking into account the different cutting finger length of mat, i.e., 7 to 17 mm. The 22 cm width of seedling mat is cut through 14 strokes of transplanting fingers that is equivalent to 1.57 cm per stroke. The curves between seedling density and number of seedlings per hill corresponding to each cutting finger length were drawn as shown in **Fig 3**. The data related to total mat requirement per hectare have also been calculated which are shown in **Fig. 4**.

The theoretical relationships were also developed between transplanting finger length and number of mats per hectare corresponding to three hill spacings of 10, 12 and 14 cm. With reference to seedlings per hill and seedling density, the transplanting finger length can be determined with the help of **Fig. 3**. For estimating the number of mat per hectare against the above cited finger length in respect of selected hill to hill spacing of 10, 12 and 14 cm so as to achieve 42, 35 and 30 hills/m^2, respectively, **Fig. 4** will be used.

The percentage variation between the theoretically predicted and experimentally observed number of seedlings per hill are determined and shown in **Table 3**. The predicted numbers of seedlings per hill were always greater than the observed values. The small number of seedlings during laboratory experiment than theoretically predicted values at 17 mm cutting finger length might be due to less than 17 mm downward movement of the mat which resulted in smaller cut area of mat per stroke thereby giving lower number of seedling per hill. The lesser number of seedlings per hill at 7 mm transplanting finger length was due to the small cutting area of the mat due to intermingling of roots which gave hindrance to cut the required mat area. In the case of 12 mm transplanting finger length, the variation between predicted and observed number of seedlings was quite low in the range of 3.29 to 4.70 per cent only. This was due to the sufficient downward movement of mat to, i.e., 12 mm which might be equivalent to the actual cut length of mat by the transplanting fingers.

It may be inferred from the above predicted number of seedlings per hill that in order to achieve optimum seedlings per hill (i.e., 2 to 3), the density should be in between 2.00 to 3.00, 1.25 to 2.00 and less than 1.25 seedlings per cm^2 at 7, 12 and 17 mm finger length, respectively. It has also been deduced that the requirement of the number of mats for transplanting one hectare would be 350 to 420 at minimum cutting finger length of 7 mm.

Missing Hills

The missing hills were determined in the laboratory experiment in relation to different seedling densities, operating speeds, transplanting finger lengths and ages of seedling. The data are shown in **Table 4**. The number of missing hills

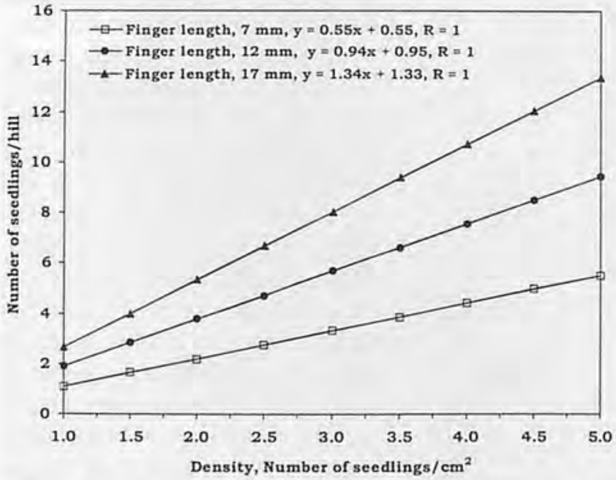

Fig. 3 Predicted seedlings per hill at different seedling densities at three cutting finger length.

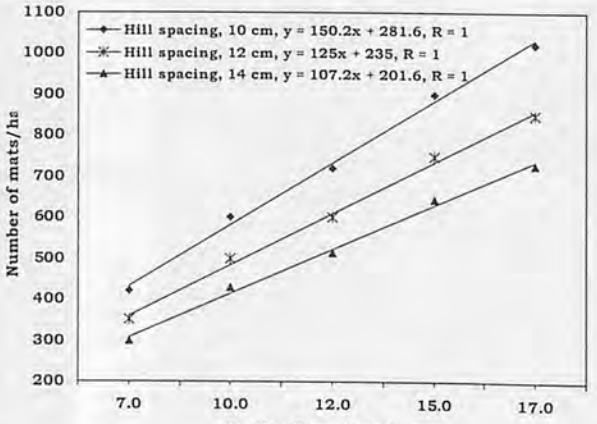

Fig. 4 Mat requirement per hectare at different cutting finger lengths at three-hill spacings.

decreased significantly from 14.10 to 0 percent with increase in density from 2.71 to 5.57 seedling/cm^2 for all ages of seedling, cutting finger lengths and operating speeds under both types of nursery. The missing hill percentage varied from 1.96 to 14.1, 1.96 to 10.83, 0 to 8.3 and 0 to 6.64 for densities of 2.71, 3.32, 4.37 and 5.46 seedling/cm^2, respectively, in heavy soil nursery. On the other hand, the variation was observed from 2.38 to 11.19, 1.54 to 9.40, 0 to 8.34 and 0 to 6.66 for seedling densities of 2.71, 3.62, 4.79 and 5.57 seedling per cm^2, respectively, in light soil nursery for all ages, finger lengths and both operating speeds.

In general, the missing hills were marginally higher in the case of heavy soil nursery as compared to light soil with few exceptions due to the sticky nature of heavy soil which reduced the downward sliding of the mat in the tray. Such phenomenon has also been observed by Singh *et al.* (1985).

The seedling density, cutting finger length and age of seedling had significant effect on the missing hills in heavy and light soil nurseries. However, the effect of age of seedlings and operating speed was non-significant in light soil nursery. **Table 4** indicates that when the operating speed increases from 1.40 to 1.80 km/h, the number of missing hills decreased marginally with a few exceptions. With an increase in the cutting finger length, the number of missing hills decreased in respect of all densities, age of seedling and both operating speeds. This was due to an increase in the area of the mat which was cut by the transplanting fingers giving greater number of seedlings and thereby resulting in lower percentage of missing hills. However, in the case of older seedlings, the number of missing hills were marginally high as compared to the younger seedlings with a few exceptions due mainly to lesser number of seedlings picked up by the transplanting fingers because of thicker stem of the older seedlings.

The number of missing of hills was primarily due to the non-uniformity in seedling distribution in the mat. The non-uniformity of seedlings was greater at lower seedling density leading to greater number of missing hills. It was observed that the transplanting fingers always cut a portion of the mat during operation of the machine irrespective of whether there are or no seedlings in the mat. Similar observations were also reported by Mufti and Khan (1995) and Behera (2000). In order to reduce the number of missing hills, it is, therefore, necessary to maintain the optimum uniformity of seedlings in the mat along with seedling density. The recommended hill population is 30 to 35, 35 to 40 and 40 to 50 hills/m^2 for best, medium and poor crop management, respectively. In the

Table 3. Predicted and Observed Number of Seedlings per Hill at Different Cutting Finger Lengths and Seedling Density

Observeddensity, seedling /cm^2	Seed rate, g/mat	Finger length, mm	Predicted seedlings/hill	Observed seedlings/hill	Variation in predicted and observed seedlings/hill, %
		7	2.98	2.53	15.26
2.71	80	12	5.11	4.82	4.70
		17	7.24	6.25	13.65
		7	3.82	3.51	8.02
3.47	100	12	6.54	6.33	3.29
		17	9.27	7.53	18.74
		7	5.04	4.26	15.74
4.58	120	12	8.63	8.25	4.41
		17	12.23	9.19	24.88
		7	6.07	5.26	13.38
5.52	140	12	10.41	9.96	4.34
		17	14.74	11.46	22.28

Table 4. Effect of Seedling Mat Characteristics and Machine Parameters on Missing Hills during Laboratory Experiment

(a) Silty clay loam soil

Age of Seedling, days	inger Length, mm	Missing hills, %							
		Operating speed of 1.40 km/h				Operating speed of 1.80 km/h			
		Density, number/ cm^2 (Seed rate, g /mat)				Density, number/ cm^2 (Seed rate, g /mat)			
		2.71 (80)	3.32 (100)	4.37 (120)	5.46 (140)	2.71 (80)	3.32 (100)	4.37 (120)	5.46 (140)
	7.00	8.61	8.10	5.70	4.19	14.1	10.83	8.3	6.64
20	12.0	7.86	3.92	5.61	3.00	9.00	5.9	4.31	2.08
	17.0	3.81	2.19	1.96	3.10	4.40	2.67	2.08	0
	7.00	12.46	8.33	4.76	2.22	7.13	7.89	3.92	2.08
25	12.0	6.72	2.08	1.96	2.00	6.72	4.2	2.08	2.20
	17.0	1.96	1.96	1.50	0	4.76	1.96	0	0
	7.00	9.97	8.9	7.17	5.24	5.97	4.7	5.66	2.57
30	12.0	8.30	8.14	6.08	4.67	5.07	4.40	3.45	2.02
	17.0	5.00	4.59	3.03	3.03	2.15	4.11	2.97	2.02

(b) Sandy ioam soil

Age of Seedling, days	Finger Length, mm	Missing hills, %							
		Operating speed of 1.40 km/h				Operating speed of 1.80 km/h			
		Density, number/ cm^2 (Seed rate, g /mat)				Density, number/ cm^2 (Seed rate, g /mat)			
		2.71 (80)	3.62 (100)	4.79 (120)	5.57 (140)	2.71 (80)	3.62 (100)	4.79 (120)	5.57 (140)
	7.00	8.93	6.56	6.37	6.66	8.77	8.90	4.94	5.41
20	12.0	7.46	5.52	4.87	3.50	4.18	6.25	2.50	3.70
	17.0	4.20	4.43	0	0	2.38	1.96	0	0
	7.00	9.53	9.40	8.34	4.89	11.19	6.55	4.17	3.06
25	12.0	4.14	4.17	4.00	2.38	8.93	1.96	2.38	2.75
	17.0	4.02	2.08	4.43	1.85	4.45	2.23	0	0
	7.00	7.61	9.30	5.23	5.25	8.02	6.42	6.07	4.74
30	12.0	2.56	3.18	3.05	3.13	2.54	1.56	4.90	3.62
	17.0	2.66	3.90	1.54	1.43	3.61	1.54	1.52	0.57

present study, the maximum number of missing hills was 14.1 per cent. Since, theoretical hill population at 10 and 12 cm hill spacing was 42 and 35 hills/m^2, respectively, and, considering a maximum of 14.1 per cent missing, the hill population would be 36 and 30 hills/m^2, respectively. The above populations of 30 and 36 hills/m^2 which were obtained at minimum density of 2.71 seedlings/cm^2 and minimum cutting finger length of 7 mm are well within the accepted range. Further, in order to reduce the number of missing hills percentage, either density of seedlings or length of transplanting finger has to be increased so as to obtain greater number of hills/m^2. Considering this, if the finger length is increased from 7 to 12 mm, the maximum number of missing hills of 9 per cent will result in a population of 30 and 38 hills/m^2 at 12 and 10 cm hill spacing, respectively. Similarly, at 17 mm finger length where maximum number of missing hills is 5 per cent, the number of hills/m^2 would be 33 and 40 at above two hill spacings, respectively. It is, therefore, suggested that for further increasing the number of hills/m^2, the density of seedlings/cm^2 will have to be increased accordingly.

Table 5. Effect of Seedling Mat Characteristics and Machine Parameters on Hill Percentage with Mechanical Damaged Seedlings during Laboratory Experiment

(a) Silty clay loam soil

Age of Seedling, days	Finger Length, mm	Hill percentage having mechanically damaged seedlings							
		Operating speed of 1.40 km/h				Operating speed of 1.80 km/h			
		Density, number/ cm^2 (Seed rate, g /mat)				Density, number/ cm^2 (Seed rate, g /mat)			
		2.71 (80)	3.32 (100)	4.37 (120)	5.46 (140)	2.71 (80)	3.32 (100)	4.37 (120)	5.46 (140)
20	7.00	2.22	2.08	4.08	4.65	2.45	2.73	3.0	5.36
	12.0	3.82	4.03	4.84	6.07	3.67	4.78	4.47	6.20
	17.0	4.44	5.10	5.42	6.93	4.53	5.17	6.96	8.41
25	7.00	2.63	2.68	3.50	3.94	1.98	2.51	1.48	2.80
	12.0	3.71	3.90	4.82	6.77	3.69	3.36	5.88	8.47
	17.0	2.38	5.64	5.15	8.47	5.51	3.81	4.17	6.02
30	7.00	0.96	0.92	1.58	1.26	1.96	1.86	2.24	2.45
	12.0	1.40	1.60	1.99	2.33	1.99	3.41	4.44	5.58
	17.0	2.66	2.31	1.49	2.21	3.67	3.39	4.17	5.43

(b) Sandy loam soil

Age of Seedling, days	Finger Length, mm	Hill percentage having mechanically damaged seedlings							
		Operating speed of 1.40 km/h				Operating speed of 1.80 km/h			
		Density, number/ cm^2 (Seed rate, g /mat)				Density, number/ cm^2 (Seed rate, g /mat)			
		2.71 (80)	3.62 (100)	4.79 (120)	5.57 (140)	2.71 (80)	3.62 (100)	4.79 (120)	5.57 (140)
20	7.00	1.77	1.57	1.94	1.98	2.47	3.36	3.06	3.22
	12.0	2.26	2.25	4.31	3.78	4.51	4.68	4.40	3.65
	17.0	2.40	4.24	4.08	8.27	5.55	6.02	6.38	4.23
25	7.00	0.94	1.46	2.25	1.91	2.21	1.95	1.48	2.42
	12.0	2.27	2.16	2.64	2.83	2.88	3.78	2.59	4.45
	17.0	3.52	3.36	6.17	4.23	6.21	5.58	6.87	6.53
30	7.00	1.61	1.57	2.64	2.09	1.63	1.48	1.58	2.08
	12.0	2.11	1.74	2.57	3.59	2.36	2.11	2.37	2.70
	17.0	2.65	2.54	3.36	3.55	3.46	3.25	3.85	2.96

Hill Percentage with Mechanically Damaged Seedlings

Mechanical damage to hills was observed for the four seedling densities with three ages and transplanting finger lengths at two operating speeds. The mechanical damage was defined as the injury to stems or roots of the seedlings in terms of cutting of stems and roots completely or partially by the transplanting fingers. It was noticed that only one or in some cases two seedlings per hill were damaged during the operation of the transplanter. Thus, the mechanical damage did not affect the total hill population per m^2. The results of the mechanical damage of hills obtained during the laboratory study are shown in **Table 5**.

The hill percentage with mechanically damaged seedlings increased with an increase in the operating speed, seedling density and cutting finger length. It was also noticed that the increase was higher in the case of heavy soil as compared to light soil nursery. The mechanical damage was maximum at higher operating speed and lower age of seedlings. On increasing the finger length along with seedling densities, mechanical damage to the seedling also increased. However, an increase in the mechanical damage to seedlings was observed high when the finger length was increased from 7 to 12 mm as compared to 12 to 17 mm.

In heavy soil nursery, the lowest mechanical damage was 0.92 per cent for the 30-day old nursery with 7 mm cutting finger length at operating speed of 1.40 km/h. The highest value was 8.41 per cent for the 20-day old seedlings at 17 mm finger length with operating speed of 1.80 km/h. A similar trend of mechanical damage was also observed with variations between 0.94 and 8.27 per cent for light soil condition.

Higher mechanical damage at 17 mm finger length was due to cutting of larger volume of seedling mat which increased the chance of greater damage to seedlings. In the case of maximum seedling density, the mechanical damage was high due to greater population of seedlings in the mat leading to the damage of the seedling coming directly in contact with the transplanting finger. High mechanical damage at maximum operating speed of 1.8 km/h was due to greater impact force of the transplanting fingers on the seedlings. Greater mechanical damage on younger seedlings could have been caused due to their tenderness.

(Continued on page 38)

Development and Evaluation of Manually-operated Garlic Planter

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Abstract

A single-row manually-operated planter developed at the Department of Farm Power and Machinery, Punjab Agricultural University, Ludhiana was evaluated for sowing garlic (*Allium sativum*). The Machine consists of a planting mechanism and hopper mounted over a wheel hand hoe. The planting mechanism consists of a vertical disc with spoons on its face. The weight of the machine is about 12.0 kg. The machine is operated by 2 persons and another person is required for supplying the seed. The capacity of the machine varies from .03-.04 ha/h. The machine is quite simple in design and costs Rs. 1200. It is highly labour-saving equipment as it requires only about 83 man-h/ha in comparison to about 520 man-h/ha. The cost of planting using this machine is only 15 percent of the cost of planting by traditional method.

Introduction

Garlic (*Allium sativum*) is an important vegetable and spice crop grown during the winter season in India. Garlic is also known to possess medicinal value and its regular use is known to lower the cholesterol and blood pressure. It is sown on small scale with the help of *khurpa* and commercially sown by the *kera* method. The sowing of garlic by traditional method is highly labour-intensive and it requires about 60-70 persons to sow one hectare because row spacing and plant spacing in garlic is very low, i.e., 15 cm and 7.5 cm, respectively, (*Anonymous, 1999*). Because of the high labour requirement and scarcity of labour, crop sowing is many times delayed which leads to reduction in yield.

The cost of planting garlic is also very high, about Rs. 5,000/ha. Hence, there is a need to develop a simple machine that can overcome the difficulty of garlic planting and reduce the labour and cost of sowing. The development of such a machine will help in timely sowing of the crop and increase the yield. The reduction in cost of cultivation of garlic will help to increase the area planted to this crop. Currently, the area sown by individual farmers is less hence, a manually-operated planter was developed and tested for sowing of garlic in Punjab.

Materials And Methods

Description of the Machine

A single-row manually-operated garlic planter was developed. The machine consists of a wheel hand hoe(*Garg,Sharma,1988*) on to which a planting mechanism is mounted. The power from the wheel to the planting mechanism is provided by means of chain and sprocket. The side view of the machine is shown in **Fig. 1**. The seed metering of the mechanism consists of a vertical disc with spoons. The system of mounting the spoons on the disc is shown in **Fig. 2**. The spoons are fixed on the circular ring mounted on a circular vertical plate in the planting hopper by means of three nuts and bolts. The capacity of the hopper is 3 kg. The planter is operated by two persons. One person pulls it with the help of a rope and the other person steers it. It is also provided with markers on either side to maintain the desired row spacing. The planter in stationary position is shown in **Fig. 3** and in operation in **Fig. 4**. Plant spacing can be varied by varying the number of spoons on the disc or by changing the sprockets. Brief specifications of the planter are shown in **Table 1**.

Evaluation Procedure

Initial trials on the garlic planter were conducted at the PAU farms in order to study its field performance. For this purpose, garlic kernels were separated from the garlic bulbs and graded. The number of spoons on the plate were set in such a way that the plant spacing of approximately 7.5 cm was manufactured. Data recorded during initial trials (**Table 2**) indicated that the

Table 1. Specifications of the Manually-Operated Garlic Planter

Type of planter	Manually operated	
Source of power	Two persons	
Machine suitability	For planting garlic kernels	
Overall machine dimensions	Length, cm	107
	Width, cm	46
	Height, cm	110
No. of rows	One	
Row-to-row spacing, cm	Adjustable	
Capacity of seed box, kg	3.0	
Type of seeding mechanism	Vertical disc with spoons	
Number of spoons on the plate	12	
Shape of spoon	Elongated cavity	
Type of power transmission	Through chain and sprocket from wheel	
Transmission ratio from wheel to planting mechanism	1:1	
Type of furrow openers	Shovel type	
Approximate machineweight,kg	12.0	
Machine cost	Rs. 1200	

germination after 10 days of planting was only 35.26 percent as compared to 58.33 percent in manual planting. The depth of planting was 6.3 cm in comparison to 2.7 cm in the case of manual planting.

Crop yield in machine planting was also low (57.42 q/ha) in comparison to manual planting (72.26 q/ha). Subsequently, experiments were conducted at the farm to study the effect of depth of planting. The germination of garlic at higher depth of 7.5 cm was only 72.22 percent in comparison to germination of 91.25 percent at lower depth of 2.5 cm (**Table 3**). It was also observed during initial trials that delayed germination due to deep placement of the kernels had an adverse effect on the yield.

Necessary adjustments were therefore made in the furrow opener to control the depth of planting. This was done by providing a gauge wheel. Also, the shapes of the spoons were modified on the basis of initial trials. The modified prototype was evaluated at the PAU farms and at the farmer's fields. For this purpose, four prototypes of the garlic planter were fabricated. The machine field performance data in comparison to manual planting is shown in **Table 4**. Experiments were also conducted to study the effect of different positions of garlic kernels dropped by the machine on germination and yield. The germination end of the kernel was placed in three different positions, i.e., downward, upward and longitudinally. The results are shown in **Table 5**.

Table 2. Field Performance of the Garlic Planter, 1998-99

Description	Machine-planted plots				Manually-planted plots			
	R1	R2	R3	Mean	R1	R2	R3	Mean
Plot area, m^2	301.5	301.5	302	-	301.5	301.5	302	-
Seed rate, kg/ha	347.5	422.9	443.7	404.7	480.9	487.5	530.0	499.4
Depth of planting, cm	6.7	5.9	6.2	6.3	2.2	3.2	2.7	2.7
Plant spacing, cm	9.5	11.0	8.7	9.7	7.4	8.1	7.9	7.8
Row spacing, cm	15.0	17.5	18.0	16.83	15.2	15.8	14.9	15.3
Labour requirement for sowing, man-h/ha	71.9	66.3	66.2	68.3	625.3	646.8	609.8	627.3
Germination after 10 days, %	22.43	42.76	40.58	35.26	57.5	56.67	60.83	58.33
Germination after 20 days, %	87.67	72.46	65.96	75.36	95.8	89.20	95.8	93.6
Missing kernels,%	3.5	4.0	2.9	3.47	-	-	-	-
Places where seed dropped double, %	15.4	18.0	14.2	15.87	-	-	-	-
No. of plants/m^2	58	63	52	57.67	81	79	86	82.0
Theoretical plant population/m^2	-	-	-	88	-	-	-	88
Yield, q/ha	60.37	58.1	53.8	57.42	69.42	71.02	76.05	72.16

Table 3. Effect of Depth of Planting of Garlic on Germination.

Depth of planting, cm	Number of kernels germinated after 20 days of planting out of 210 plants				
	Plot no.1	Plot no.2	Plot no.3	Mean	Percentage germination
7.5	120	183	152	151.66	72.22
5.0	120	184	169	157.66	75.07
2.5	180	204	192	192	91.42

Table 4. Field Performance of Modified Garlic Planter

Description	Machine-planted plots				Manually-planted plots		
	R1	R2	R3	Mean	R1	R2	Mean
Seed rate, kg/ha	590.9	575.0	609.1	591.7	635.17	520.6	577.6
Depth of Planting, cm	3.04	3.08	2.80	2.97	3.04	3.11	3.08
Plant spacing, cm	7.71	7.02	7.33	7.35	7.25	7.40	7.34
Row spacing, cm	16.97	14.07	14.92	15.32	16.88	17.61	17.25
Labour requirement for sowing, man-h/ha	86.8	80.0	82.3	83.1	505	535	520
Orientation of seed, %							
Flat	32.58	39.0	35.12	35.57	50.57	32.96	41.74
Upward	46.36	29.35	41.07	38.93	49.49	67.04	58.26
Downward	21.06	31.65	23.81	25.51	0	0	0
Germination after 10 days, %	89.0	84.1	84.6	86.56	95.7	92.9	94.3
Germination after 20 days, %	97.6	91.5	89.7	95.6	98.6	96.4	97.5
Missing, %	3.1	3.9	3.4	3.46	-	-	-
Places where seed dropped double, %	20.6	16.0	15.2	17.26	-	-	-
Number of plants/m^2	74.4	86.6	80.2	80.4	81.0	79.4	80.2
Theoretical plant population/m^2	-	-	-	88	-	-	88
Machine speed, km/h	1.81	1.92	1.83	1.85	-	-	-
Machine capacity, ha/h	0.03	0.032	0.029	0.03	-	-	-
Yield, kg/ha	79.75	97.45	94.3	90.50	83.67	98.25	91.96
Weight of harvested kernels, Number /kg	46.5	52	46.5	48.33	47	56	51.50

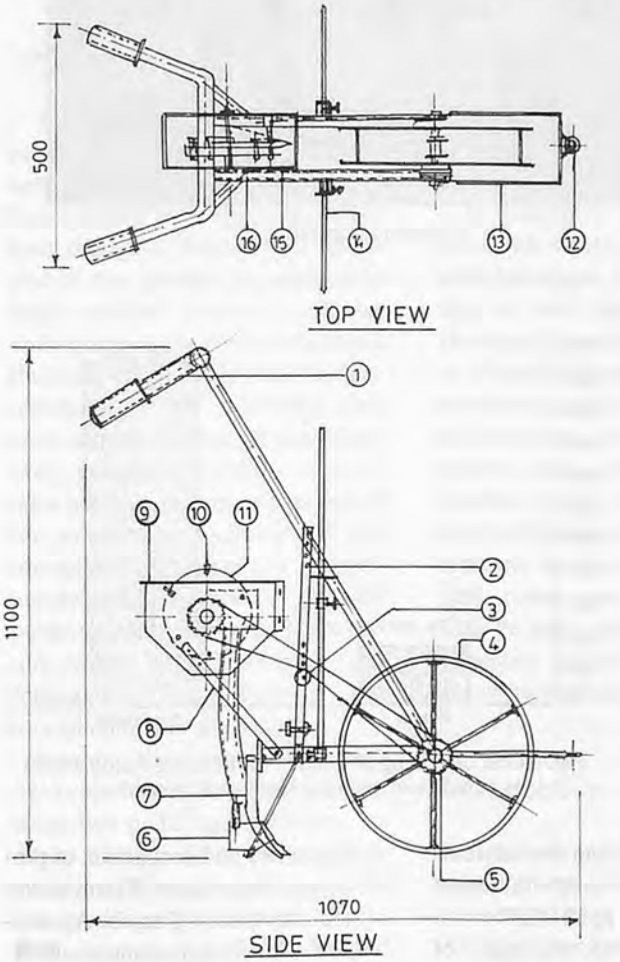
Results And Discussion

The field performance results in **Table 4** show that the field capacity of the manual planter for sowing garlic on large-scale varied from .029-.032 ha/h by employing 2-3 persons. The average germination percentage after 10 days of sowing was 86.56 percent in comparison to 94.3 percent in manual planting. After 20 days of sowing the germination percentage in machine planting was 95.6 and 97.5 percent in manual planting. The low germination in the beginning in machine planting was due to the wrong position of kernels by the machine. The downward germination end took a few days more to germinate. **Table 5** shows that garlic kernels with upward germination end had the highest germination of 76.92 percent after 10 days of sowing. The downward position of germination end had the lowest germination percentage of 70.57. Overall, the germination of kernels planted by the machine was 86.56 percent after 10 days of sowing in comparison to 94.3 percent in manually planted plots. Not much difference in germination after 20 days of planting was observed. The labour involved in harvesting operation also varied depending upon the position. Higher labour requirement was required to harvest the plots planted with the downward position of kernels. Also, in this case, a number of kernels were left in the field after manual harvesting. The results presented in **Table 4** also show that the depth of planting by the machine was reduced to 2.97 cm, which is close to that of the manual planting depth. The performance of modified planter was satisfactory.

Labour requirement for sowing garlic with the planter was only 83.0 man-h/ha in comparison to 520 man-hr/ha by traditional method (**Fig. 5**). Also, the cost of sowing with the planter was Rs. 858/ha in comparison to Rs. 5200/-ha with traditional system (**Fig. 6**).

Conclusions

The garlic planter is a high labour-saving equipment requiring only 83 man-h/ha in comparison to 520 man-h/ha in the traditional



1. Handle 2. Fork and handle support 3. Idler pulley 4. Wheel ring
5. Free/wheel assembly (18T) 6. Furrow opener 7. Tine assembly
8. Fork and seed box support 9. Seed box 10. Seed cup
11. Disc holding seed cup 12. Hook 13. Hook frame 14. Marker
15. Wheel Frame 16. Chain

Fig. 1 Manually-operated garlic planter.

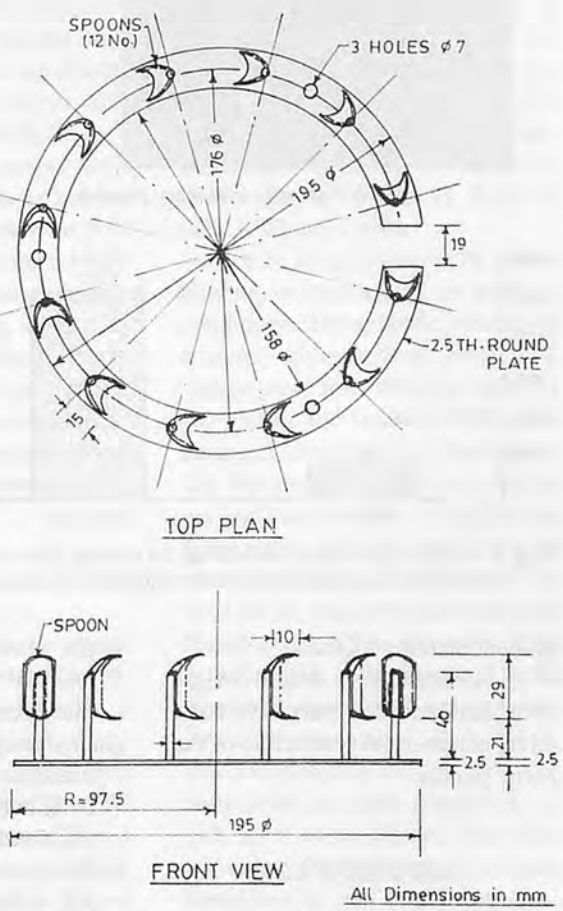


Fig. 2 Seed metering disc for garlic planter.

Table 5. Effect of Position Of Garlic Kernel On Germination And Yield

Description	Position of the garlic seed											
	Downward				Flat				Upward			
	R1	R2	R3	Mean	R1	R2	R3	Mean	R1	R2	R3	Mean
Number of kernels geminated after 10 days of planting, %	59.50	78.50	73.78	70.57	71.42	76.14	73.78	73.78	80.92	83.28	66.64	76.92
Number of kernels geminated after 30 days of planting, %	76.14	83.28	80.42	79.94	81.42	86.92	80.92	83.08	83.28	88.07	80.92	84.07
Weight of harvested kernels, Number/kg	51	58.5	61	56.8	46	49	41	45.3	49.5	52	46.5	49.3
Yield q/ha	66.5	72.8	75.2	71.5	102.4	83.85	84.5	90.25	92.97	94.8	73.25	87.0
Labour requirement for Harvesting, man-h/ha	410.4	328.1	318.7	352.2	382.7	273.4	237.0	297.7	397.5	218.7	309.9	308.7
Number of kernels left in the field after harvesting, Number /field	116	38	58	70.67	63	55	28	48.67	59	35	70	54.67

Fig. 3 Planter in stationary position.

Fig. 4 Planter in operation.

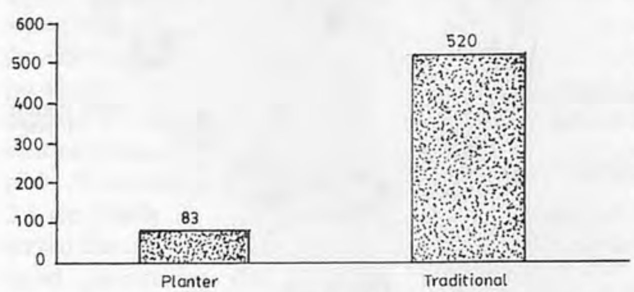


Fig. 5 Labour requirement (man-h/ha) for sowing garlic using the planter in comparison with the traditional method.

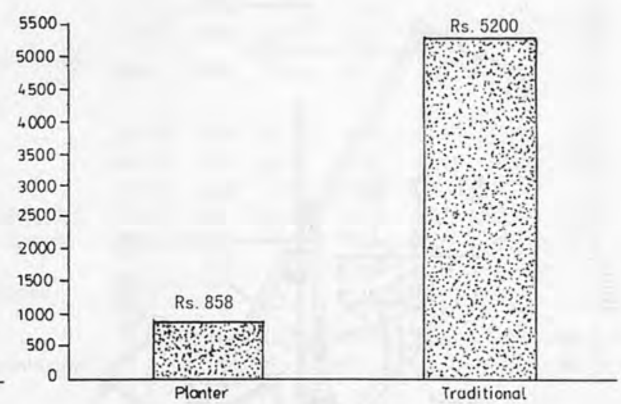


Fig. 6 Cost of sowing (Rs./ha) of garlic using the planter in comparison with the traditional method.

manual planting method.

The planter had a simple design. Two local manufacturers have started its commercial production of the garlic planter.

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Performance Evolution of Self-propelled Rice Transplanter under Different Puddled Field Conditions and Sedimentation Periods

by

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Abstract

Transplanting of rice by self-propelled transplanter provides timeliness in operation, savings in cost of transplanting and minimizing of human drudgery. Satisfactory operation of rice transplanter requires an ideal puddled condition togather with optimum sedimentation period. Puddling creates a favourable physico-chemical and microbiological environment for crop growth. However, excessive puddling necessitates a higher sedimentation period for satisfactory operation of rice transplanter. Therefore, a comprehensive study in respect of different puddling equipment and sedimentation periods in light soil on the performance of self-propelled rice transplanter was undertaken.

Keeping these points in view, a field experiment was conducted by using two puddling equipment, i.e, rotary blade puddler and peg type puddler with two levels of puddling (one and two passes) under three sedimentation periods 12, 18 and 24 hours. Based on the findings in the above study, another experiment was undertaken in a well prepared field by using a peg type puddler (one and two passes), rotary blade puddler (one pass) and a treatment with no puddling with a view to minimizing the sedimentation period with respect to three sedimentation periods of 0, 6 and 12 hours.

In general, it was observed that the depth of transplanting, traction wheel slippage, hill spacing, deviation in row spacing, buried and floating hills increased with the level of puddling and decreased with increasing sedimentation period for all treatments. But it was more pronounce in the case of rotary blade puddler. Since, there was no significant difference in grain yield with reduced level of puddling, therefore, rotary and peg type puddler may be used with one pass so as to minimize the sedimentation period for transplanting operation.

Introduction

Rice is a major crop that is grown in more than 110 countries. The total area planted to rice in India is 42.20 million hectares which is largest in the world against a total area of 148.40 million hectares. The total rice production of the world was 527 million tonnes out of which 84.74 million tonnes were produced in India, second after China's 187 millions tonnes in an area of 31 million hectare (Survey of Indian Agriculture, 1999). Though India has largest area planted to rice, it is still among the countries with low yield of only 1.9 t/ha in comparison to Egypt's (8.3 t/ha) and China's (6.1 t/ha). The yield level of rice has to increase by 25 to 30 percent from the present level of 1.9 t/ha if the country is to remain self-sufficient by 2010. (Survey of Indian Agriculture, 1999 and 2000).

Rice is largely grown by transplanting of seedlings under puddled conditions. Transplanting rice gives a more uniform crop stand with higher yield than direct seeding of rice (Khan and Gunkel, 1988). The nature of planting rice is backbreaking that involves enormous drudgery and human stress. Transplanting takes about 250-300 man-hr per ha which is roughly 25 per cent of the total labour requirement of the crop (Singh *et al.*, 1985). Non-availability of labour during transplanting season has emerged as a major problem in the rice regions. The mechanical transplanting of rice has been considered the most promising option, as it saves labour, minimizes stress and drudgery, ensures timely transplanting and attains optimum plant density that contributes to high productivity.

Self-propelled rice transplanters are classified into two major groups on the basis of the type of nursery used, i.e., (i) washed-root seedlings; and (ii) soil bearing (mat type) seedlings. Both washed-root and mat-type seedling transplanters are popular in China, Korea, Philippines and Japan. In first type, rice seedlings with 4 to 6 leaves and height of 18 to 35 cm are uprooted before transplanting and thoroughly washed with water. The performance of the machine depends upon thorough washing of seedlings and trimming of their leaves and roots to 20 cm and 2 cm, respectively. This process requires considerable manual labour which is already scarce in the country (Khan and Gunkel, 1988). It has been observed that the mat-type transplanters give better results in terms of less missing hills and floating of seedlings during transplanting and lesser labour requirement as compared to washed-root transplanters.

Like all other wetland agricultural machinery, the self-propelled rice transplanter also has problems of poor traction, sinkage and steerability. Hence, there is need to quantify the state of puddling and sedimentation period so that soft puddled soil at the top must have sufficient bearing capacity to prevent sinking of float. High degree of puddling severely affects the mobility of the transplanter and its performance. It also takes longer sedimentation period when the transplanter is operated. Efficient working of the self-propelled rice transplanter requires a suitable puddled soil condition, optimum depth of puddling and soil strength of puddled field. Investigations have been carried out to study the influence of different puddlers, numbers of passes and sedimentation period for efficient operation of the transplanter in silty clay soil (Behera, 2000).

Therefore, the present study was undertaken in order to identify ideal puddled soil conditions under light soil with respect to better puddling equipment, level of puddling and optimum sedimentation period for satisfactory performance of self-propelled rice transplanter as well as crop growth.

Materials and Methods

A Chinese made 8-row self-propelled rice transplanter (Model: 2 ZT-238-8) was used in two different field investigations. It has 23.80 cm fixed row to row spacing and variable hill to hill spacing of 10 and 12 cm at corresponding operating speeds of 1.57 and 1.94 km/h, respectively. The detailed technical specifications of the transplanter are shown in **Table 1**.

Field Experiments

The field experiments were conducted during the summer of the year 2000 and kharif seasons of the same year to evaluate the effect of puddling on the performance of the self-propelled rice transplanter and rice crop in respect of different sedimentation periods.

The first field experiment was conducted by using two puddling equipment viz., rotary blade puddler and peg type puddler with two levels of puddling (one and two passes) which accounted for four main plot treatments. Three sedimentation periods of 12, 18 and 24 hours of puddled field were taken as sub-plot treatments to evaluate the performance of the transplanter with reference to the elapsed time after pudlling.

On the basis of the first experiment and observations subsequently made, a treatment of rotary blade puddler with two passes was dropped off in the second experiment. Therefore, for the second experiment, 4 treatments viz., one level of puddling by rotary puddler, two levels of puddling (one and two passes) with peg type puddler and no puddling were considered as the main plot treatments. The forth treatment, i.e., no puddling was taken considering the fact that in certain areas, farmers prepare the dry seedbed and transplant rice directly after flooding the field. Three sedimentation periods 0, 6 and 12 hours were chosen as sub-plot treatments.

Experimental Procedure

For this experiment, the seedlings were grown between 15th February to 8th April 2000. Due to the cold winter season during nursery raising, the temperature varied between 4.5° to 10.9° C. The proper seedling growth was restricted and, therefore, the seedlings were ready for transplanting only after 50 days. The experimental field was divided in to three blocks of 60 × 10 m size. Each block was further divided in to four equal parts of size 15 × 10 m to accommodate the main plot treatments as puddling equipment and level of puddling. Each main plot was again partitioned into three

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

Items	Specifications
Model	2 ZT-238-8
Dimension (L × W × H), cm	241× 213.1×130
Engine power, kW	2.4
Fuel	Diesel
Cooling system	Air cooled
Weight, kg	320
Walking mechanism	Single wheel driven
Type of float	Fiber glass
Working mechanism	Separate crank connecting rod transplanting mechanism
Number of rows	8
Row spacing, cm	23.8
Hill to hill spacing, cm	10 and 12
Frequency of transplanting, strokes / min	238
Depth of transplanting	Adjustable with screw rod (2 to 12 cm)
Traction wheel	
(a) Diameter, cm	70
(b) No. of lugs	15
(c) Lug angle, degree	22 upward
Frequency of strokes of fingers in maximum displacement of tray, no.	14
Max. depth of finger entering the mat, cm	1.7

sub-plots of size of 10 × 4 m each to study the effect of sedimentation periods of 12, 18 and 24 hours. Each treatment was replicated three times.. Hill to hill spacing was set at 12 cm for experiment.

The second field experiment was undertaken during the kharif season of the year 2000. The seedlings were raised between 15^{th} June and 10^{th} July 2000. The field was divided into three blocks of size 60 × 15 m each and further partitioned into 4 main plots of size 15 × 15 m for treatments of puddling equipment along with the level of puddling such as rotary blade puddler with one pass, peg type puddler with one and two passes and control (no puddling). The three sedimentation periods of 0, 6 and 12 hours were taken as sub-plot treatments in each main plot of size 15 × 4 m. Transplanting was done by the self-propelled transplanter with hill to hill spacing of 10 cm during 12 to 13 July 2000.

The results were analyzed statistically using analysis of variance (ANOVA) technique according to different experimental designs followed during the investigations. The overall significance of treatments was tested by 'F' test. The data were compared pair-wise with the help of critical difference (CD) at 5 per cent level wherever the F-test result was found significant.

Results And Discussion

The performance of the transplanter with respect to depth of transplanting, traction wheel slippage, hill-to-hill spacing, deviation in row spacing, buried and floating hills, hill percentage with mechanically damaged seedlings, missing hills, seedlings per hill and number of hills/m^2 were studied under different puddling conditions and sedimentation periods.

Depth of Transplanting

Depth was measured after transplanting in all the treatments with respect to sedimentation period during both experiments. The data obtained on depth of transplanting are presented in **Table 2**. In general, the depth of transplanting increased with increasing the puddling level and decreased with increasing the sedimentation period during both experiments. The maximum depth of transplanting of 5.63 cm was obtained in the case of treatment R_2 at 12 hours and minimum for treatment P_1 (3.48 cm) at 24 hours sedimentation period in first experiment. However, it was maximum as 7.21 cm and minimum as 4.27 cm in the case of R_1 at zero and P_1 at 12 hours sedimentation period, respectively in the second experiment. The depth of transplanting was significant with respect to puddling equipment and sedimentation periods in both experiments.

The depth of transplanting decreased significantly with increasing the sedimentation period in the first experiment. However, it was statistically at par in the case of R_1 and R_2 when sedimentation period increased from 12 to 18 hours. In the second experiment, there was no significant difference in treatment N and P_2 but there was significant difference in the case of R_1 and P_1 when the sedimentation period increased from 0 to 6 hours. While increasing the sedimentation period from 18 to 24 hours in first experiment, the depth decreased significantly for treatments R_2, P_1 and P_2 in first experiment but not significant for treatment R_1. However, in the second experiment, the depth decreased significantly for all treatments, i.e., R_1, P_1 and P_2 when sedimentation increased from 6 to 12 hours except for no puddling treatment (N) in which case the depth of transplanting was statistically at par for all sedimentation periods.

During both field experiments, the depth of transplanting was set at 3 cm. However, it was observed more than the preset value due to sinkage of the float of transplanter. The depth of transplanting was high at low sedimentation period due to higher float sinkage because of greater softness of puddled soil. With the increase in sedimentation period, the puddled soil gained strength thereby reduced the float sinkage which resulted in lower depth of transplanting. Greater depth in transplanting in the case of rotary blade puddler as compared to peg type puddler at the same number of passes was due to better quality of puddling and slow settlement of soil particles. The above results were in agreement with the findings of Mori (1975).

Traction Wheel Slippage

The traction wheel slippage of the transplanter was determined for different puddling equipment with respect to sedimentation periods in both experiments. In general, the traction wheel slippage increased significantly with the sedimentation period. The data obtained are given in **Table 2**.

The minimum and maximum traction wheel slippage in the first experiment was observed in the case of treatments R_2 (4.02%) at 12 hours and P_1 (12.57%) at 24 hours sedimentation period, respectively. However, it was 2.75 per cent at zero and 10.91 per cent at 12 hours sedimentation periods in the case of treatments R_1 and P_1, respectively in the second experiment. In the first experiment at 12 hours sedimentation, the traction wheel slippage was statistically at par in respect of treatment R_2 (4.02) with P_2 (4.45%) and P_1 (8.88) with R_1 (7.98%). However, the wheel slippage for treatments P_1 and R_1 was significantly higher than treatments R_2 and P_2. A similar trend was observed at 18 hours sedimentation period. At 24 hours sedimentation period, wheel slippage in the cases of treatments R_1 (12.25), P_1 (12.57) and P_2 (11.86%) were statistically at par but significantly higher than R_2 (6.98%) in the first experiment. When the sedimentation period increased form 12 to 18 hours, the wheel slippage increased significantly in treatments R_1, P_1 and P_2 but not significant in treatment R_2 whereas it increased significantly in all treatments when the sedimentation period increased from 18 to 24 hours during the first experiment.

In the second experiment, at zero sedimentation period, the maximum wheel slippage of 6.83% was obtained for treatment N which was significantly higher as compared to P_1 (5.51), P_2 (3.48) and R_1 (2.75%), respectively. The treatments R_1 and P_2 were statistically at par but significantly lower than treatment P_1. At 6 hours sedimentation, significantly higher value was obtained in treatment P_1 (8.57%) than other treatments, i.e., N (6.38), R_1 (4.21) and P_2 (4.48%). The treatments R_1 and P_2 were statistically at par but significantly lower than treatment N. At 12 hours sedimentation period, there was no significant difference between treatments R_1 (6.39) and P_2 (5.59%). However, these were significantly lower than treatment N (8.88%) which was statistically inferior to treatment P_1 (10.91%). When the sedimentation period increased from 0 to 6 hours in the second experiment, the wheel slippage increased significantly in the cases of treatments R_1 and P_1 and not significant in treatments N and P_2. While changing the sedimentation period from 6 to 12 hours, the wheel slippage increased significantly in all treatments except P_2.

The traction wheel slippage was less at the lower sedimentation period for all the treatments and in both experiments. This might be due to better lubrication effect at the interface of the float of the transplanter and puddled soil because of easy flow of partially settled soil particles in front of the transplanter float resulting in smooth movement of the machine. In addition, the water level in the field was low at the sedimentation period which enhanced the process of lubrication. The puddled soil became harder with increasing sedimentation period where the water level of the field was also reduced gradually which increased the drag force and simultaneously wheel slippage.

Hill Spacing

The hill-to-hill spacing was preset at 12 cm and 10 cm in the first and second experiments, respectively, and measured in each treatment with corresponding sedimentation period. The data are shown in **Table 3**.

The hill spacing decreased with an increase in the sedimentation period in both experiments. The maximum hill spacing in the case of treatment R_2 (12.58 cm) which was 4.83 per cent higher than the prefixed value followed by P_2 (12.41), R_1 (12.37) and P_1 (12.28 cm) at 12 hours sedimentation period. Similarly, the minimum hill spacing of 11.84 cm in the case of P_1 at 24 hours sedimentation period which was 1.33 per cent lower than preset hill spacing in the first experiment. The variation in hill spacing was not significant in the case of all treatments for all sedimentation periods during the first experiment.

In the second experiment, where hill spacing was fixed at 10 cm, the hill spacing was greater than the preset value for all sedimentation periods of 0, 6 and 12 hours in all the treatments except in the case of P_1 (9.70 cm) at 12 hours sedimentation period. The maximum and minimum hill spacing of 10.69 and 9.70 cm were obtained in the case of P_2 at zero sedimentation and P_1

Table 2. Influence of Puddling Equipment on Depth of Transplanting and Traction Wheel Slippage at Different Levels of Sedimentation Period

1st Experiment: Summer rice (2000)

Treatments (Puddling equipment)	Depth of transplanting, cm				Traction wheel slippage, %			
	Sedimentation period, h			Mean	Sedimentation period, h			Mean
	12	18	24		12	18	24	
R_1	4.98	4.73	4.45	4.72	7.98	10.95	12.25	10.39
R_2	5.63	5.14	4.32	5.03	4.02	4.71	6.98	5.24
P_1	4.74	4.22	3.48	4.15	8.88	10.62	12.57	10.69
P_2	4.95	4.22	3.63	4.27	4.45	6.76	11.86	7.69
Mean	5.08	4.58	3.97	4.54	6.33	8.26	10.92	8.50
Factors	SEm ±		$CD_{(0.05)}$		SEm ±		$CD_{(0.05)}$	
Puddling equipment (a)	0.086		0.30		0.56		1.93	
Sedimentation period (b)	0.084		0.25		0.25		0.74	
Interaction (a × b) 1*	0.169		0.51		0.49		1.48	
2**	0.163		0.51		0.69		2.27	

2nd Experiment: Kharif rice (2000)

Treatments (Puddling equipment)	Depth of transplanting, cm				Traction wheel slippage, %			
	Sedimentation period, h			Mean	Sedimentation period, h			Mean
	0	6	12		0	6	12	
R_1	7.21	5.83	4.78	5.94	2.75	4.21	6.39	4.45
P_1	5.73	5.05	4.27	5.02	5.51	8.57	10.91	8.33
P_2	6.42	5.88	4.93	5.74	3.48	4.48	5.59	4.52
N	5.22	5.10	4.90	5.07	6.83	6.38	8.88	7.37
Mean	6.14	5.47	4.72	5.44	4.64	6.02	7.94	6.17
Factors	SEm ±		$CD_{(0.05)}$		SEm ±		$CD_{(0.05)}$	
Puddling equipment (a)	0.16		0.56		0.47		1.64	
Sedimentation period (b)	0.10		0.31		0.20		0.59	
Interaction (a × b) 1*	0.21		0.63		0.40		1.19	
2**	0.24		0.75		0.57		1.90	

* Interaction (1): For comparing two sedimentation periods for same puddling equipment

** Interaction (2): For comparing two puddling equipment at same or different levels of sedimentation period

R_1: Rotary puddler one pass R_2: Rotary puddler two passes P_1: Peg type puddler one pass P_2: Peg type puddler tow passes N: No puddling at 12 hours, respectively, which was 6.9 per cent higher and 3.0 per cent lower than the preset value. There was no significant difference in hill spacing among the treatments at all sedimentation periods.

The hill spacing depended on the traction wheel slippage. The higher hill spacing at lower sedimentation period was due to lower wheel slippage than the designed value of the transplanter. Similarly, at higher sedimentation period, the hill spacing was less due to greater wheel slippage. Similar results were also reported by Mori (1975) and Behera (2000).

Deviation in Row Spacing

The deviations in row spacing which were determined with respect to the existing row spacing of the transplanter (23.8 cm), are shown in **Table 3**. The deviation in row spacing from its prefixed value of 23.80 cm was significantly higher at 12 hours sedimentation period as compared to 18 and 24 hours in all the treatments during the first experiment. After the 12 hours sedimentation period, the deviations in row spacing for treatments R_2 (4.73%), P_2 (4.48%), R_1 (3.85%) and P_1 (3.57%) were statistically at par. A smilar trend was found at 18 hours as well as 24 hours sedimentation periods where there was no significant difference among the treatments.

During the second experiment, at zero sedimentation period, deviation in row spacing was statistically at par in the case of treatments R_1 (5.46), P_1 (4.83) and P_2 (5.95%) but these were significantly higher than treatment N (1.52 %). At 6 hours sedimentation period, there was no significant difference in treatments R_1 (3.68%), P_2 (2.84%) and P_1 (2.24%). Whereas, treatment N (0.46%) was significantly lower as compared to treatments R_1 and P_2 and statistically at par with P_1. However, at 12 hours sedimentation period there was no significant difference in the deviation in row spacing among the treatments.

Higher deviations in row spacing from the prefixed value of 23.8 cm at12 hours in first and at zero sedimentation period in the second experiment were due to great flow of puddled soil by the movement of the float of the transplanter which disturbed the row spacing. High variation in the case of rotary blade puddler as compared to peg type puddler was due to inadequate settling of soil particles leading to greater sinkage of the float which resulted in greater displacement of mud. With the increase in sedimentation period, there was greater settlement of soil particles resulting in less flow of puddled mass which in turn decreased the deviation in row spacing. These findings were in agreement with studies made by Mori (1975) and Behera (2000).

Buried and Floating Hills

Buried and floating hills were observed after transplanting and expressed in percentage are given in **Table 4** for both experiments.

Buried Hills

The percentage of buried hills were high at 12 and zero hour of the sedimentation period in the first and second experiments, respectively. But in the second experiment, the percentage of buried hills was high in comparison to the first experiment which was mainly due to lowering down the sedimentation period. The buried hills decreased significantly from 4.87 to 0.61, 6.21 to 1.42, 4.44 to 1.28, and 5.21 to 1.28 per cent for treatments R_1, R_2, P_1 and P_2, respectively, in the first experiment when the sedimentation period increased from 12 to 24 hours. Whereas, it decreased significantly from 11.39 to 3.07, 7.23 to 1.04 and 14.91 to 1.49 per cent in the case of treatments R_1, P_1 and P_2, respectively, but not significant for treatment N (3.12 to 0.97 per cent) in the second experiment while sedimentation period increased from

Table 3. Influence of Puddling Equipment on Hill Spacing and Deviation in Row Spacing at Different Levels of Sedimentation Period

1st Experiment: Summer rice (2000)

Treatments (Puddling equipment)	Hill spacing, cm: Sedimentation period, h 12	18	24	Mean	Deviation in row spacing, %: Sedimentation period, h 12	18	24	Mean
R_1	12.37	12.20	11.96	12.18	3.85	3.29	2.38	3.17
R_2	12.58	12.40	12.14	12.37	4.73	2.84	2.44	3.67
P_1	12.28	12.17	11.84	12.10	3.57	2.49	2.03	2.70
P_2	12.41	12.18	11.95	12.18	4.48	3.43	1.33	3.08
Mean	12.41	12.23	11.97	12.21	4.16	3.26	2.04	3.16

Factors	Hill spacing SEm±	Hill spacing $CD_{(0.05)}$	Deviation SEm±	Deviation $CD_{(0.05)}$
Puddling equipment (a)	0.029	0.10	0.34	NS
Sedimentation period (b)	0.026	0.08	0.089	0.27
Interaction (a × b) 1*	0.051	NS	0.18	0.54
2**	0.051	NS	0.37	1.26

*, **: See footnotes at the bottom of Table 2

2nd Experiment: Kharif rice (2000)

Treatments (Puddling equipment)	Hill spacing, cm: Sedimentation period, h 0	6	12	Mean	Deviation in row spacing, %: Sedimentation period, h 0	6	12	Mean
R_1	10.59	10.46	10.26	10.44	5.46	3.68	1.75	3.63
P_1	10.28	10.05	9.70	10.00	4.83	2.24	0.95	2.67
P_2	10.69	10.56	10.29	10.51	5.95	2.84	1.33	3.37
N	10.55	10.33	10.38	10.42	1.52	0.46	1.61	1.20
Mean	10.52	10.35	10.16	10.34	4.44	2.31	1.41	2.72

Factors	Hill spacing SEm±	Hill spacing $CD_{(0.05)}$	Deviation SEm±	Deviation $CD_{(0.05)}$
Puddling equipment (a)	0.12	NS	0.40	1.38
Sedimentation period (b)	0.084	0.25	0.33	0.99
Interaction (a × b) 1*	0.169	NS	0.66	1.98
2**	0.184	NS	0.67	2.12

zero to 12 hours. In the first experiment at 24 hours sedimentation period, the buried hills were low which varied from 0.61 to 1.42 per cent in all the treatments.

Floating Hills

Like the buried hills, the floating hill percentage was high at 12 hours in the first and at zero sedimentation period in the second experiment. The floating hills decreased significantly with an increase in the sedimentation period in both experiments. The floating hill varied from 2.33 to 5.64 per cent after 12 hours sedimentation period with the lowest and highest being in the case of P_1 and R_2, respectively, in first experiment. However, it ranged from 8.64 to 3.62 per cent at zero sedimentation period with maximum and minimum in the case of P_2 and N, respectively, during the second experiment. By increasing the sedimentation period from 12 to 18 hours, the percentage of floating hills was low which further declined after 24 hours sedimentation period but was statistically not significant. In the second experiment, the number of floating hills decreased significantly with an increase in the sedimentation period from 0 to 6 hours for treatments R_1, P_1 and P_2 but not significant for treatment N. However, with an increase in the sedimentation period from 6 to 12 hours, the number of floating hills decreased significantly in the case of P_2 but not significant for all other treatments.

A high percentage of buried and floating hills at lower sedimentation period were due to poor anchorage of seedlings in the soft puddled soil and movement of puddled soil mass along the float due to its sinkage. The puddled soil because of inadequate settlement remained in a flowable state and had low soil strength resulting in poor gripping capacity of seedlings (**Table 4**). The depth of transplanting increased at lower sedimentation period due to greater float sinkage which would have also contributed towards the buried hills. In addition to the above reasons, high water level at low sedimentation period created a wavy action which washed away the transplanted seedlings and thereby increased the number of floating hills. Normally two rows of previously transplanted swath were affected due to the flow of puddled mass.

The reduction in numbers of buried and floating hills with an increase in sedimentation period was due to increase in the strength of puddled soil and consequent reduction in its flow along the float. At high sedimentation period, the seedling withdrawal force was greater which gave a better anchorage to seedlings. Similar findings were also reported by Mori (1975); Singh and Garg (1976); Singh *et al.* (1981); Singh *et al.* (1985); Kanoksak *et al.* (1988); Khan and Gunkel (1988) and Behera (2000).

Hill Percentage with Mechanically Damaged Seedlings

Mechanical damage was determined by counting the number of hills with mechanical injuries to the stems or roots of the seedlings. In most cases, all the seedlings in a particular hill were not damaged except one or two of them due to mechanical injury.

The data on percentage of damaged hills are given in **Table 5** showing tthat the number of hills varied from 0 to 2.60 per cent which is highest in the case of P_1 at 12 hour sedimentation period in the first experiment. However, the number ranged from 0 to 1.33 per cent as maximum in the case of treatment P_1 at zero sedimentation period in the second experiment. The average number of mechanically damaged hills were 0.64 per cent (S.d.= 0.84) and 0.39 per cent (S.d.= 0.40) during first and second experiments, respectively. The higher standard deviation in the first case indicated an inconsistency in the values of mechanically damaged seedlings. A high mechanical damage of 2.60 per cent was ob-

Table 4. Influence of Puddling Equipment on Buried and Floating Hills at Different Levels of Sedimentation Period

1st Experiment: Summer rice (2000)

Treatments (Puddling equipment)	Buried hill, %				Floating hill, %			
	Sedimentation period, h			Mean	Sedimentation period, h			Mean
	12	18	24		12	18	24	
R_1	4.87	2.28	0.61	2.25	3.76	3.60	3.00	4.12
R_2	6.21	3.10	1.42	3.57	5.64	4.68	2.67	4.33
P_1	4.44	1.78	1.28	2.50	2.33	2.06	1.17	1.85
P_2	5.21	2.45	1.28	2.98	4.74	3.71	2.07	3.33
Mean	5.18	2.40	1.15	2.91	4.12	3.38	2.23	3.24
Factors	SEm ±		$CD_{(0.05)}$		SEm ±		$CD_{(0.05)}$	
Puddling equipment (a)	0.61		NS		0.41		1.39	
Sedimentation period (b)	0.56		1.67		0.37		1.07	
Interaction (a × b) 1*	1.12		NS		0.71		NS	
2**	1.10		NS		0.71		NS	

*, **: See footnotes at the bottom of Table 2

2nd Experiment: Kharif rice (2000)

Treatments (Puddling equipment)	Buried hill, %				Floating hill, %			
	Sedimentation period, h			Mean	Sedimentation period, h			Mean
	0	6	12		0	6	12	
R_1	11.39	3.41	3.07	5.94	5.93	2.69	1.28	3.23
P_1	7.23	1.99	1.04	3.42	4.94	2.07	2.02	3.00
P_2	14.91	7.06	1.49	7.82	8.64	5.28	2.01	5.31
N	3.12	0.97	1.26	1.78	3.62	3.97	2.4	3.33
Mean	9.16	3.36	1.71	4.75	5.74	3.50	1.93	3.72
Factors	SEm ±		$CD_{(0.05)}$		SEm ±		$CD_{(0.05)}$	
Puddling equipment (a)	0.85		2.95		0.52		NS	
Sedimentation period (b)	0.48		1.42		0.35		1.04	
Interaction (a × b) 1*	0.95		2.84		0.69		2.08	
2**	1.15		3.75		0.77		2.47	

served in the case of the peg type puddler after 12 hours sedimentation period followed by 0.98 after 24 hours and 0.46 per cent after 18 hours sedimentation period in the first experiment. However, it was 1.33 per cent at zero and 1.07 per cent after 6 hours sedimentation periods in the second experiment.

Statistical analysis indicated that there was no significant effect in puddling equipment as well as sedimentation period on the percentage of mechanically damaged hills. The percentage of mechanically damaged seedlings was basically due to the forward speed of the transplanter. High operating speed of the transplanter resulted in simultaneous increase of the fingers speed which caused injury to the stems or roots of the seedlings.

Hill Mortality

Findings on hill mortality situation are presented in **Table 5** for both experiments showing that hill mortality decreased with an increase in the sedimentation period. In the first experiment, the maximum mortality (11.34%) was obtained for treatment R_2 after 12 hours sedimentation period followed by P_2 (10.63 per cent), P_1 (9.29 per cent) and R_1 (6.42 per cent). Similar trends were also observed after 18 and 24 hours sedimentation periods. In the first experiment, the effects of puddling equipment and sedimentation period on mortality rate were not significant. In the second experiment, the highest mortality was found in the case of treatment P_2 (16.38%) followed by R_1 (15.21%), P_1 (9.08%) and N (5.56%) at zero hour sedimentation period. The treatments R_1 and P_2 showed significantly higher percentage than treatment P_1 compared to treatment N. At 6 hours sedimentation period, treatment P_2 (9.40%) was significantly higher than in treatments N (4.70%) and P_1 (3.77%) which were statistically at par and significantly lower than for treatment R_1 (6.76%). After 12 hours sedimentation period, the hill mortality was not significant among the treatments with values of N (2.54), R_1 (2.79), P_1 (3.52) and P_2 (1.74%) in the second experiment.

The relationships between the extent of buried and floating hills with mortality were established in **Figs. 1** and **2**. In most cases, mortality were less than for the total buried and floating hills with few exceptions where mortality was high due to the survival of some of the floating and buried hills. The mortality rate decreased with an increase in sedimentation period which may be due to the reduction in buried and floating hills. The hill mortality was high in the case of the second experiment due to lowering the level of sedimentation period for high percentage of buried and floating hills resulting in excessively high mortality of hills.

Missing Hills

Data in respect of missing hills are shown in **Table 6** for both experiments showing that missing hills varied from 6.37 to 13.45 per cent in the first experiment with an average of 9.65 per cent (S.d. = 1.95). However, in the second experiment, the percentage varied from 5.35 to 14.12 for an average of 9.60 (S.d. =2.22). The number of missing hills depended mainly on the seedling density and uniformity in the mat (Mufti and Khan, 1995). In the field experiments, the missing hill percentage was a little high due to nonuniformity of seedlings in the mat. In addition, silty clay soil of the seedling mat which was sticky created problems in the smooth sliding of the mats in the tray which resulting in a high percentage of missing hills. Similar results were reported by Singh *et al.* (1985).

During the experiments, the average percentage of missing hill

Table 5. Influence of Puddling Equipment on Hill Percentage Having Mechanically Damaged Seedlings and Hill Mortality at Different Levels of Sedimentation Period

1st Experiment: Summer rice (2000)

Treatments (Puddling equipment)	Hills with damaged seedlings, %				Hill mortality, %			
	Sedimentation period, h			Mean	Sedimentation period, h			Mean
	12	18	24		12	18	24	
R_1	1.19	0.00	0.00	0.40	6.42	4.37	3.06	4.62
R_2	0.00	0.00	0.50	0.17	11.34	8.06	2.29	7.23
P_1	2.60	0.46	0.98	0.13	9.29	3.85	0.00	4.38
P_2	1.96	0.00	0.00	0.65	10.63	6.38	3.38	6.80
Mean	1.44	1.14	0.37	0.64	9.42	5.66	2.18	5.76

Factors	SEm ±	$CD_{(0.05)}$	SEm ±	$CD_{(0.05)}$
Puddling equipment (a)	0.33	NS	1.52	NS
Sedimentation period (b)	0.31	0.92	0.89	2.67
Interaction (a × b) 1*	0.61	NS	1.78	NS
2**	0.60	NS	2.11	NS

*, **: See footnotes at the bottom of Table 2

2nd Experiment: Kharif rice (2000)

Treatments (Puddling equipment)	Hills with damaged seedlings, %				Hill mortality, %			
	Sedimentation period, h			Mean	Sedimentation period, h			Mean
	0	6	12		0	6	12	
R_1	0.36	0.19	0.00	0.18	15.21	6.76	2.79	8.25
P_1	1.33	1.07	0.00	0.80	9.08	3.77	3.52	5.46
P_2	0.56	0.19	0.45	0.40	16.38	9.40	1.74	9.17
N	0.27	0.00	0.26	0.18	5.56	4.70	2.54	4.27
Mean	0.63	0.36	0.18	0.39	11.56	6.16	2.65	6.79

Factors	SEm ±	$CD_{(0.05)}$	SEm ±	$CD_{(0.05)}$
Puddling equipment (a)	0.22	NS	0.44	1.53
Sedimentation period (b)	0.25	NS	0.35	1.04
Interaction (a × b) 1*	0.50	NS	0.69	2.07
2**	0.50	NS	0.72	2.27

Table 6. Number of Seedlings per Hill and Missing Hill under Different Puddling Equipment at Different Levels of Sedimentation Period

1st Experiment: Summer rice (2000)

Treatments (Puddling equipment)	Missing hill, %				Seedliing per hill			
	Sedimentation period, h			Mean	Sedimentation period, h			Mean
	12	18	24		12	18	24	
R_1	10.81	6.37	7.15	8.11	2.57	2.36	2.23	2.39
R_2	13.45	10.26	10.59	11.43	3.01	2.59	2.74	2.78
P_1	8.55	7.16	9.63	8.45	2.96	2.64	3.16	2.92
P_2	9.75	11.49	10.54	10.59	2.77	2.40	2.95	2.71
Mean	10.64	8.82	9.48	9.65	2.83	2.50	2.77	2.70

2nd Experiment: Kharif rice (2000)

Treatments (Puddling equipment)	Missing hill, %				Seedliing per hill			
	Sedimentation period, h			Mean	Sedimentation period, h			Mean
	0	6	12		0	6	12	
R_1	6.82	8.98	10.5	8.77	3.58	2.88	3.16	3.20
P_1	11.79	8.59	9.08	9.82	3.44	3.02	3.13	3.19
P_2	10.80	14.12	5.35	10.09	3.40	3.76	3.67	3.61
N	10.96	10.13	8.10	9.73	3.41	3.11	2.88	3.13
Mean	10.10	10.43	8.26	9.60	3.46	3.19	3.21	3.29

R_1: Rotary puddler one pass R_2: Rotary puddler two passes P_1: Peg type puddler one pass P_2: Peg type puddler tow passes N: No puddling

was 9.6 per cent. If the hill spacing is kept 10 and 12 cm, the theoretical hill population was determined at 42 and 35 hills/m^2, respectively. In subtracting the average missing hills of 9.6 per cent, the number of hills/m^2 would be 38 and 32 hills, respectively, which are well within the recommended number of hills per square meter.

Seedlings per Hill

The data on the number of seedlings per hill are shown in **Table 6**. The number of seedlings per hill varied from 2.23 to 3.16 and 2.88 to 3.76 in both experiments with corresponding mean values of 2.70 (S.d. = 0.27) and 3.29 (S.d. = 0.29), respectively. There was no significant effect of puddling equipment and sedimentation periods on the number of seedlings per hill in both experiments. Greater number of seedlings per hill in the case of the second experiment was due to high density of 3.50 seedlings/cm^2 as compared to 2.70 seedlings/cm^2 in the first experiment.

Hill Population

The number of hills per m^2 were counted in all the treatments with corresponding sedimentation periods. The hill population data expressed as number of hills per m^2 are shown in **Table 7**.

The hill population/m^2 increased with an increase in sedimentation period in both experiments. The data show that in the first experiment, the hill population increased from 28.89 to 31.06, 26.67 to 29.05, 29.08 to 31.50 and 28.56 to 29.67 hills/m^2 in the case of treatments R_1, R_2 P_1 and P_2, respectively, when the sedimentation period increased from 12 to 24 hours. However, in the second experiment, the increase was from 30.44 to 35.95, 31.11 to 36.78 and 28.11 to 35.11 hills/m^2 for treatments R_1, P_1 and P_2, respectively, while sedimentation period increased from 0 to 12 hours. In the case of no puddling treatment, the hill population remained almost constant. In the first experiment, the same was not significant with the increase in sedimentation period of both treatments. In the second experiment, the increase in hill population was significant in the case of P_1 and R_1 but not significant for the P_2 treatment when the sedimentation period increased from 0 to 6 hours. However, it was significant in treatment P_2 but not significant for R_1 and P_1 when the sedimentation increased from 6 to 12 hours.

When the puddling level increased from 1 to 2 passes, the hill population decreased for both puddlers. However, there was no significant difference among the treatments in first experiment except for the peg type puddler after 6 hours sedimentation period and not

R1 = Rotary blade puddler (one pass) R2 = Rotary blade puddler (two passes)
P1 = Peg type puddler (one pass) P2 = Peg type puddler (two passes)

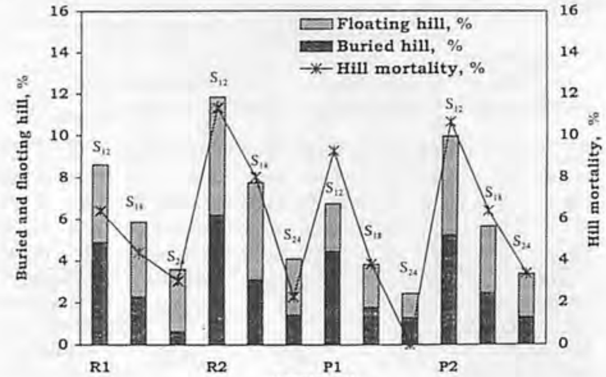

Fig. 1 Influence of puddling equipment on buried hill, floating hill and hill mortality at 12, 18, 24 hours of sedimentation period (summer rice, 2000).

R1 = Rotary blade puddler (one pass) P1 = Peg type puddler (one pass)
P2 = Peg type puddler (two passes) N = No puddling

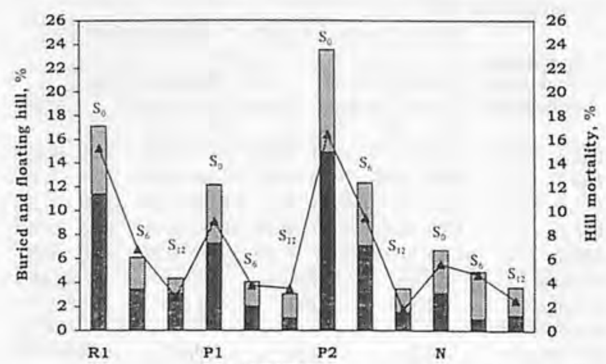

Fig. 2 Influence of puddling equipment on buried hill, floating hill and hill mortality at 0, 6, 12 hours of sedimentation period (kharif rice, 2000).

significant at zero as well as 12 hours sedimentation periods in the second experiment. In the second experiment, at zero hour sedimentation period, a significantly high hill population was in the no puddling treatment (34.0) but not for treatments R_1 (30.44) and P_2 (28.11) which were statistically at par with P_1 (31.11). Also, the treatments R_1, P_1 and P_2 were statistically not significant. After 6 hours sedimentation period, the hill population was statistically at par in treatments N, R_1 and P_1 which were significantly higher than treatment P_2. However, after 12 hours sedimentation period there was no significant difference within treatments. The number of hills per m^2 was greater in the second experiment in comparison with the first experiment mainly due to less hill spacing of 10 cm in second experiment compared with 12 cm for the first experiment. The extent of hill population depended upon mortality, hill spacing and missing hills. Increase in hill population with respect to sedimentation period was mainly due to a reduction in number of buried and floating hills resulting in low mortality. The traction wheel slippage also increased with sedimentation period leading to a decrease in hill spacing per unit area.

Grain Yield

The grain and straw yields were recorded and presented in **Table 8**. In the first experiment, the grain yield increased with an increase in the sedimentation period and decreased in the level of puddling. The effect of puddling equipment as well as sedimentation period was significant on grain yields, however, their interaction was not significant.

A comparison of grain yield at various levels of sedimentation period shows that after 12 hours sedimentation period, the lowest and highest grain yields were obtained in the cases of treatments R_2 (3.04) and P_1 (3.53 t/ha), respectively. After 18 hours sedimentation period, the grain yield demonstrated a similar behaviour. However, at 24 hours sedimentation period, the maximum grain yield was 3.75 t/ha in treatment P_2 which was at par with treatments P_1 (3.74 t/ha), R_1 (3.74 t/ha) and R_2 (3.66 t/ha).

In comparing the main factor means, i.e., puddlers, the highest yield of 3.63 t/ha was obtained in treatment P_1 followed by R_1 (3.55), P_2 (3.46) and R_2 (3.29 t/ha). The yield of treatment P_1 was significantly higher than for treatments P_2 and R_2 but statistically equivalent to R_1. The yield of treatment R_2 was significantly lower than P_2. During the second experiment, the only sedimentation effect was observed significant on grain yield. At zero hour sedimentation period, the maximum grain yield of 5.40 t/ha was obtained in the case of no puddling treatment with the lowest for P_2 (4.84 t/ha). After 12 hours sedimentation period, the highest yield was observed in P_1 (6.12 t/ha) and lowest of 5.01 t/ha in the case of P_2. However, the maximum average yield was in treatments P_1 (5.72 t/ha) followed by N (5.64), R_1 (5.53) and P_2 (5.48 t/ha) in the second experiment with no significant effect of puddling equipment as well as sedimentation period on grain yield.

Grain yield is mainly affected by physico-chemical status of the soil and optimum plant population treating other parameters as constant for all treatments. The increase in grain yield with an increase in the sedimentation period was due to high plant population on account of less number of buried and floating hills with subsequent reduction in hill mortality. These findings are in agreement with Sharma and De Datta (1986); Sharma *et al.* (1988); Rath (1999) and Behera (2000). Although the puddling quality was good in the case of R_2, yet its performance in terms of yield was low in the case of the first experiment. Similar observation was also made in the case of treatment P_2 during the second experiment due perhaps to low plant

Table 7. Hill Population and Depth of Water under Different Puddling Equipment and Sedimentation Periods

1st Experiment: Summer rice (2000)

Treatments (Puddling equipment)	Number of hills per sq.m, Sedimentation period, h: 12	18	24	Mean	Water depth, cm, Sedimentation period, h: 12	18	24	Mean
R_1	28.89	30.11	31.06	30.02	3.17	2.20	1.96	1.78
R_2	26.67	27.92	29.05	27.88	3.07	2.96	2.59	2.54
P_1	29.08	30.80	31.50	30.47	3.22	2.25	2.17	2.21
P_2	28.56	29.00	29.67	29.08	3.33	2.11	2.07	2.17
Mean	28.30	29.47	30.32	29.36	3.30	2.38	2.20	2.18

Factors	SEm ±	$CD_{(0.05)}$
Puddling equipment (a)	0.38	1.31
Sedimentation period (b)	0.33	0.99
Interaction (a × b) 1*	0.66	NS
2**	0.66	NS

2nd Experiment: Kharif rice (2000)

Treatments (Puddling equipment)	Number of hills per sq.m, Sedimentation period, h: 0	6	12	Mean	Water depth, cm, Sedimentation period, h: 0	6	12	Mean
R_1	30.44	33.22	35.95	33.20	3.80	3.00	2.32	3.04
P_1	31.11	36.22	36.78	34.70	2.31	2.39	1.89	2.20
P_2	28.11	29.39	35.11	30.87	2.55	1.99	1.83	2.12
N	34.0	35.67	34.45	34.71	1.83	2.63	2.50	2.32
Mean	30.92	33.63	35.58	33.38	2.62	2.50	2.14	2.42

Factors	SEm ±	$CD_{(0.05)}$
Puddling equipment (a)	0.63	2.18
Sedimentation period (b)	0.49	1.48
Interaction (a × b) 1*	0.99	2.96
2**	1.02	3.25

*, **: See footnotes at the bottom of Table 2

Table 8. Influence of Puddling Equipment on Grain and Straw Yield of Rice Crop at Different Levels of Sedimentation Period

1st Experiment: Summer rice (2000)

Treatments (Puddling equipment)	Grain yield, t/ha				Straw yield, t/ha			
	Sedimentation period, h			Mean	Sedimentation period, h			Mean
	12	18	24		12	18	24	
R_1	3.19	3.43	3.74	3.55	4.88	4.98	5.21	5.02
R_2	3.04	3.16	3.66	3.29	4.64	4.80	4.92	4.78
P_1	3.53	3.62	3.74	3.63	5.19	5.27	5.38	5.28
P_2	3.11	3.52	3.75	3.46	4.89	5.00	5.09	4.99
Mean	3.22	3.44	3.72	3.46	4.95	5.07	5.13	5.05
Factors	SEm ±		$CD_{(0.05)}$		SEm ±		$CD_{(0.05)}$	
Puddling equipment (a)	0.048		0.16		0.13		NS	
Sedimentation period (b)	0.056		0.17		0.14		NS	
Interaction (a × b) 1*	0.112		NS		0.28		NS	
2**	0.146		NS		0.26		NS	

*, **: See footnotes at the bottom of Table 2

2nd Experiment: Kharif rice (2000)

Treatments (Puddling equipment)	Grain yield, t/ha				Straw yield, t/ha			
	Sedimentation period, h			Mean	Sedimentation period, h			Mean
	0	6	12		0	6	12	
R_1	5.06	5.67	5.87	5.53	7.99	7.95	8.05	8.00
P_1	5.29	5.76	6.12	5.72	7.72	8.30	8.62	8.21
P_2	4.84	5.59	5.01	5.48	7.46	7.69	8.46	7.87
N	5.40	5.61	5.90	5.64	7.53	7.94	7.06	7.51
Mean	5.15	5.66	5.98	5.59	7.67	7.97	8.05	7.90
Factors	SEm ±		$CD_{(0.05)}$		SEm ±		$CD_{(0.05)}$	
Puddling equipment (a)	0.28		NS		1.08		NS	
Sedimentation period (b)	0.13		0.39		0.82		NS	
Interaction (a × b) 1*	0.26		NS		1.64		NS	
2**								

population on account of greater numbers of buried and floating hills leading to high mortality. In addition, the bulk density of experimental plots was high with increased level of puddling causing a reduction in yield. Reduction in yield at high bulk density was also reported by Ghildayal and Satyanarayan (1969); Gupta and Jaggi (1979); Sharma *et al.* (1988) and Behera (2000). The soil physical properties obtained after puddling were statistically at par in the case of treatments P_2 and R_1 but the yield of treatment R_1 was marginally higher than P_2 which was due to higher number of panicles per m^2 because of less buried and floating hills. Low grain yield in the first experiment as compared to the second was due to growing of rice crop in summer season in which the regular water supply for irrigation was a major constraint leading to poor crop establishment and low yield.

Field Performance of the Transplanter

The field capacity of self-propelled rice transplanter was 0.16 ha/h with field efficiency of 60.02 per cent at an average operating speed of 1.40 km/h. The turning time loss was estimated as 9.38 per cent with machine index of 87.50 per cent (**Table 9**). Nursery feeding and their time to time placement consumed 18.75 per cent of total time of operation when 3 persons (two loaders and one feeder) were employed during field operation of rice transplanter. A few times clogging of transplanting fingers with seedling was also observed because of buckling of mat at the base of tray. The fuel consumption of rice transplanter was measured as 0.46 l/h and 2.87 l/ha.

Conclusions

1. Increase of traction wheel slip with respect to sedimentation period was significant in the cases of all treatments. Traction wheel slip was found to vary between 4.02 to 12.57 and 2.75 to 10.91 per cent in the first and second experiment, respectively.
2. Hill spacing decreased when sedimentation period increased. Hill spacing was greater than the preset spacing for all treatments at 12 and 18 hours sedimentation period with total variations of 12.17 to 12.58 cm and less than the preset value in treatments R_1, P_1 and P_2 at 24 hours sedimentation period varying between 11.84 to 11.96 cm during the first experiment. Hill spacing in the second experiment was always greater than the preset spacing except in the case of P_1 with variation between 9.70 to 10.69 cm for all sedimentation periods.
3. The number of buried and floating hills increased with an increasing level of puddling which were greater in the case of the rotary blade puddler versus the peg type puddler. The numbers of buried and floating hills were reduced significantly with an increase in the sedimentation period. The percentages of buried and floating hills were high in the case of the second experiment compared to the first due to the low level of the sedimentation period.
4. The hill mortality rate was high at zero and 12 hours sedimentation period in the second and first experiment, respectively. The highest hill mortality was in treatment P_2 (16.38 %) followed by R_1 (15.21), P_1 (9.08) and N

Table 9. Field Evaluation of the Self-propelled Rice Transplanter

Particulars	Values
Average operating speed, km/h	1.40
Average turning time, min/ha	34.97
Width of operation, cm	196.0
Field capacity, ha/h	0.16
Field efficiency, %	58.67
Per cent distribution of operating time	
a. Transplanting time	65.63
b. Total time losses during operation	34.38
i. Turning loss time	9.38
ii. Mat feeding and adjustment	18.75
iii. Others (cleaning of clogged fingers, engine shut down, etc.)	6.25
Machine index, %	87.50
Fuel consumption, l/ha	0.46

(5.56 %) at zero hour sedimentation period in the second experiment while it was R_2 (11.34 %), P_2 (10.63), P_1 (9.29) and R_1 (6.42 %) at 12 hours sedimentation period in the first experiment. The hill mortality rate decreased with an increase in the sedimentation period.

5. The number of hills/m^2 increased with increasing sedimentation period due to the reduction in hill mortality. The hill population decreased with the level of puddling and was greater in the case of the rotary blade puddler at the same level of puddling.
6. Crop yield increased with the sedimentation period for both experiments but decreased with the level of puddling which was more pronounced in the treatment of the rotary blade puddler versus the peg type puddle due to high hill mortality rate resulting in low hill population. The maximum grain yield of 3.63 t/ha obtained in treatment P_1 was significantly higher than treatments P_2 (3.46) and R_2 (3.29 t/ha) but statistically at par with treatment R_1 (3.55 t/ha) in the first experiment. In the second experiment, the maximum average yield was recorded in treatment P_1 (5.72 t/ha) followed by N (5.64), R_1 (5.53) and P_2 (5.48 t/ha). The grain yield was appreciably high during the second experiment due to favourable weather and proper water availability.
7. The field capacity, field efficiency and fuel consumption of the transplanter were 0.16 ha/h, 60.02 per cent and 0.46 l/h, respectively. Nursery feeding to the transplanter used up 18.75 per cent of total time of operation.

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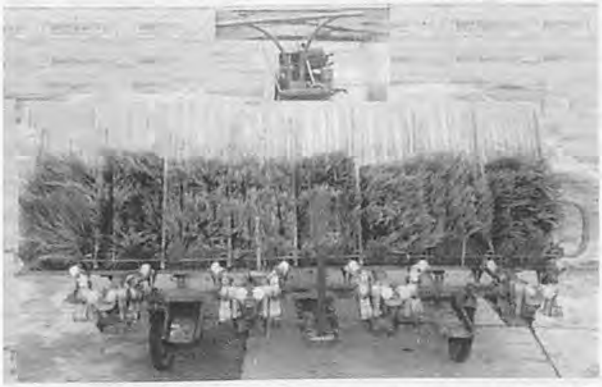

Fig. 3 Self-propelled rice transplanter used in the experiment (rear view).

Fig. 4 Self-propelled rice transplanter in action.

Ergonomics of Selected Soil Working Hand Tools in South India

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Abstract

In spite of improved farm mechanization, the use of the hand tools is inevitable in certain agricultural operations. Four such commonly used and high energy demanding soil working tools like spade, shovel, digger fork and hand hoe of various models available in South India were selected to analyse there ergonomics. Specifically, studies were conducted to evaluate energy expenditure, cardiovascular load and cardio-respiratory stress in the use of the tools. Energy required for spades ranged from 27.6 to 35.7 kJ/min while the cardiovascular load is from 128 to 158 beats/min. Fatigue factor (H/R) ranged from 3.2 to 3.7. For shovels, digger fork and hand hoes energy expenditure ranged from 24.3 to 25.5 kJ/min 20.5 to 25.4 kJ/min and 19.5 to 22 kJ/min, respectively. The cardiovascular load for these three tools were 103 to 121, 110 to 136 and 93 to 100 beats/min and the fatigue factor ranged from 2.8 to 3.9, 3.6 to 4.3 and 2.4 to 2.5, respectively. There was a lot of variation in energy requirements and cardiovascular stress in similar operations with same tools due to changes in design parameters.

Introduction

In developing countries like India, in spite of the progress in farm mechanisation, certain operations like sowing, transplanting, hoeing, and weeding are best performed manually with hand tools and equipment. Most designers of agricultural equipment concentrate to improve efficiency and durability, but none seem to give due importance to the operators' comfort. They regarded the operator as generally only another part of a man-machine system.

With the advent of technology, such disregard for human factor is no longer possible. Hence there is an urgent need to critically analyse these agricultural tools/equipment for their ergonomics in order to improve man-machine system efficiency without sacrificing performance. The application of ergonomics principles are more relevant in the present-day situation in terms of providing proper design of hand tools and farm equipment. In view of this, the study on various types of hand tools in relation to the operational comfort of agricultural workers was undertaken with the objective of determining the energy expenditure and physiological responses on the use of selected hand tools.

Materials and Methods

Selection of Tools

The criteria for selecting the hand tools were: i) high energy demanding; ii) greater usage; and iii) tools that are well accepted in terms of improving the work environment by reducing human drudgery. In this process, Sen and Bhattacharya (1976), Nag, *et al.* (1980), De and Sen (1986), and Gite (1991) reported that the high energy demanding tools were the soil working ones. Accordingly, for the present study, the following soil working tools which were largely accepted were selected: spade, shovel, digger fork and hand hoe. Different models of these hand tools available in south India were collected. Their specifications are tabulated in **Table 1**.

Selection of Subjects

The anthropometric data for the selected farm workers of both male and female were collected by using anthropometric data measuring kit. For the collected anthropometric data on 5th and 95th percentiles were calculated using the equation given by Vasudha Atreya and Gaur G. Ray (1998) categorizing them as A type and B type groups as shown in **Table 2**.

A bio-clinical analysis of the blood of the selected workers was carried out for blood sugar, blood urea, hemoglobin, serum cholesterol for identifying hypertension ailments and hypothyroid diseases, and urine analysis for diabetes. Based on the analysis, 4 males and 4 females healthy subjects were identified and selected.

Table 1. Specifications of Selected Hand Tools

Item		Blade angle (degrees)	Weight (kg)	Blade size (cm)	Handle diameter (cm)	Handle length (cm)
Spade						
Long blade	SPL1	20 - 30	2.00	25 × 17	35	70
	SPL2	20 - 30	2.50	30 × 17	35	70
Short blade	SPS1	40 - 45	1.75	20 × 17	30	65
	SPS2	30 - 40	2.25	20 × 17	30	65
Quintani	SPQ	65 - 70	2.00	20 × 15	35	70
Shovel						
Light wt.	SH1	15	2.00	28 × 26	30	65
Heavy wt.	SH2	15	3.00	28 × 25	30	65
Digger fork						
Kitchen garden digger	DF1	10	1.75	25 × 18	--	70
Light wt.	DF2	15	2.50	33.5 × 20	--	76
Heavy wt.	DF3	15	3.25	33.5 × 20	--	76
Hand hoe (Weeders)						
Narrow blade	HH1	30	0.50	10 × 7.5	2.0	35
Broad blade	HH2	30	0.75	10 × 10	2.0	35
Wide angle	HH3	45	0.50	10 × 7.5	2.5	35

Table 2. Anthropometric Data of Selected Farm Workers

Dimensions	Male subjects				Female subjects			
	A1	A2	B1	B2	FA1	FA2	FB1	FB2
Age	31	33	32	27	35	33	34	30
Stature (cm)	152.6	154.5	172.1	173.0	144.1	142.3	154.2	156.7
Weight (kg)	48	49	76	79	47	46	55	52
BMR (k. cal.)	1334	1436	1522	1480	1077	1046	1108	1182
O_2 (l/min.)	0.22	0.23	0.25	0.24	0.18	0.17	0.18	0.19

Physiological Cost Measurement

The oxygen consumption was used as an index of work load for determining the energy requirements which were measured with the Oxylog-2 apparatus. The heart beat rates were measured by using the Polar pacer heart rate monitor in ambulatory position directly in the field. The selected subjects were given due practice to get acquainted with the gadgets. The same type of soil and field conditions for various operations were selected and earmarked as 5 × 5 m area for spading (hoeing), shoveling, digging and weeding. The weeding operation was carried out in a sorghum field.

To minimize the effect of ambient environment on physiological responses, the same test timing was selected to represent the normal ambient conditions of the season. Energy requirements and work output studies were conducted with one subject at a time, operating the selected tool in a particular field. The subject workers were asked to rest before the start of each experiment for stabilizing their heart rate at normal level. They were asked to operate the tools with their normal way of operation. The oxygen consumption, heart rate and respiration were recorded. Each of the experiments was replicated three times. Since the Oxylog is used for measuring oxygen consumption energy expenditure it was computed by using the calorific value of 20.93 kJ/ l of oxygen (Anon 1987). The fatigue factor (H/R) was used as an index of cardio-respiratory stress (Moitra *et al.* 1974). This is the ratio of heart beat rate to respiration rate.

The *Oxylog-2* is a portable instrument of 18.5 × 8.2 × 21.5 cm and 1800 g weight (**Fig. 1**). The instrument was designed to measure the oxygen consumption and aspiration rate of an ambulatory subject. On the other hand, the *Polar Pacer heart rate monitor* is a compact portable instrument to monitor the heart beat rate (**Fig. 2**). This can be used in the field directly where the telemetry system cannot be used.

Review of Literature

Nag and Dutt (1979) studied the effectiveness of seven weeders with reference to physiological responses. The heart beat rate varied from 105 to 120 beats/min and oxygen uptake varied from 0.569 to 1.158 l/min in weeding operation. Annon (1987) suggested that when the Oxylog is used for measurement of oxygen consumption rate, the energy expenditure rate is to be com-

Fig. 1 The Oxylog – 2 Apparatus.

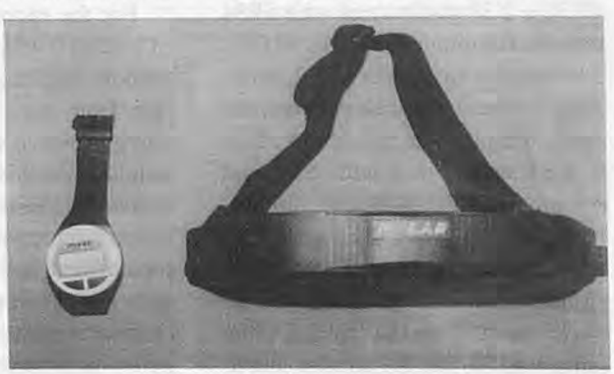

Fig. 2 The Polar Pacer heart rate monitor.

Table 3. Physiological Responses for Different Kinds of Spades

Item	Subject Type	Spades									
		SPL1		SPL2		SPS1		SPS2		SPQ	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Stroke rate/min	A	41.71	3.13	39.23	3.96	45.12	4.73	42.14	40.24	45.12	4.14
	B	44.82	4.71	40.18	5.13	47.71	2.36	41.19	5.13	43.46	7.10
Heart rate, beats/min	A	140	9	158	12	132	16	144	12	133	10
	B	133	4	148	11	128	7	133	9	128	11
Respiration, breath/min	A	40	4	43	8	39	6	42	11	39	10
	B	41	7	41	11	40	8	40	6	39	9
O_2 uptake, l/min	A	1.42	0.21	1.71	0.42	1.34	0.23	1.48	1.148	1.32	0.04
	B	1.40	0.09	1.63	0.61	1.28	0.35	1.46	0.50	1.39	1.05

Table 4. Physiological Responses for Different Kinds of Shovels

Item	Subject type	Shovels			
		SH1		SH2	
		Mean	SD	Mean	SD
Stroke rate/min	A	32.71	4.32	30.18	2.91
	B	36.88	3.21	31.36	4.73
Heart rate, beats/min	A	108	7	121	8
	B	103	12	119	6
Respiration, breath/min	A	38	8	40	6
	B	37	15	41	9
O_2 uptake, l/min	A	1.17	0.35	1.22	0.10
	B	1.15	0.07	1.23	0.71

Table 5. Physiological Responses for Different Kinds of Hand Hoes

Item	Subject type	Hand hoe					
		HH1		HH2		HH3	
		Mean	SD	Mean	SD	Mean	SD
Stroke rate/min	FA	55.20	5.36	54.30	4.22	56.23	6.17
	FB	54.30	4.72	56.70	3.17	59.71	5.11
Heart rate, beats/min	FA	96	9	98	7	96	3
	FB	99	4	100	6	93	11
Respiration, breath/min	FA	39	16	39	8	39	10
	FB	40	9	40	11	38	6
O_2 uptake, l/min	FA	1.09	0.05	1.09	0.21	0.96	0.12
	FB	1.10	0.35	1.07	0.36	0.94	0.35

Table 6. Physiological Responses for Different Kinds of Digger Forks

Item	Subject type	Digger fork					
		DF1		DF2		DF3	
		Mean	SD	Mean	SD	Mean	SD
Stroke rate/min	A	20.60	2.14	16.70	2.46	13.64	1.75
	B	22.30	1.89	17.30	1.73	14.20	1.61
Heart rate, beats/min	A	120	4	127	12	136	9
	B	110	16	118	8	128	11
Respiration, breath/min	A	30	12	31	4	32	6
	B	30	6	32	8	33	11
O_2 uptake, l/min	A	1.05	0.14	1.09	0.45	1.21	0.54
	B	0.98	0.27	1.19	0.07	1.22	0.06

puted by using the calorific value of 20.93 kJ/l of oxygen. Nwuba and Kaul (1987) concluded that the type of tool selection was a very important factor since various tools were available.

Results and Discussion

The average work measurement and the physiological responses with respect to spades, shovels, hand hoes and digger forks were shown in **Tables 3**, **4**, **5** and **6**, respectively. From the data, it is evident that the operational rate differed for different types of spades. The maximum value was 47.70 ± 2.30 strokes/min with SPS1 and the minimum value was 39.20 ± 3.90 strokes/ min with SPL2. Similarly, in the case of the shovel, the operation rate was maximum 32.71 ± 4.32 strokes/min with SH1 and minimum of 30.18 ± 2.91 strokes/ min with SH2. For the digger fork the range was between 13.60 ± 1.70 strokes/min and 22.30 ± 1.90 strokes/min. For the hand hoe the range was 59.70 ± 5.1 strokes/min to 54.30 ± 4.20 strokes/min.

Energy expenditure obtained through oxygen consumption while operating with the spades significantly varied from 1.27 ± 0.35 to 1.71 ± 0.42 l/min. For shovels, the variation was from 1.14 ± 0.35 to 1.23 ± 0.09 l/min; for the digger fork, from 0.98 ± 0.3 to 1.20 ± 0.10 l/min; and for the hand hoe, from 0.90 ± 0.30 to 1.10 ± 0.30 l/min. The oxygen deficit during the maximal work is the indicator of energy reserve and it amounts to about 5.8 l for average farmers. The reserve will remain undisturbed as long as the work is aerobic and the oxygen consumption is approximately below1.00 to 1.25 l/min. (Nag and Pradan, 1992).

For the excess oxygen demands of 0.02 to 0.46 l/min. in spading operation requiring oxygen consumption from 1.27 to 1.51 l/min, the energy reserve will last roughly 13 minutes. At this point a disproportionate increase in respiration may cause fatigue, unless the reserve is replenished by work pauses. The duration of rest can be estimated by subtracting the average resting oxygen consumption of 0.24 l from the assured standard level of oxygen consumption of 1.0 to 1.25 l/min. The excess oxygen uptake of about 0.7 to 1.0 l/min during rest to replace the energy reserve will require approximately 6-9 minutes. This suggests that the work (spading with SPL 2 type spade) at oxygen consumption of 1.63 to 1.71 l/ min requires rest for about 6-9 min for every 13 min work for minimum cardio-respiratory stress. It is evident that working with the spade SPS1 which is the lightest kind of spades (1.75 kg), the study requires oxygen consumption of 1.28 to 1.34 l/min which is marginally more than the standard level of oxygen consumption of 1 to 1.25 l/min that allows the user to work for more duration of 30 min with same rest pause of 6-9 min.

The cardiovascular load, as reflected in heart beat rates, ranged for the spades between 128 ± 7 and 158 ± 12 beats/min. For the shovel the range was from 103 ± 12 to 121 ± 8 beats/min, 110 ± 16 to 136 ± 9 beats/min for the digger fork and 100 ± 6 to 93 ± 11 beats/min for the hand hoe.

Cardio-respiratory stress is indicated through the fatigue factor (H/

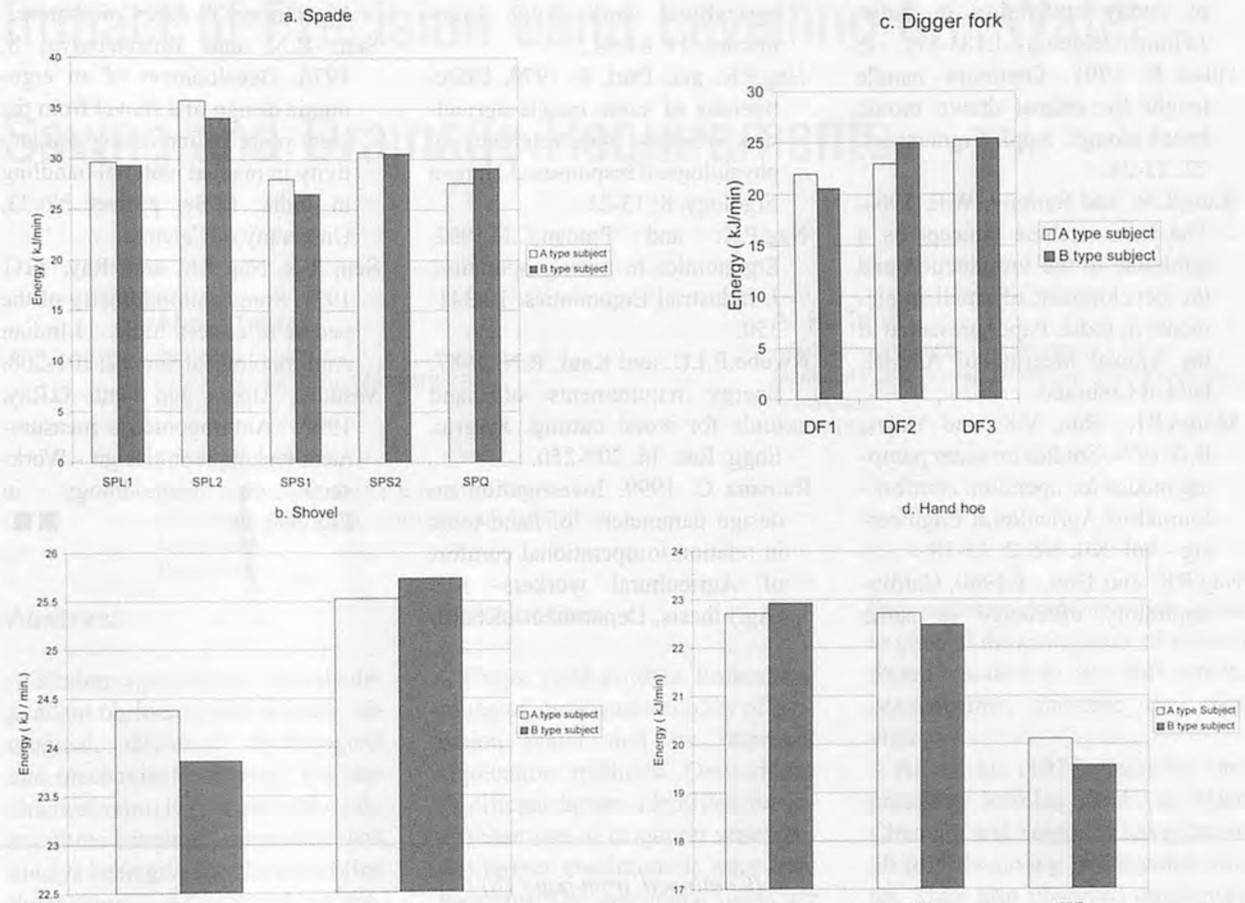

Fig. 3 Energy demands for different tools.

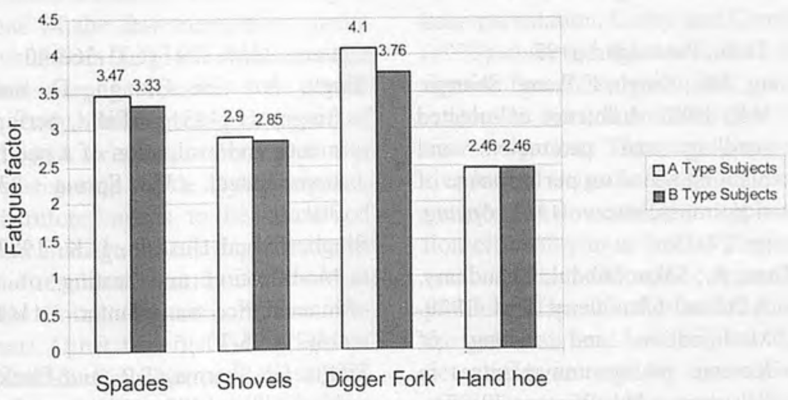

Fig. 4 Mean fatigue factors of subject tools.

R) with a range from 3.2 to 3.7 for the spade, 2.80 to 3.90 for the shovel, 3.60 to 4.25 for the digger fork and 2.4 to 2.5 for the hand hoe, respectively, suggesting that operation with digger fork causes very high cardio-respiratory stress.

Conclusions

Spade and digger fork operations require maximum energy among the selected tools. Fatigue factor is too high in operations with the same tools which can be classified as "heavy work" followed by the operation with the shovel as a "moderate work" and the least oxygen consuming (<1 l/min) with the hand hoe as "light work".

It is also evident that the variations in energy requirements, cardiovascular stress in the same operations, i.e., spading, digging, shoveling and hoeing were due to changes in design parameters. Hence, the user must be conscious about both the work and tool to minimize the drudgery.

Over all, physiological responses of type A and type B subjects are similar excepting the magnitude.

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(Continued from page 18)

Influence of Seedling Mat Characteristics and Machine Parameters on Performance of Self-propelled Rice Transplanter

The operating speed, seedling density, cutting finger length and age of seedlings had significant effect on the mechanical damage on seedlings in heavy as well as light soil nursery. The effect of density was insignificant in the case of light soil. The interaction of operating speed and cutting finger length with the age of seedlings had significant effect only in the case of light soil nursery.

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Impact of Precision Land Levelling on Water Saving and Drainage Requirements

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Abstract

Modern agriculture is heavily dependent on four inputs, namely; biological, chemical, hydrological and mechanical. Although the mechanical input is an input to the other three inputs, emphasis had always been given to the use of first three inputs while the role of mechanical input has been undermined. Precision land levelling is one of the few mechanical inputs which can help to reduce seepage and deep percolation and, consequently, drainage requirements of the soil. Irrigation water in Pakistan is becoming scarce day by day and, therefore, needs to be conserved and managed. This paper presents the results of a study conducted at the Cotton Research Station, Vehari. Other benefits from precision land levelling can save about 27% of water applied to the land along with the benefit of no drainage requirement. Precision land levelling minimizes the deep percolation and uneven storage of irrigation water in soil profile hence it should be adopted to contain drainage problem and to save precious water resource and foreign exchange involved in drainage installations.

Introduction

Crops yield is often limited because of inadequate supply of irrigation water and its improper application methods. One of the significant factors identified for inefficient use of irrigation water under farmer conditions is poor land levelling. The unlevelled fields are characterized with non-uniform distribution of irrigation water and deep percolation. Corey and Clyma (1973) observed that traditional irrigation practices combined with unlevelled bunded units resulted in over irrigation. Therefore, excessive loss of irrigation water as deep percolation lowered the application efficiency to as low as 25 percent with induced drainage problem. They further added that the precision land levelling has the potential to increase the application efficiency to over 50 percent. Khan (1986) has reported the benefits of precision land levelling in the form of: (i) about 24% reduction in saline area; (ii) 2 to 3% addition in cultivable area in Punjab and Sind; (iii) 37 to 40% increase in cropping intensity; and (iv) increase in the yield of major crops (wheat 15%, sugarcane 42%, rice 61% and cotton 66%). Other researchers such as Cheema (1986) have also indicated that precision land levelling helps to control the emergence of salt-affected patches in the soil which, consequently, increase the crop yield.

Ali et al. (1975) reported that precisely levelled fields in Mian Channun and Sargodha have shown 30 to 50% saving in irrigation water. They also observed uniformity in crop stand and growth, reduced fertilizer leaching, more uniform soil conditions for farm operations and increase in crop yield. A saving of 34 to 47% irrigation water has also been reported by Khattak et al. (1981) in his study pertaining to the effect of land levelling on soil, water use and yield of wheat crop.

Precision land levelling is the process of smoothing the land surface within ± 2 cm of its average elevation. It creates a favorable environment by having a uniform moisture in the seed bed. It facilitates uniform distribution of irrigation water and its application to an even depth. Without such uniform irrigation application, yield is generally low on both high and low spots of the field. At low spots in the field, plants suffer from oxygen deficiency while at high spots the plants are subjected to soil water stress. In general, precision land levelling helps to minimize the drainage requirements of agricultural lands by avoiding deep percolation which otherwise raise the water table and thereby level of salinity in the soils. The precision land levelling can be best performed with the help of laser equipment. This equipment has a high initial cost but reduce the operational cost and ensure the field level to a desired gradient.

Agricultural experts and farmers alike accept precision that land levelling as beneficial but necessary data to support its effects on crop yield and water saving are scarce. Cotton being an important cash crop and major source of foreign exchange for the country was selected for this research study. It is grown over an area of about 2.84 million hectares each year (GOP, 1997). Its yield, however, is very low as compared to other countries with similar soil and climatic conditions. Among many other factors responsible for low cotton yield, unlevelled fields is quite important. The crop is sown in May/June and is harvested in December. Water is usually short as compared to crop requirement except during monsoon (rainy) season. The yield is affected due to moisture stress during dry season as well as by excessive soil water in monsoon season, especially on unlevelled fields.

The use of precision land levelling at farms is done by "On Farm Water Management Deaprtments" of provincial governments on the request of a farmer. By the precision land levelling the irrigation application efficiency increases. A tractor mounted !and leveller employs laser beam to precisely indicate the difference in elevation and then actuate the hydraulic system of tractor to cut or fill the site. Laser assisted levellers are locally manufactured.

Objectives

In general, the study aimed at determining the effect of precision land levelling on water saving and crop yield with the following specific objectives in mind:

i) To compare irrigation efficiencies of precisely levelled field with traditionally levelled field.
ii) To estimate the deep percolation as water saving causing drainage problems.
iii) To determine increase in crop yield due to precision land levelling.

Methodology

The study was conducted at the Cotton Research Station, Vehari to appreciate the benefits of precision land levelling over traditional land levelling. The cotton crop, being the more sensitive to moisture deficit/excess, was selected for this study. Two irrigation bunded units of 0.18 hectare (30 m × 60 m) each were randomly selected at the cotton research farm. Both fields had almost similar soil conditions and degree of level (± 6 cm). One of the selected fields was precisely levelled (PL) within ± 2 cm of its average elevation while the other was left as is to represent traditional or farmer's field (TL). The impact of land levelling for both traditional levelled and precisely levelled fields was evaluated by replicating each treatment for 3 times and recording data on: (1) water depth required to completely irrigate the field under farmers conditions; (2) water stored in the root zone and its wastage because of over irrigation and deep percolation; (3) quantity of water applied; (4) application efficiency; (5) distribution efficiency; and (6) crop performance, i.e., crop stand, plant population and yield of seed cotton.

Results and Discussion

The study provided an opportunity to compare the irrigation efficiencies under precisely levelled and traditionally levelled fields. The quantity of water saved and increase in crop yield was calculated as an attribute of precision land levelling. The crop response to water was studied while keeping all the inputs uniform for all the experimental units in comparison. Finally the water use efficiency was calculated from the yield of seed cotton obtained against total quantity of water applied.

Water Depth Applied/Stored

Water depths applied to the fields under two different levels were calculated from the irrigation application time recorded. It was observed that greater water depth was required to irrigate the TL field during each irrigation application (**Table 1**). On the average, 12.44 cm of water depth was required to irrigate the TL field as against 9.13 cm depth applied to the PL field. As a result an excess water depth by 19.86 cm was to be applied to TL field (**Table 1**).

The depth of water stored in the soil up to 120 cm depth of comparative fields was determined for each irrigation application. On the average, 7.90 and 7.41 cm water depth was stored in PL and TL fields. **Table 1** shows that the depth of water stored in the TL field was slightly less than the depth stored in the PL field. This indicates that elevated portions of the TL field remained under irrigated inspite of heavy irrigation applications while the shallow spots of this field caused deep percolation. The water depth stored along the filed length was uniform in the case of the PL field while it varied along the length of the TL field.

Application Efficiency

Application efficiencies were calculated for both PL and TL

Table 1. Water Depth Applied and Stored in PL and TL Fields

Treatment	Water depth applied (cm)		Water depth stored (cm)	
	Mean	Total	Mean	Total
PL	9.13	54.78	7.90	47.40
TL	12.44	74.64	7.41	44.46
Difference	3.31	19.86	0.49	2.94

Table 2. Comparative Application and Distribution Efficiency

Treatment	Application efficiency (Ea)	Distribution efficiency (Ed)
PL	86.7	95.9
TL	60.4	86.2
Difference	26.3	9.7

fields. During the first irrigation (rauni) the average application efficiency was 80 percent for the PL field as against 43 percent for the TL field. The details of application efficiencies for both comparative sites are shown in **Table 2**. The application efficiencies were improved for both fields during the later irrigation applications. The overall average application efficiencies for the entire crop season were 86.7 and 60.4 percent for the PL and TL fields, respectively. The increase in application efficiency by 26.3 % is attributed to the precision land levelling.

The application efficiencies achieved on the PL and TL fields during each level of irrigation application are shown in **Fig. 1**. It is well evident from the graph that the application efficiencies of the PL field remained higher than the TL experimental units during all irrigation applications. Secondly, it refers to improved application efficiencies on both fields during later irrigations when compared with the first irrigation.

Distribution Efficiency

Delivering the desired quantity of water to the field is not enough, its even distribution is also important. TL fields are characterized to uneven water distribution which means too much water to some plants and too little to others as shown in **Fig. 2**. Either is bad, especially in the case of cotton, which is sensitive to moisture stress as well as excess water. The average distribution efficiencies were 93.7 and 78.3 percent during the first irrigation (rauni) on PL and TL fields, respectively. These relatively increased on both fields in comparison with during later irrigations because of reduced infiltration rate and increase in bulk density of soil. **Fig. 2** shows that high distribution efficiencies were achieved in all cases of PL field. The overall increase in distribution efficiency on account of precision land levelling was about 10 percent.

Water Saving

Greater depths of water were applied to the TL experimental units as compared to the PL field during all irrigation applications. **Fig. 1** shows the depth of water applied to PL and TL experimental units. The only reason of greater application depths was uneven surface of the TL experimental units. It indicates the savings on water due to precision land levelling or wastage of water due to traditional levelling otherwise. Improved application efficiencies on precisely levelled field reduced water losses during all irrigation applications. Precision land levelling resulted in overall saving of 357.3 m^3 water as shown in **Table 3**.

Yield of Seed Cotton

The yield of seed cotton obtained from the TL field was 79.9 percent of the yield achieved from the PL field. The reduction in yield up to 20.1 percent on TL field was believed due to the following reasons:

a) Low plant population with the TL field as compared to the PL field.
b) Greater variation in plant stand from average plant height. Tallness and shortness of the plants within the TL field declined fruit formation and fruit bearing capacity of the plants, respectively.
c) Late crop maturity or prolonged vegetative growth due to excessive water applied to the TL field.

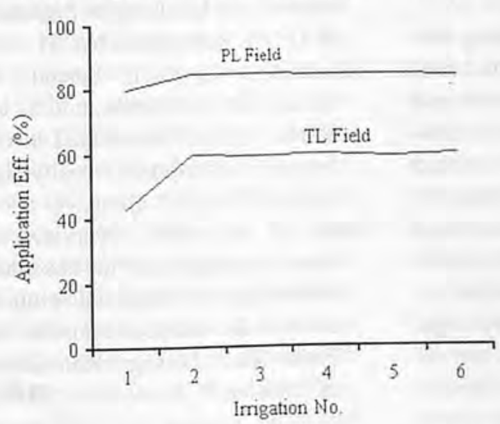

Fig. 1 Application efficiency in precisely and traditionally leveled fields.

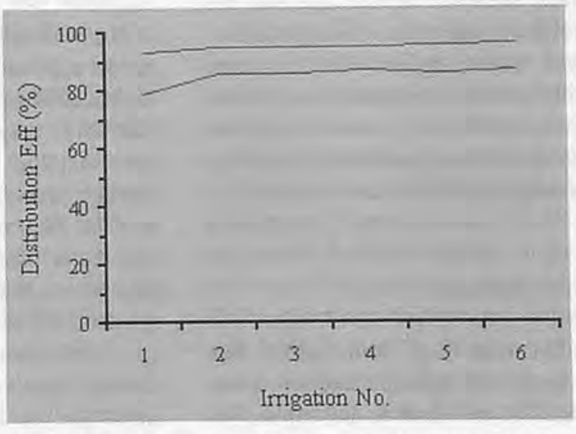

Fig. 2 Water distribution efficiency in precisely and traditionally leveled fields.

Table 3. Quantity of Water Applied to PL and TL Fields

Treatment	Total water depth applied (cm)	Area of Exp. units (m^2)	Quantity of water applied (m^3)
PL	54.80	1800	986.4
TL	74.65	1800	1343.7
Difference	19.85	-	357.3

Table 4. Yield of Seed Cotton of PL and TL Fields

Picking No.	Yield of seed cotton(kg)		Difference	Yield increase (%)
	PL	TL		
1	218	118	100	45.87
2	70	112	42	60
Total	288	230	58	20.1

Table 5. Comparative of Water Use Efficiency in PL and TL Fields

Treatment	Water applied (m^3)	Yield of seed cotton (kg)	Water use efficiency kg/m^3	Water use efficiency (%)
PL	986.4	288	0.292	63.1
TL	1343.7	230	0.171	36.9

The yield of seed cotton achieved from the PL field was 288 kg as against 230 kg from the TL field (**Table 4**). It was not competing the yield potential of the crop, however, it was competing the average yield (574 kg per hectare) for the year 1992. The reason for the overall low average was that the crop was severely damaged by virus. The plants affected by virus were removed to prevent further loss of the crop. This resulted in decreased plant population and ultimately the yield of the crop of both fields under comparison.

Water Use Efficiency

The overall water use efficiency for both PL and TL experimental units was calculated at 0.292 kg/m^3 and 0.171 kg/m^3, respectively. **Table 5** shows the water use efficiency observed for PL and TL fields.

The inefficient use of water by about 26 percent in the TL field indicates the sensitivity of crop to water. The yield was affected by the water stress on elevated spots of the field, on one hand, and by the excess water applied, on the other. The tremendous difference in water use efficiency is due to the reduced yield as against high quantity of water applied to the TL field.

Conclusions

1) The results of study show that about 36 percent excess water (357.3 m^3) had to be applied to irrigate the TL field. The greater variation in surface level of TL resulted in wastage of water, on one hand, and less water depth stored by about 6 percent, on the other.
2) The average application and distribution efficiencies for the TL field were short by 26.3 and 9.7 percent.
3) The crop responded sharply to the deficit/excess of water at higher and lower field spots of the TL filed where the yield of seed cotton in the TL field was less by 20 percent when compared with the PL field.
4) The water use efficiency of the TL field was computed to be 0.171 against 0.292 kg of seed cotton/m^3 of applied water for the PL field. The decrease in water use efficiency by 41.4 percent reflects the sensitivity of crop to water excess/deficit, a characteristics of undulating surface of the TL field.

Recommendations

The wastage of water during irrigation application was estimated at 13.5 and 40.4 percent on the PL and TL field, respectively. This indicates that 26.9 percent can be saved through precision land levelling. A total of 78.7 and 46.0 million acre feet water is available at the farm gate from canals and tubewells, respectively. The huge water wastage, i.e., more than 40 percent, can be reduced considerably if the farmer's fields are precisely levelled. Hence the need of time demands that:

1) The benefits of PL should be disseminated through the Agriculture Extension services.
2) The manpower directly or indirectly related to the agriculture sector should be equipped with the knowledge of this valuable technology.
3) Farmers should be persuaded for PL and latest equipment (Laser) should be provided for PL execution by the government.

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Design, Development and Performance Evaluation of Rotary Potato Digger

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Abstract

A rotary potato digger was designed and manufactured at the Agricultural Engineering Research Workshop, AMRI Division, Faisalabad. The digger was tested and evaluated in the field during 1985 and 1986. Its field capacity was 0.2 ha/hr at field speed of 6 km/hr. The digger saved US$ 66/ha as compared to manual harvesting of potatoes. The potatoes harvested with the rotary potato digger were free of any cut, damage or bruising.

Introduction

The area planted potato cultivation in Pakistan during 1999-2000 was 112.8 thousand hectares and gave a production of 1871 thousand tones with an average yield of 1.4 t/ha. It was very low as compared to the yield in other countries, i.e., 25-40 t/ha (Economic Survey, 2000). This low yield per hectare narrowed down the margin in profit and discouraged the farmers to increase their potato areas. The major causes of low yields were manual planting, improper seed placement, defective configuration of ridge, inaccurate seeding techniques, low seed rate, unavailability of seasonal labor and improper harvesting of the crop. Also, the farmers were unaware of the latest mechanized techniques for potato cultivation (Yasin, 1994). The adaptation of mechanized techniques and latest innovations in potato from planting to harvesting can increase cultivation and production.

Potato harvesting is one of the major labor-consuming operations in potato production. The majority of farmers in Pakistan still harvest potato crop manually with the help of spade or hand hoe, which is a tedious, labor-intensive, and time-consuming operation. It is estimated that 700 man-h/ha are required for manual harvesting of the potato crop. The percentage of potato damage due to cutting action of spade or hoe is sometimes significant which reduces its market value and storability. About 10% of the tubers are cut or bruised during manual harvesting.

The labor shortage and unfavorable weather conditions during the peak harvest time delay harvesting and results in a loss of potato crop in the field. The bullock-drawn potato diggers are used in some areas, which reduces the cost of operation, but damage the potato tubers 50% as compared to manual harvesting.

The need for mechanical potato harvesting of potato was felt because the scarcity of labor and rapidly increasing labor charges. Mechanical harvesting of potato saves approximately 65% and 45% of time and cost, respectively, as compared to manual digging (Hamid, 1997). Finishing earlier avoids unfavorable weathering conditions and loss to the farmers. Thus a project was started in 1984 at the Agricultural Mechanization Research Institute (AMRI) Division, Faisalabad to design and develop a rotary potato digger with the following objectives:

i) To design a tractor-mounted rotary potato digger for harvesting potato crop;
ii) To test, modify and evaluate the rotary potato digger in field performance; and
iii) To demonstrate the final version of a rotary potato digger to the farmers and manufacturers for its adaptation.

Literature Review

Misener (1985) designed and developed a potato digger which was capable of digging potatoes with minimum injury. The average percentage of damaged tubers was 3.2% and some tubers were partially skinned. Sharma, et al., (1986) designed a tractor-mounted single-row potato digger which sustained 4% skin damage to potatoes. Saqib and Wright (1986) designed and tested a vibratory digger-blade potato harvester and found that it caused less damage to potatoes, produced smaller soil clods and reduced the soil bulk density.

Hyde (1986) compared the performance and power requirements of a rotary blade and conventional fixed-blade potato harvester and determined that the rotary blade caused only 3% of tubers damage and negligible blade cuts. Hutchinson (1988) conducted a laboratory experiment, which indicated that the impact of the hollow-web rod caused less damage to potatoes as compared to the impact of solid rod. Melrose (1991) examined the external damage and internal bruising received by potatoes due to the impact of conventional solid rod web and hollow rod web. The hollow rod web caused less external damage and internal bruising to potatoes which reduced the damage index by 45% and 30% in bruising index. Kang and Halderson (1991) designed and tested a tractor-mounted, two-row vibratory potato digger and reported that the digger impact damaged the tubers, but reduced the draft force. Gupta and Bohra (1993) developed a vibratory potato digger with a spring-mounted 600 mm dia disk share which increased harvesting efficiency by approximately 97%, 86% tuber exposure and 4% cut tubers and no bruising.

Katiwat and Khommueng (1994) developed a power tiller-mounted potato digger with an average field capacity of 0.14 ha/h and average field efficiency of 80%. They determined that tubers cut and left over in soil loss were about 2.0 and 4.3%, respectively.

Kathirval and Manian (2001) developed a power tiller-mounted single row ridge type sliding potato digger and compared its performance with oscillating type digger and manual digging. They reported that it gave 44% savings in cost as compared to manual digging.

Materials and Methods

The rotary potato digger was designed at the Agricultural Engineering Workshop, AMRI Division, Faisalabad in 1984. The design specification and dimensions were based upon local farm and farmers' conditions. The first prototype of rotary potato digger was fabricated at the same workshop in 1984 using locally available materials, fabrication techniques and facilities. It was tested in the laboratory and field and the data was recorded. Modifications were incorporated in various systems of the potato digger. The second prototype was developed and tested also in the field, and again modified taking into account the field test results and farmer's comments regarding its performance.

The improved version of the rotary potato digger (subject of this re-

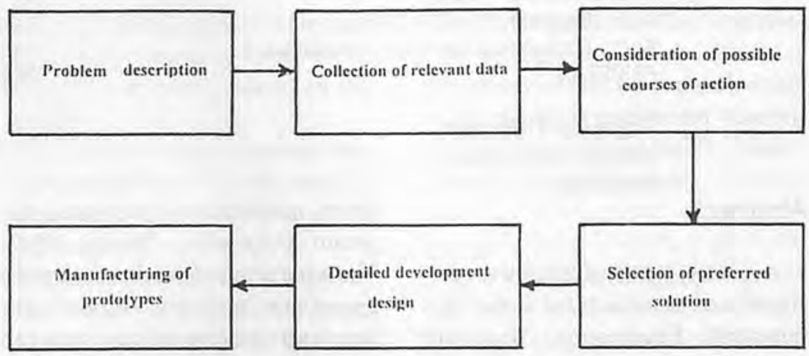

Fig. 1 Design approach used in design and development of the rotary potato digger.

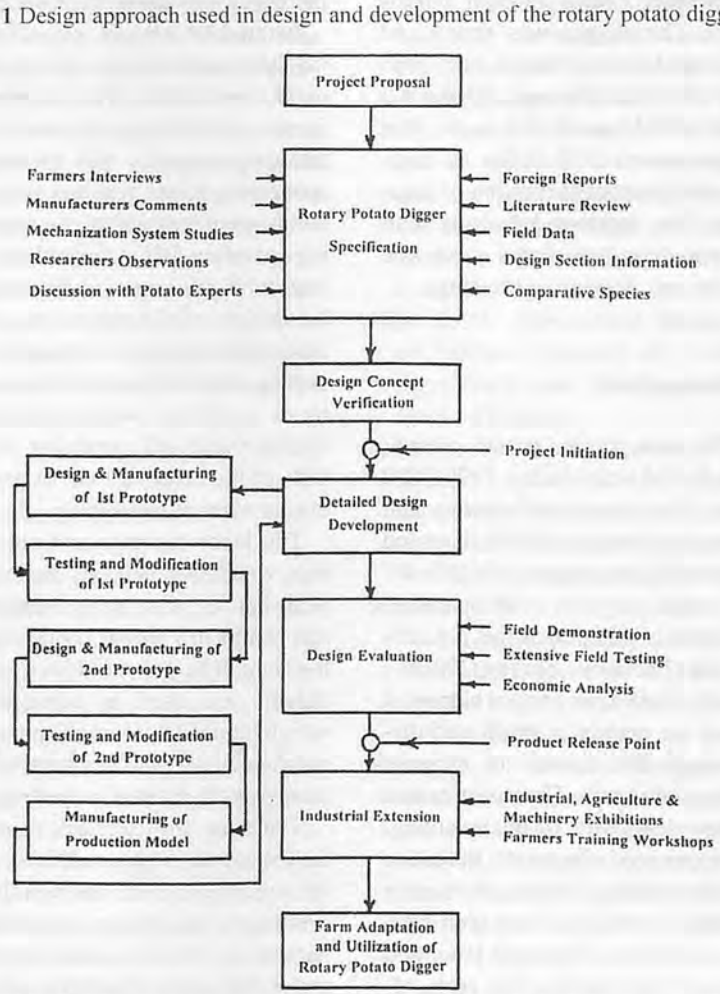

Fig. 2 Rotary potato digger design, development and adaptation process.

search) was developed at the same workshop in 1985. The potato digger was tested and evaluated in the field at two moisture content levels (10.3% and 13.2%) and three forward speed levels of 5.0, 6.0 and 6.5 km/h. The soil was sandy loam. The data was recorded for the tubers exposed, those left in soil, cut/damaged and bruised tubers.

Results And Discussion

Design and Fabrication

The design of the rotary potato digger was prepared after complete investigation for specification, justification, customer's needs and economic analysis (**Fig. 1**). The design was reviewed, conceptually evaluated and then submitted to the workshop for fabrication of first prototype. The fabricated prototype was tested in the laboratory and in the field. The design and development process are shown in **Fig. 2**. The design parameters were simple, semi-automatic, low cost and tractor-mounted pto driven. The design specification was selected based upon soil characteristics, ridge configuration, field size, digging depth, cutting width and horsepower requirement.

The potato digger is a single-row, tractor-driven and rear mounted machine. It is operated with the tractor of 22-36 kW. Its major components are a frame, cutting blade, soil digging wheel and gearbox (**Fig. 3**). The frame is made of M.S. channel 1220*102*6 mm and the digging wheel of dia.1175 mm with 10 equally spaced round bars of which each upper end is a fork. The blade is made of alloy steel with 711 mm length, 120 mm width and 10 mm thickness. The gearbox consists of two spur gears of 457 and 63.5 mm dia. With 105 and 13 teeth, respectively. The digger performs two functions simultaneously: cutting the ridge and separating the tubers from the soil.

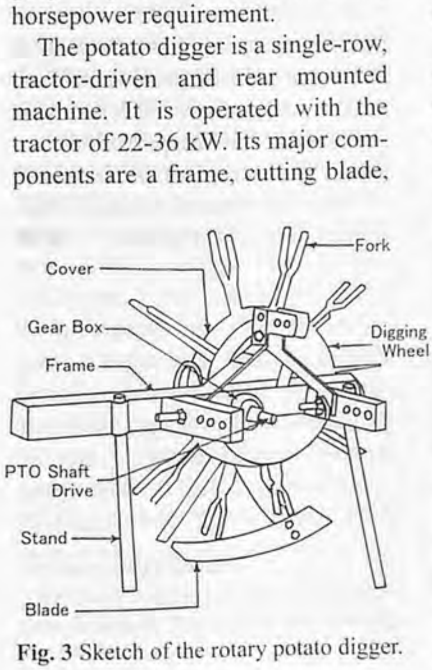

Fig. 3 Sketch of the rotary potato digger.

Testing and Modification

The potato digger frame was made of channel box and the overall size was reduced to 1245*850*1030 mm as compared to old one of size 1575*920*1210 mm (**Fig. 5**). The size of the cutting blade was also enlarged in order to match the lower width of the ridge to cut the ridge properly avoiding damage to potatoes. The length and width of the blade were increased by 14.3% and 5%, respectively. The cutting depth of blade was 178 to 203 mm. The depth wheel/coulter of 410 mm dia. was attached to the potato digger in order to cut the potato plants, weeds and control the digging depth.

The gearbox was fitted with new spur gears of 305 and 63.5 mm dia. with 51 and 12 teeth, respectively. Thus the gear ratio was reduced from 1:8 to 1:4.25. The rpm of the digging wheel was increased from 67 to 127 rpm with 540 rpm of tractor pto shaft in order to achieve faster digging and separation of potatoes through increased forward speed.

Fig. 4 The rotary potato digger in action.

Field Demonstration and Industrial Extension

The improved version of the digger was demonstrated in the field at various places to the farmers and manufacturers for its adaptability and industrial extension. It was exhibited on district fairs, industrial and agricultural exhibitions, farmers' days national horse and cattle show, farm machinery exhibitions and farmer training workshops from 1986 to 1993. The test results, field photographs, benefits and farmer's remarks were discussed with the interested farmers and manufacturers. The farmer's training workshops were also conducted to impart training to the farmers for its operation and maintenance. The terms and conditions for industrial extension of rotary potato digger were prepared and discussed with the interested firms and industries. The manufacturing materials, fabrication techniques, costs and overheads were discussed with the firms/industries who were compelled to sell the digger at minimum profit margin in order to promote this product within the country.

Adaptability and Utilization

The digger was accepted and adapted by the local manufacturers/industries for mass production and distribution to farmers (**Fig. 6**). Seventeen industries have been manufacturing the digger since 1986. Harvesting of the potato crop is now mostly done with the digger. Approximately 50 units of this digger are now manufactured annually in the country.

Summary

The major problems of low yield of potato crop are: improper seed placement, defective configuration of ridge, low seed rate and im-

Table 1(a). Performance of the Rotary Potato Digger*

Tractor Engine (rpm)	Digging Wheel (rpm)	Field Speed (km/h)	Potato exposed (%)	Potato left in soil (%)	Potato cut (%)	Potato bruised (%)
1200	90	5.5	94	5	1	0.1
1300	100	6.0	95	3	2	0.0
1400	110	6.5	95	4	1	0.3

* 13% soil moisture content, varying digging wheel rpm and three field speeds/hr.

Table 1(b). Performance of Rotary Potato Digger*

Tractor Engine (rpm)	Digging Wheel (rpm)	Field Speed (km/h)	Potato exposed (%)	Potato left in soil (%)	Potato cut (%)	Potato bruised (%)
1200	90	5.5	98	2	0.2	0.2
1300	100	6.0	99	1	0.4	0.1
1400	110	6.5	97	3	0.4	0.0

* 10.3% soil moisture content, varying digging wheel rpm and three field speeds/hr.

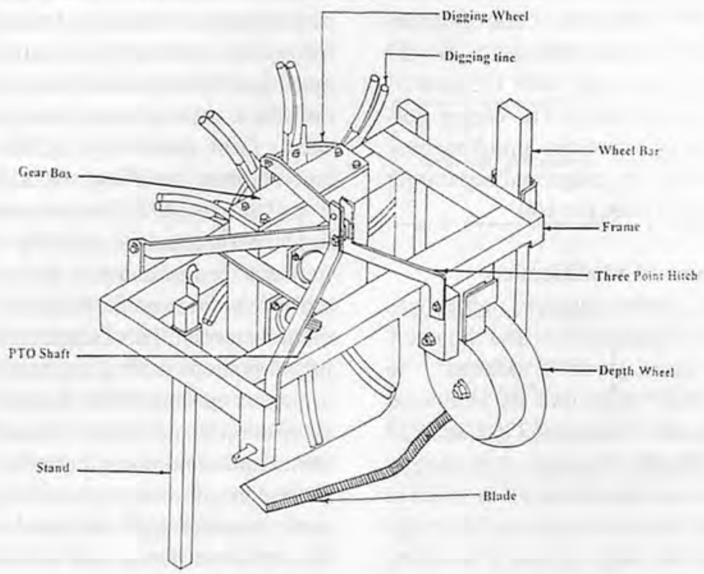

Fig. 5 Rotary potato digger improved version.

Fig. 6 Rotary potato digger being sold in the market.

proper harvesting. The harvesting of potatoes with the rotary potato digger saves labor, time and energy and is appreciated by the potato growers making approximately 65% on time and 45% on cost compared with the use of the traditional manual harvesting. The potatoes harvested with this digger are free of any cut, damage or bruising. The digger gives an average field capacity and digging efficiency of 0.2 ha/h and 97%, respectively, at 6 km/h field speed saving US$66/ha compared to the manual digging system. Mass production of the rotary potato digger started in 1986.

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Effect of Variety and Moisture Content on the Engineering Properties of Paddy and Rice

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Abstract

The physical properties: shape and size, thousand grain weight, bulk density, particle density, porosity, angle of repose and coefficient of friction on GI and plywood surfaces, were determined for raw paddy, parboiled paddy, raw rice and parboiled rice of ADT 39 and CO 43 varieties at various moisture levels. All these physical properties were found to increase with moisture content. The physical properties of these two varieties differed from each other at equal moisture contents.

The length, width, thickness, geometric mean diameter (GMD) and sphericity of raw paddy were observed in the range of 7.070 - 7.754 mm, 2.085 - 2.554 mm, 1.209 - 1.556 mm, 2.480 - 3.105 and 0.35 - 0.40, respectively. The thousand-grain weight, bulk density, particle density, porosity, angle of repose, and static coefficient of friction on GI and plywood surfaces of raw paddy were in the range of 18.56 - 25.38 g, 564.9 - 585.3 kg m^{-3}, 1112 - 1277 kg m^{-3}, 47.6 - 54.2%, 25.9 - 30.7°, 1.87 - 2.85 and 1.62 -2.46, respectively, in the moisture content range of 14.3 to 25.7%.

Among the tested paddy and its constituents, raw paddy had the highest values of porosity and angle of repose, parboiled paddy had the highest values of length, width, thickness, GMD, sphericity and thousand grain weight, raw rice had the highest values of bulk density and, coefficient frictions on both the GI surface and on the plywood surface, and parboiled rice had the highest value of particle density.

Acknowledgements
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Introduction

The physical properties of cereal grains and oilseeds are important as are the essential engineering data in the design of machines, structures, processes and controls, and in analyzing and determining the theoretical performance, power requirements and efficiencies of machines or operations used in handling and processing of grains (Mohsenin, 1980).

The description of any physical object shape and size values are equally important. The shape and physical dimensions (length, width and thickness) are useful data for the design of pneumatic or electrostatic machines that separate grains from admixtures. Sphericity and geometrical mean diameter, which are computed from the physical dimensions, are used for the determination of aerodynamic properties such as terminal velocity, drag coefficient and Reynolds number (Tado et al., 1999) and for the design of fluidized bed drier and winnower. The shape and size characteristics are useful for the design and development of sizing and grading machines.

The bulk and particle density values of grains are useful in the design of silos and storage bins, design of specific gravity separators, and in the grading of grains for price fixing. The porosity or the percentage voids of grains will often be needed in airflow, heat flow and drying studies such as determining the Reynolds number in pneumatic and hydraulic handling of grains, and in calculating thermal diffusivity in drying and other heat transfer problems.

The coefficient of friction of grains on various surfaces such as metal and wood has been used by engineers for the design of grain bins, silos and other storage structures as well as for the design and for the prediction of motion of grains in harvesting and handling equipment. The coefficient of friction is also important in determining the pressure exerted by grains against the bin walls and silos (Mohsenin, 1980).

Paddy or rough rice (*Oryza sativa L.*) is the stable food in most Asian countries, particularly India which produced 82.3 million tonnes of paddy during 1997-98 (Singhal, 1999). Paddy supports for the production of wide varieties of byproducts such as silicon, furfural, rice flour, baby foods, snack foods and bran oil from its constituents like husk, bran, rice and brokens (Bandyopadhyay and Roy, 1992).

Paddy is a region specific crop and cultivated around the world, which is identified by its variety name. Every variety has its own physical and biological characteristics. Therefore, the machine designed based on the characteristics of a particular variety of a locality may not be suitable for a variety in another locality.

The objectives of the current study were to determine the physical properties such as size (length, width and thickness), thousand grain weight, bulk density, particle density, porosity, angle of repose and coefficient of friction. These were done on galvanized iron and plywood surfaces for ADT 39 and CO 43 varieties' of raw paddy, parboiled paddy, raw ice and parboiled rice (hereafter referred to as samples), and to investigate the effect of moisture content on these physical properties. The varieties ADT 39 and CO 43 are two varieties commonly grown in southern India.

Materials and Methods

Sample Preparation

These two varieties of paddy were used for the physical properties determination. The moisture content at the time of purchase was 10 % for the ADT 39 variety and 11 % for the CO 43 variety. To increase the moisture content, grains were conditioned by adding and mixing with required amounts of distilled water. The grains were sealed in plastic bags for 24 h to allow for moisture equilibration.

Both varieties were locally parboiled to obtain parboiled paddy samples. Raw rice and parboiled rice were obtained by hulling both raw and parboiled paddies of the subject varieties, respectively, in a huller type rice mill.

The moisture contents of the samples were determined by oven drying 15 g of samples at 130 ℃ for 19 h. The moisture content values reported in this paper are all in wet basis (w.b).

Physical Properties

The size (length, width and thickness), thousand grain weight, bulk density, particle density, porosity, angle of repose and static coefficient of friction on galvanized sheet and plywood sheet surfaces were determined using the standard procedures given by Mohsenin (1980) for the ADT 39 and CO 43 varieties' samples at various moisture contents.

The physical properties for the raw paddy were determined at moisture contents ranging from 14.3 to 25.7%, for the raw rice and parboiled rice at 12.5%, and for the parboiled paddy at 43.5% and 40.8% for the ADT 39 and CO 43 varieties, respectively. All experiments were replicated thrice and the average values were calculated and reported.

The physical properties data for both ADT 39 and CO 43 variety were fitted to the following polynomial equation:

$Y = aM^2 + bM + c$ ....(1)

Where Y is the physical property at the wet basis moisture content M, and a, b and c are empirical constants.

Physical Dimensions

The three mutually perpendicular axial dimensions (length, width and thickness) of 30 grains were measured. Length and width were measured using a vernier caliper with a least count of 0.02 mm whereas the thickness was measured by a micrometer with a least count of 0.01 mm. The geometric mean diameter (GMD), and sphericity (the shape factor of the samples relative to that of a sphere of equal volume) were calculated from the axial dimensions using the following expressions (Mohsenin, 1980):

Geometric mean diameter, $d_g = (LWT)^{1/3}$ ....(2)

Sphericity, $S = d_g / L$ ....(3)

Where d_g is the geometric mean diameter of grain in mm, S is the sphericity, L is the length of grain in mm, W is the width of the grain in mm and T is the thickness of the grain in mm.

Thousand Grain Weight

One thousand grains of each sample were randomly selected and weighted in a digital electronic balance having an accuracy of 0.01 g. The thousand grain weight of samples was calculated by averaging measurements from three replicates.

Density

The bulk density of the samples was determined using a 500 cc capacity receiving cup. A hopper of about 700 cc capacity was placed near the center and just above the brim of the cup. The hopper outlet was closed and the hopper was filled with the samples. The samples were instantaneously allowed to fill the cup. The excess sample at the top of the cup was tapped and the contents were weighed. The bulk density of the samples was calculated by the **equation (4)**.

The particle density of the samples was determined from the specific gravity. The specific gravity of samples was determined by pycnometer method. By soaking the samples in toluene and finding the weight difference, it was found that the samples were non-absorbents of toluene.

The specific gravity of the samples was found using the **equation (5)**.

The specific gravity of toluene is obtained from the ratio of weight of toluene to the weight of water. The particle density ρ_p was calculated by multiplying specific gravity by 1000, and expressed in kg m^{-3}.

Porosity

The porosity Φ of the samples was calculated using the following expression:

$\Phi = (1- (\rho_b / \rho_p)) \times 100$ ....(6)

Where ρ_b is the bulk density in kg m^{-3} and ρ_p is the particle density in kg m^{-3}.

Angle of Repose

An equipment consisting of a hopper of 10-kg capacity fitted at the top of a plywood container of 1.0-m × 1.0-m × 0.3-m size. One side of the plywood container was made of removable acrylic sheet and pasted with a 1.0-m metric ruler, vertically.

The hopper has a sliding gate at the bottom and it was closed before filling the samples. The samples were filled to the hopper and allowed to fill the container suddenly. The height of the heap of samples H was noted from the vertical ruler and the diameter of the heap of samples D was measured using a 1.0-m metric ruler. The angle of repose of the samples θ was calculated using the following expression:

$\theta = \tan^{-1} (2H / D)$.....................(7)

Coefficient of Static Friction

The coefficient of static friction of the samples was determined on two surfaces: galvanized iron (GI) and plywood sheets. A tabletop arrangement, similar to the one used by Jha and Prasad (1993), was made which consisted of a plastic container with 0.1-mm thickness, 0.2-m height and 0.15-m diameter. This container was connected to a hanging weight carrier by means of a string, which passed over a pulley of minimum friction at one and of the table. The container was placed on the selected surface sheets (GI or plywood) and it was filled with the samples. The container was slightly raised above the sheets to eliminate the effect of plastic container bottom rim on the value of static coefficient of friction. Weights were added to the hanging carrier in small amounts until the container filled with the samples start to slide on the sheet. The weight of the sample W_s and the weight required for sliding the sample on the surface W_f were noted. The coefficient of friction C_f was calculated by the formula:

$C_f = W_f / W_s$............................(8)

Results and Discussion

Effect of Moisture Content

The axial dimensions (length, width and thickness), geometric mean diameter, thousand grain weight, bulk density and particle density of raw paddy increased with an increase in the moisture content (**Figs. 1** through **3**) because of the fact that the addition of moisture would normally increase the weight and volume of any agricultural products. The increase in volume due to the increase in the moisture caused an increase in axial dimensions. The porosity of raw paddy also increased with an increase in moisture content since it is derived from the bulk and the particle densities. The empirical constants a, b and c of equation 1 for various physical properties are given in **Tables 1** and **2**. Using these constants' the required physical properties of raw paddy can be estimated at various moisture contents within the range of moisture content tested.

An increase in the moisture content of raw paddy caused an increase in the angle of repose due to higher internal friction created by high moistures (**Fig. 4**). The coefficient of static frictions of raw paddy on GI and plywood surfaces were found to increase with an increase in the moisture content. The coefficient of static friction on GI sheet was higher than that of plywood sheet. This must have been due to the fact that the GI sheet surface was rougher than the plywood surface. High moisture grains adhere easily to the surfaces than the low moisture paddy and rice grains. This may have also contributed to the increase in static coefficient of friction on both surfaces with an increase in the moisture content (**Fig. 5**). In general, all the measured physical properties increased with an increase in moisture content, in the range of 14.3 to 23.8% for ADT 39 variety, and 15.6 to 25.7% for CO 43 variety.

Effect of Variety

There were marked differences in the physical property values between the ADT 39 and CO 43 varieties. **Tables 3** and **4** show the variation in axial dimensions and other physical properties of raw paddy of both varieties, respectively. These axial dimensions are very useful in the design of processing

Equations

Bulk density, ρ_b = Weight of sample in the cup (kg) / volume of the cup (m^3)(4)

$$\text{Specific gravity of a sample} = \frac{\text{Specific gravity of toluene} \times \text{Weight of sample}}{\text{Weight of toluene displaced by the sample}} \quad ...(5)$$

Table 1. Empirical Constants a, b and c of Equation 1 for Various Physical Dimensions of ADT 39 and CO 43 Raw Paddy Varieties

Property	ADT 39*			CO 43**		
	a	b	c	a	b	c
Length (mm)	-7.622	6.919	6.235	42.975	-15.772	8.971
Breadth (mm)	-18.395	8.017	1.314	-9.111	6.253	1.549
Thickness (mm)	1.766	-0.124	1.191	4.545	-0.924	1.494
GMD (mm)	-38.337	16.952	0.838	11.026	-2.715	3.076
Sphericity	-3.271	1.449	0.210	-1.506	0.761	0.305

R^2 (correlation coefficient) =1, for all the equations.
* Moisture content ranges from 14.3 to 23.8% (wet basis).
** Moisture content ranges from 15.6 to 25.7% (wet basis).

Table 2. Empirical Constants a, b and c of Equation 1 for Various Physical Properties of ADT 39 and CO 43 Raw Paddy Varieties

Property	ADT 39*			CO 43**		
	a	b	c	a	b	c
1. 1000 grain weight, g	0.006	-0.022	17.457	0.004	0.073	20.793
2. Bulk density, kg m^{-3}	0.022	-0.548	583.410	0.095	-1.911	571.500
3. Particle density, kg m^{-3}	-1.804	84.321	274.190	0.874	-30.511	1484.100
4. Porosity, %	-0.084	3.863	9.575	0.054	-2.214	75.365
5. Angle of repose, deg	-0.023	1.048	18.748	0.042	-1.508	39.195
6. Coefficient of friction on						
a. Galvanized iron sheet	-0.002	0.094	0.869	0.001	-0.013	2.608
b. Plywood sheet	0.015	-0.479	5.430	0.016	-0.601	7.571

R^2 (correlation coefficient) =1, for all the equations.
* Moisture content ranges from 14.3 to 23.8% (wet basis).
** Moisture content ranges from 15.6 to 25.7% (wet basis).

machines. A separator, for instance, designed to clean the ADT 39 paddy cannot be used for cleaning the CO 43 paddy. This is due to the fact that the CO 43 has larger axial dimension values than the ADT 39 paddy.

The thousand grain weight of CO 43 variety was on an average 24% higher than that of ADT 39 variety for the tested moisture content ranges (**Fig. 1**). The ADT 39 variety had higher bulk and particle densities than those of the CO 43 variety. However, lower particle density was observed for the ADT 39 variety at the moisture content of 14.3% (**Figs. 2** and **3**).

The angle of repose of ADT 39 variety was an average of 19% higher than that of the CO 43 variety (**Fig. 4**). Therefore, a hopper designed using the angle of repose value of the CO 43 paddy cannot completely discharge the whole bulk of the ADT 39 paddy. The coefficient of friction of the CO 43 variety on both the GI sheet and plywood surfaces were higher than that of the ADT 39 variety. From the curves of coefficient of friction (**Fig. 5**) it can be concluded that the coefficient of friction on plywood surface for both paddy varieties were close to each other. The CO 43 variety had an average of 30% higher coefficient of friction on GI surface than that of the ADT 39 variety.

Effect of Constituents

From **Table 3** it is clear that breadth and thickness of parboiled paddy are higher than those of raw paddy. On an average, the breadth and thickness of parboiled paddy were 25% and 38% higher than that of raw paddy, respectively. The axial dimensions for both raw rice and parboiled rice were nearly equal at 12.2% moisture content. The sieve or screen designed for sorting and grading or for dryer floor based on raw paddy's axial dimensions may not be suitable for both raw and parboiled rice since the latter two had smaller axial dimensions. Therefore, while designing these handling systems adjustable or removable screen should be provided for effective operation. **Table 3** provides the axial dimensions, GMD and sphericity values of paddy and its constituents. The thousand grain weight, bulk density, particle density, porosity, angle of repose, and coefficient of friction on both GI and plywood surfaces for parboiled paddy were higher than those of raw paddy (**Table 4**). This may be due to higher moisture content of parboiled paddy. Raw rice produced higher values of thousand grain weight, bulk density, particle densi-

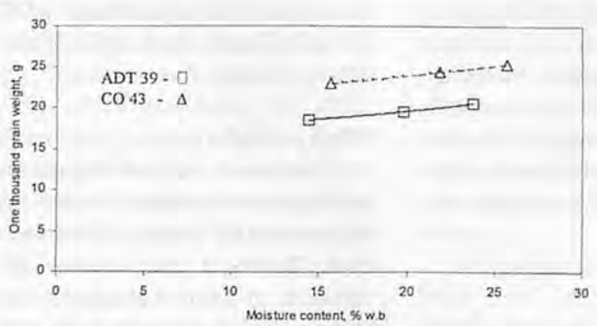

Fig. 1 Effect of moisture content on thousand grain weight of paddy. The data points show the measured values and the curves show the values predicted using the empirical model (Eqn. 1).

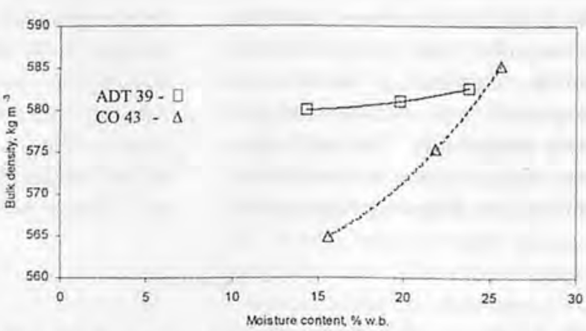

Fig. 2 Effect of moisture content on bulk density of paddy. The data points show the measured values and the curves show the values predicted using the empirical model (Eqn. 1).

Table 3. Average Physical Dimensions of Two Varieties of Paddy and Their Constituents

Property	ADT 39				CO 43			
	Raw Paddy (14.33%*)	Parboiled Paddy (43.51%)	Raw Rice (12.22%)	Parboiled Rice (12.26%)	Raw Paddy (15.57%)	Parboiled Paddy (40.82%)	Raw Rice (12.99%)	Parboiled Rice (12.33%)
Length (mm)	7.070	6.997	4.914	4.978	7.557	7.790	5.003	5.007
Breadth (mm)	2.085	2.653	2.015	1.965	2.302	2.801	1.997	2.024
Thick-ness (mm)	1.209	1.853	1.174	1.146	1.460	1.801	1.187	1.191
GMD (mm)	2.480	3.221	2.257	2.232	2.920	3.435	2.257	2.291
Sphericity	0.351	0.462	0.461	0.449	0.387	0.441	0.453	0.458

* The values within the parentheses are the wet basis moisture contents at which the dimensions were measured.

Table 4. Average Physical Properties of Two Varieties of Paddy and Their Constituents

Property	ADT 39				CO 43			
	Raw Paddy (14.33%*)	Parboiled Paddy (43.51%)	Raw Rice (12.22%)	Parboiled Rice (12.26%)	Raw Paddy (15.57%)	Parboiled Paddy (40.82%)	Raw Rice (12.99%)	Parboiled Rice (12.33%)
1000 grain weight, g	18.46	28.04	13.38	13.05	22.93	30.78	15.83	15.97
Bulk density, kg m^{-3}	580.00	596.89	843.32	835.38	564.87	582.25	868.59	838.62
Particle density, kg m^{-3}	1112.00	1229.00	1506.00	1425.00	1221.00	1216.00	1454.00	1518.00
Porosity, %	47.61	51.43	44.00	41.38	54.00	52.12	40.25	44.76
Angle of repose, deg	29.05	27.67	24.86	25.38	25.9	29.89	24.39	26.31
Coefficient of friction on								
a. Galvanized iron sheet	1.871	2.616	2.933	2.372	2.620	2.493	3.456	3.440
b. Plywood sheet	1.620	3.546	3.449	3.100	1.983	2.481	2.757	3.310

* The values within the parentheses are the wet basis moisture contents at which the properties were determined.

ty, porosity and coefficient of friction on both GI and plywood surfaces than those of parboiled rice. The angle of repose of raw rice was slightly lower than that of parboiled rice. The slight variation in physical properties between raw rice and parboiled rice could have been effected by the degree of drying and milling, and differences in moisture contents.

Among the tested paddy and its constituents, raw paddy produced the highest values of porosity (54.15% at 25.7% moisture content). The angle of repose was 30.68° at 23.8% moisture content. Parboiled paddy produced the highest values of length (7.79 mm), width (2.801 mm), thickness (1.853 mm), GMD (3.435 mm), sphericity (0.462). The thousand grain weight (30.78 g) at the moisture content range of 40.8 to 43.5%, raw rice at the moisture content range of 12.2 to 12.9% had the highest values of bulk density (868.59 kg m^{-3}), coefficient frictions on both the GI surface (3.456) and on the plywood surface (3.449), and parboiled rice at 12.3% moisture content produced the highest particle density of 1518 kg m^{-3}.

Conclusions

The length, width, thickness, GMD and sphericity of raw paddy were in the range of 7.07-7.754 mm, 2.085-2.554 mm, 1.209-1.556 mm, 2.48-3.105 and 0.35-0.40, respectively. The thousand grain weight, bulk density, particle density, porosity, angle of repose, and static coefficient of friction on GI and plywood surfaces of raw paddy were in the range of 18.56-25.38 g, 564.9-585.3kg m^{-3}, 1112-1277 kg m^{-3}, 47.6-54.2%, 25.9-30.7°, 1.871-2.852 and 1.620-2.456, respectively, in the moisture content range of 14.3 to 25.7%.

All the tested physical properties increased with an increase in moisture content.

Using the empirical constants a, b and c in equation 1 the physical properties of both the ADT 39 and

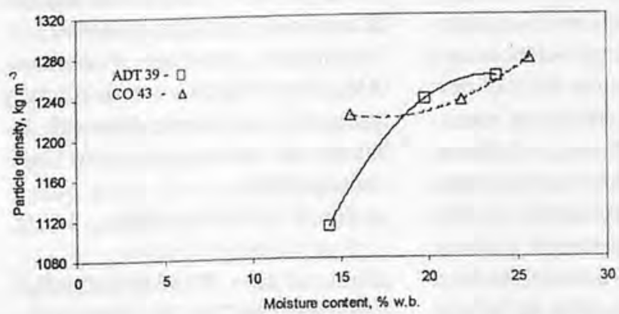

Fig. 3 Effect of moisture content on particle density of paddy. The data points show the measured values and the curves show the values predicted using the empirical model (Eqn. 1).

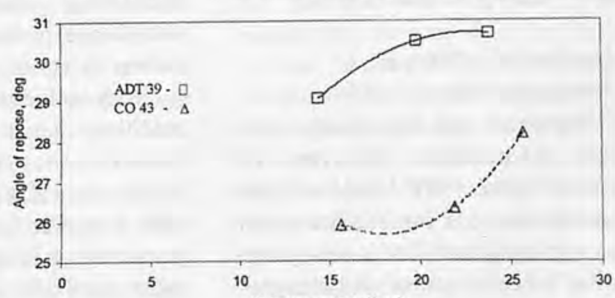

Fig. 4 Effect of moisture content on angle of repose of paddy. The data points show the measured values and the curves show the values predicted using the empirical model (Eqn. 1).

CO 43 varieties can be calculated for various moisture content levels.

The physical properties of the ADT 39 and CO 43 varieties differed from each other. Of these two varieties, higher values of thousand grain weight and coefficient of friction on GI and plywood surfaces were measured for the CO 43 variety whereas higher values of bulk density, particle density, porosity and angle of repose were produced by the ADT 39 variety at a particular moisture content.

Among the tested paddy and its constituents, raw paddy had the highest values of porosity and angle of repose, parboiled paddy had the highest values of length, width, thickness, GMD, sphericity and thousand grain weight, raw rice had the highest values of bulk density and, coefficient of frictions on both the GI surface and on the plywood surface, and parboiled rice had the highest value of particle density.

When designing machines like separators, dryers, threshers and similar machines for post harvest processing of paddy, proper attention must be given to the physical properties and their variations with moisture content levels and variety.

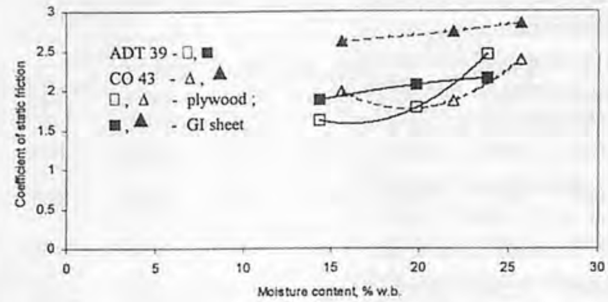

Fig. 5 Effect of moisture content on coefficient of static friction of paddy. The data points show the measured values and the curves show the values predicted using the empirical model (Eqn. 1).

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New Co-operating Editor

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Assessment of Cereal Straw Availability in Combine Harvested Fields and its Recovery by Baling


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Abstract

Combine harvesting of paddy and wheat is replacing the traditional harvest methods in many states of India. The information on availability of combine harvested straw is important for planning and management of mechanical straw recovery systems. The effect of height of cut of a combine harvester on availability of paddy and wheat straw has been studied. The straw availability is not directly proportional to the height of cut and a significantly higher amount of straw was found in the lower portions of plant than that of top portions. The average linear densities of straw swaths left after a combine harvester were 0.548 kgDM/m at a cutting height of 32 cm for paddy straw and 0.642 kgDM/m at a cutting height of 40 cm for wheat straw. A conventional field baler was used for recovery of paddy straw from swaths left behind a combine harvester. The baler recovered only about 32 and 24 % of potential paddy straw yield for heights of cut of 23 and 32 cm, respectively.

Introduction

Paddy and wheat are major cereal crops grown in Northern India with an annual production of about 160 million tonnes. Combine harvesting of paddy and wheat is replacing the traditional harvest methods and presently there are more than 16,000 grain combine harvesters in use on Indian farms. In the major cereal crop producing state of Punjab at least 90 % of paddy and 60 % of wheat are harvested by combine harvesters (Singh, 1997). The recovery of straw following combining, however, adds extra operations which are times consuming and costly. Also, combining sacrifices 40-60 % of recoverable straw because of high cut to reduce the volume of straw passing through the combine and consequent loss of chaff, leaf tissue and brittle fragments (Alam, 1998).

The straw yield is usually calculated from grain production data based on straw : grain ratios. Kossila (1984) suggested a number of multipliers for calculating the amount of fibrous by-products on the basis of annual production figures of various crops. Jain et al. (1996) gave straw : grain ratios of 1:1 and 1.3: 1 for wheat and paddy, respectively. The methods of harvesting, i.e., machine or manual can affect the cutting height and, therefore, the extent of recovery and quality of straw. Straw quantity is closely proportional to the height of cut (Smith et al., 1975). Dobie et al. (1977) used weight distribution curve to estimate the availability of rice straw on the basis of height of stubble and found that out of a potential straw production of 8.9 t/ha only 3.7 t/ha straw was available for removal from the field after combining the crop at a height of 43 cm. Allen (1988) investigated wheat dry matter (DM) yield and straw portions which are potentially recoverable by different harvesting methods. Where all DM was removed by hand and threshed, the grain, straw and chaff fractions averaged to about 40, 50 and 10 % of the total material, respectively. When the stubble was swathed and baled after conventional combine harvesting at 36 cm height of cut,

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the baled straw accounted for only 15 to 17 % of total DM.

Straw availability in combine harvested field could be assessed from the values of linear density of swaths which also affects bale density and amount of baler pickup unit losses. The linear densities of wheat straw swaths were from 0.25 to 1.6 kgDM/m (Hilmersen et al., 1984) and from 1.5 to 3.5 kgDM/m with average value of 2.5 kg/m (Neale and Williams, 1993). Cundiffa (1996) reported that there was an inverse relationship between the bale density and swath density and found that swath density had a significant effect on baling cost. Baler capacity was maximized when the density of hay in the windrow was between 2.2 and 3.6 kg/m at 15 % moisture content.

Enhanced utilization of paddy and wheat straws attracts increased attention due to concerns associated with environmental impacts from open field burning and economic concerns for conservation of a valuable natural resource. The knowledge of straw availability from paddy and wheat crops is crucial for planning and management of mechanized systems for the recovery of straw from combine harvested fields. Quality and quantity of straw produced per unit area is a factor of variety, agronomic practice, environment, harvesting, threshing, cleaning and handling practice. In contrast to grain yield, which can be readily measured, straw yields are reported with less accuracy because of variations in height of cut under field conditions and loss of chaff and leaves when sampling is done following a combine harvester. A field study was, therefore, planned to determine the effect of cutting height of combine on straw yields and to assess the recovery of straw from combine harvested fields using a conventional field baler which is presented in this paper.

Materials and Methods

Two field investigations were carried out to collect necessary data for assessment of straw availability. The first investigation was carried out on two varieties each of paddy, namely; Pant Dhan 4 and TDC 16-1 in 1999 and wheat, namely; UP 2338 and PBW 373 in 2000. Whole plant samples were manually harvested from randomly selected sample areas of 1 m^2 each at ground level using a hand sickle when the crop reached at its harvest maturity. These samples were used to determine the potential straw yields, straw to grain ratios and effect of height of cut on straw availability and losses as stubble. The plants were carefully fastened in bundles keeping the lower ends of the plants at par. The heads were separated from stalks and thereafter, weighed and threshed .The weights of grains and stalks were measured and representative samples were taken for determination of moisture content. Later on five to six segments with a length of 100 mm each were cut one after another from the stalks starting from the root side. The weights of each segment were measured and expressed in terms of DM weight per hectare. These data were used to estimate the potential availability of straw at a given height of cut. The potential availability of straw refers to the straw mass available above a particular height of cut for collection which could be calculated by subtracting the straw mass left as stubble from the potential straw yield as follows:

$$Y_h = Y_p - L_s \quad \text{.........................(1)}$$

Where,

Y_h = potential straw availability at 'h' height of cut, kg/ha;

Y_p = potential straw yield, kg/ha; and

L_s = straw losses as stubble, kg/ha.

The second investigation was carried out on one variety of paddy, i.e., Pant Dhan 4 in 1999 and two varieties of wheat, i.e., UP 2338 and PBW 373 in 2000. In this investigation, the linear density of straw swath left by a commercial combine was measured at randomly selected swath segments at stubble heights varying from 28 to 42 cm. The length of each segment was chosen as 15 m (Pant Dhan 4) and 20 m (UP 2338 and PBW 373). The linear density of swath is defined as the weight of loose straw found in one meter length of swath. The results of this experiment were used to estimate straw availability in swaths and straw losses associated with the combine. Loose straw present in each meter of selected swath segments was collected using a manual fork and weighed. Representative straw samples were taken for the determination of moisture content. Straw losses due to combining represent the quantity of chaff and straw that has been shattered and perished on the ground due to mechanical action of different units of the combine and that can not be collected. These losses were estimated as the difference between the straw potentially available at a given height of cut and effective straw availability in swaths as given below:

$$L_c = Y_h - 10000\,(\rho_h / w_c) \quad \text{....(2)}$$

Where,

L_c = straw losses due to combining, kg/ha;

ρ_h = linear density of swath at 'h' height of cut, kg/m; and

w_c = effective width of cut of combine, m.

An experiment to determine the recovery of paddy straw (Pant Dhan 4) by baling and straw losses during baling was also carried out. Baling was done using a conventional field baler which produces bales of 360 mm × 460 mm cross sectional dimensions and 310 to 1320 mm adjustable lengths (**Fig. 1**). Straw losses by the baler include the losses incurred at the pickup unit and bale chamber of the machine. Pickup unit loss is the loose straw that is left over the ground surface when the swath is lifted by the pickup unit and is affected by swath parameters and straw moisture content. Bale chamber loss is the material that is disassociated and dropped during the formation of bales in the bale chamber. Swaths 200 m long each and two heights of cut of 23 and 32 cm were baled. The bales produced in each swath were collected and weighed. Representative straw samples were collected for the determination of moisture content. The baling loss has been considered as the difference between the effective straw availability in a swath at a given height of cut and the yield of baled straw and calculated using the following formula:

$L_b = (10{,}000/w_c)(\rho_h - W_b/B_s)$ (3)

Where,

L_b = baling losses at 'h' height of cut, kg/ha;

W_b = total weight of bales collected from a swath, kg; and

B_s = length of swath, m.

Results and Discussion

Effect of Height of Cut on Wheat Straw Availability

The relationships between the availability and loss of straw as stubble with height of cut are shown in **Fig. 2** for wheat and in **Fig. 3** for paddy varieties. Both wheat varieties were medium with the mean height of plants excluding the ear heads as 85 cm for PBW 373 and 75 cm for UP 2338. Grain yields were estimated as 5638 kgDM/ha (6633 kg/ha at 15 % moisture content) for PBW 373 and 3866 kgDM/ha (4548 kg/ha at 15% moisture content) for UP 2338. The potential straw yield was 6216 and 4816 kgDM/ha for PBW 373 and UP 2338, respectively. The average straw to grain ratios on dry matter basis were calculated at 1.1:1 for PBW 373 and 1.31:1 for UP 2338. The measurements of straw DM distribution along plant height (**Table 1**) showed that the amount of straw in the lower portions of plants was significantly higher than that of top portions suggesting that the straw availability is not directly proportional to the height of cut. A best fit to data points was obtained using polynomials as follows:

Table 1. Straw Dry Matter Distribution along Plant Height

Segments of stalks, cm	Potential straw DM availability in a segment, kg / ha			
	Wheat varieties		Paddy varieties	
	UP 2338	PBW 373	Pant Dhan 4	TDC 16-1
0 – 10	891	1096	1292	813
10 – 20	863	1061	1150	740
20 – 30	794	942	1002	667
30 – 40	715	875	768	620
40 – 50	668	858	695	567
> 50	885	1384	1368	2633

(a) For PBW 373

$$Y_h = 0.64\,h^2 - 130.9\,h + 6238 \quad (R^2 = 0.99) \quad (4)$$

(b) For UP 2338

$$Y_h = 0.5\,h^2 - 102.8\,h + 4869 \quad (R^2 = 0.99) \quad (5)$$

Where,

Y_h = potential straw availability at 'h' height of cut, kgDM/ha; and

h = height of cut, cm

Effect of Height of Cut on Paddy Straw Availability

The mean heights of plants excluding the ear heads were measured as 78 cm for Pant Dhan 4 and 116 cm for TDC 16-1. Grain yields were estimated as 5598 kgDM/ha (6586 kg/ha at 15 % moisture content) for Pant Dhan 4 and 4373 kgDM/ha (5145 kg/ha at 15 % moisture content) for TDC 16-1. The potential straw yield was found as 6275 and 6040 kgDM/ha for Pant Dhan 4 and TDC 16-1, respectively. The average straw to grain ratios on dry matter basis were found as 1.13:1 and 1.4:1 for Pant Dhan 4 and TDC 16-1 varieties, respectively. The measurements of straw DM distribution along plant height (**Table 1**) showed that the amount of straw in the lower portions of plant was significantly higher than that of top portions. When compared with wheat straw, it is evident that the reduction in weight per unit length with increasing height of cut was higher in case of paddy straw. This may be explained by the fact that the proportion of leaves in the lower parts of the paddy plants is comparatively

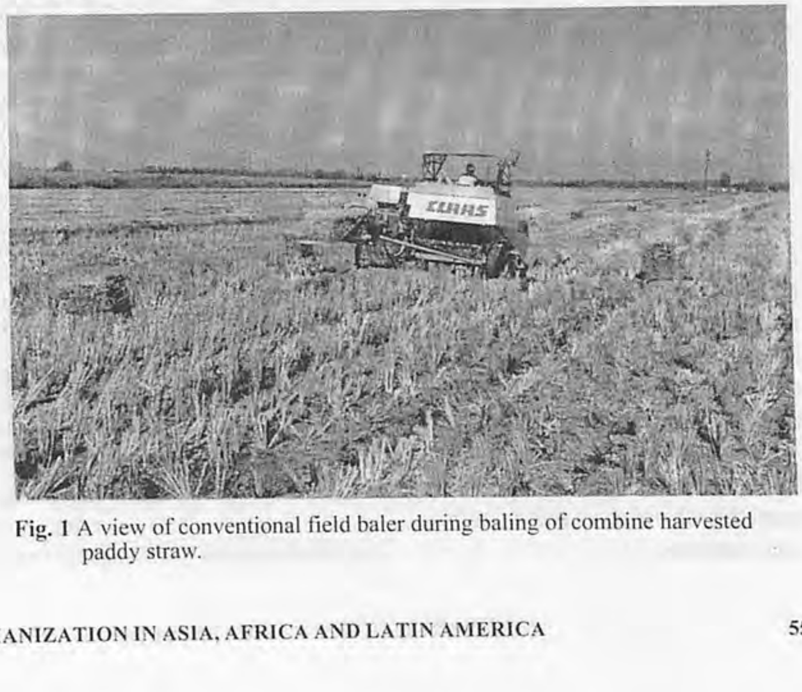

Fig. 1 A view of conventional field baler during baling of combine harvested paddy straw.

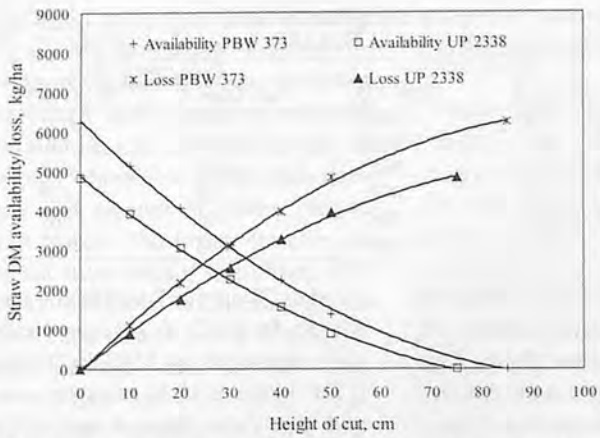

Fig. 2 Effect of height of cut on availability and loss of wheat straw as stubble.

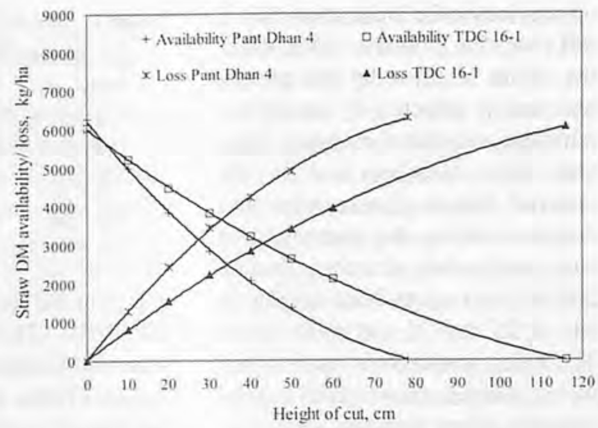

Fig. 3 Effect of height of cut on availability and loss of paddy straw as stubble.

high which gives higher values of weight per unit length. A best fit to data points was obtained using polynomials as follows:

(a) For Pant Dhan 4

$$Y_h = 0.67\,h^2 - 132.2\,h + 6245 \quad (R^2 = 0.99) \qquad (6)$$

(b) For TDC 16-1

$$Y_h = 0.24\,h^2 - 79.9\,h + 6013 \quad (R^2 = 0.99) \qquad (7)$$

Effect of Height of Cut on Linear Density of Straw Swaths

Straw swaths left behind the combine are not uniform in terms of their width, linear density and profile of a cross section perpendicular to the swath length. The feed rate of a straw collection machine is related to the linear density of swath and forward speed of machine as follows:

$$Q_f = \rho_h\, v \qquad (8)$$

Where,

Q_f = feed rate, kg/s;

ρ_h = linear density, kg/m; and

v = forward speed, m/s.

Hence, the variations in linear density would indicate the expected load variations on straw collection machine. Also, the characteristics of straw swath indicate to: (i) effective straw availability for collection; (ii) straw losses as stubble and losses associated with combining of the crop; and (iii) straw losses caused by the pick up unit of collection machine.

Linear Density of Wheat Straw Swath

The measured values of linear density of swath are presented in **Table 2** which shows that the swaths with low stubble heights had higher linear density. The stubble heights of selected swaths were 40 cm for swath No.1 (S_1), 40 cm for swath No.2 (S_2) and 42 cm for swath No.3 (S_3) for PBW 373 and 28 cm (S_1), 28 cm (S_2) and 34 cm (S_3) for UP 2338. In all the segments, variation of linear density was large ranging from 0.283 to 1.152 kgDM/m for PBW 373 (S_1) and 0.178 to 1.608 kgDM/m for UP 2338 (S_2). The average percentage variation of linear density with respect to the mean value was as 26.1, 22.9 and 18.8 % for S_1, S_2 and S_3, respectively, for PBW 373 and 32.1, 29.9 and 12.5 % for S_1, S_2 and S_3, respectively, for UP 2338. When these variations were evalu-

Table 2. Variations of Linear Density of Swaths Left behind a Combine Harvester

s. no. of swath segments*	Linear density, kg DM/m							
	Average Stubble height, cm							
	Paddy (Pant Dhan 4)		Wheat (PBW 373)			Wheat (UP 2338)		
	23	32	40	40	42	28	28	34
1	0.990	0.337	0.459	0.370	0.405	0.578	0.484	0.512
2	0.848	0.135	1.152	0.700	0.811	0.798	0.909	0.325
3	1.958	0.267	0.838	0.677	0.647	1.671	1.117	0.554
4	0.944	0.311	0.920	0.483	0.888	1.005	1.608	0.451
5	0.741	0.466	0.509	0.339	0.640	0.714	0.728	0.792
6	0.784	0.495	0.569	0.452	0.706	1.109	0.178	0.511
7	0.716	0.436	0.472	0.383	0.495	0.886	0.397	0.558
8	1.213	0.462	0.460	0.584	0.691	0.946	0.691	0.589
9	0.873	0.735	0.907	0.538	0.286	0.242	1.118	0.434
10	0.653	0.751	0.622	0.882	0.288	0.272	0.287	0.351
11	0.841	0.867	0.322	0.337	0.270	0.315	0.280	0.473
12	0.334	0.862	0.283	0.897	0.422	0.775	0.678	0.737
13	0.340	0.597	0.524	1.159	0.442	0.207	0.254	0.527
14	0.528	0.938	0.348	1.026	0.595	0.690	0.565	0.204
15	0.779	0.560	0.974	0.450	0.592	0.471	0.700	0.653
16			0.797	0.326	0.427	0.516	0.639	0.487
17			0.807	0.751	0.405	1.053	0.427	0.428
18			0.829	0.665	0.415	0.576	0.557	0.477
19			0.994	0.668	0.594	0.780	0.669	0.656
20			0.707	0.660	0.837	0.499	0.851	0.361
Av.	0.836	0.548	0.675	0.617	0.543	0.705	0.657	0.504
SD	0.387	0.241	0.251	0.239	0.186	0.354	0.346	0.141

*Each swath segment had a length of 1 m.

ated on the basis of the percentage changes from one meter to another, the maximum percentage changes were 179.5 % in case of PBW 373 (S_1) and 220.5 % in case of UP 2338 (S_3). This indicates that the feed rate of the straw collection machine may vary momentarily from meter to meter by up to about 1.8 times for PBW 373 (S_1) and about 2.2 times for UP 2338 (S_3).

It could be deduced that the percentage of locations whose variations fall within a range of ± 50 % of the mean value is about 70 % of the total locations measured (UP 2338, S_1). In general, this percentage ranged from 70 to 90 % of the mean value in all the segments. The knowledge of straw distribution in a swath is important because it indicates the load variations a baler will have to cope with from meter to meter. At a forward speed of about 1.39 m/s (5.0 km/h) and feed rate of 1.67 kg/s (6.0 t/h), the average linear density should be about 1.2 kg/m for maintaining the full load condition of baler. Assuming the average moisture content of straw at the time of baling as 10 %, it could be seen that for UP 2338 (S_1), the baler will operate at underload conditions in about 85 % of area since the probability of occurrence of linear density of more than 1.2 kg/m is only 15 %.

The sources of variation of linear density are due to the variations in straw yield across the field and the field conditions such as presence of ridges, field irregularities and lodging of the crop. However, the factors related to combine operation are the major sources of variation including those in width of cut, forward speed and height of cut which are governed by the operator.

Linear Density of Paddy Straw Swaths

The values of linear densities ranged from 0.334 to 1.958 kgDM/m for S_1 and from 0.135 to 0.938 kgDM/m for S_2 (**Table 2**). However, on wet basis, the densities would be much higher, especially after combining where the moisture content of straw was as high as 62 %. Even after a day of combining the moisture content was measured as 37.3 % (S_1). The average percentage variations of linear density with respect to the mean value were 28.9 and 23.5 % for S_1 and S_2, respectively. The maximum percentage variation from one meter to another was 131 % for S_1 and 97.9 % for S_2. The probability of occurrence of variations in a range of 0.5 to 1.5 times the mean value is about 72 % (S_1) and 75 % (S_2). If the average moisture content of straw at the time of baling is assumed as 20 %, it is evident from **Table 2** that for S_1 the baler would be operating at underloaded condition in about 62 % of the area. If the height of cut were high as in case of S_2, the baler would operate underloaded in 96% of the area.

Assessment of Recovery of Straw by Baling

On the basis of the results of baling experiment a number of parameters related to recovery of straw by baling have been determined and presented in **Table 3**. The following inferences could be drawn from the table:

i. Of the effective straw availability which amounted to 2,362 kgDM/ha in swaths with a height of cut of 23 cm (S_1) and 1,548 kgDM /ha in swaths with a height of cut of 32 cm (S_2), only 1,977 and 1,469 kgDM/ha was recovered by baling of S_1 and S_2, respectively.
ii. The baling losses with respect to effective straw availability in swaths decreased from 16.3 to 5.1 % when the height of cut increased from 23 to 32 cm. This is probably due to the higher elevation of swathed straw in taller stubble in which case a lesser amount of loose straw drops down on the ground surface. However, for the short stubble, the swathed straw would be closer to the ground where surface irregularities make it difficult to be lifted up by the pick up unit of the baler.
iii. The percentage recovery of straw by baling of combine harvested fields with respect to potential straw yields was estimated at 31.5 % for S_1 and 23.4 % for S_2 which shows that about 68.5 % and 76.6 % of straw was lost in the case of S_1 and S_2, respectively. The losses in straw may be partitioned into

Table 3. Results of a field test on baling of paddy straw (Pant Dhan 4)

S. No.	Parameter	Stubble height, cm	
		23 (S_1)	32 (S_2)
1	Swath length, m	200	200
2	Effective width of cut of combine, m	3.54	3.54
3	Potential straw DM yield , kg/ha	6275	6275
4	Potential straw DM availability at 'h' height of cut, kg/ha(1)	3558	2700
5	DM linear density of swath, kg/m(2)	0.836	0.548
6	Effective straw DM availability, kg/ha	2362	1548
7	Average weight of baled straw DM per swath, kg	140	104
8	Baled straw DM yield, kg/ha	1977	1469
9	Straw loss as stubble, kg/ha(3)	2717	3575
10	Straw loss caused by combine (breakage and chaff), kg/ha(4)	1196	1152
11	Baler loss (pickup unit and bale chamber loss), kg/ha(5)	385	79
12	Combine loss, % of potential yield(6)	19.0	18.4
13	Baler loss, % of potential yield(7)	6.1	1.3
14	Baler loss, % of effective straw availability(8)	16.3	5.1
15	Recovered baled straw, % of potential yield(9)	31.5	23.4

(1): Equation 6 (2): Table 2
(3): row (3) - row (4) (4): row (4) - row (6)
(5): row (6) - row (8) (6): [row (10) / row (3)] × 100
(7): [row (11) / row (3)] × 100 (8): [row (11) / row (6)] × 100
(9): [row (8) / row (3)] × 100

three types, namely; straw losses as stubble, straw losses due to combine (breakage and leaf dis-association) and baling losses. These types of losses may be related by the following equation:

$$1 - E_o = (1 - E_p)(1 - E_c)(1 - E_b) \quad ...(9)$$

Where, E_o, E_p, E_c and E_b are overall, potential, combine and baler straw recovery efficiencies, respectively. These efficiencies are defined below:

$$E_p = Y_h / Y_p$$

$$E_c = Y_{he} / Y_h$$

$$E_b = Y_b / Y_{he}$$

Where,

Y_p = potential straw yield;

Y_h = maximum straw availability at 'h' height of cut;

Y_{he} = effective straw availability in swaths; and

Y_b = recovered baled straw.

When substituting E_p E_c and E_b with their values of 56.7, 66.3 and 83.8 %, respectively, for S_1 as calculated from **Table 3**, the overall straw recovery efficiency, E_o, would be 31.5 % and the overall percentage loss would be 68.5% which is in agreement with the value estimated on the basis of recovered baled straw and potential yield.

Conclusions

The potential straw yield of two medium tall varieties of wheat ranged from 4800 to 6200 kg DM/ha with variations in straw to grain ratio on dry matter basis between 1.10 and 1.31. The potential paddy straw yield of two varieties of paddy ranged from 6000 to 6300 kg DM/ha with variations in straw to grain ratio on dry matter basis between 1.13 and 1.40.

The straw availability is not directly proportional to the height of cut and a significantly higher amount of straw is available in the lower portions of plant than that of top portions. The potential wheat straw availability decreased from 82 % of the potential yield at 10 cm height of cut to 34 % at 40 cm height of cut. In case of paddy straw the corresponding values were 83 % and 43 %.

The variations of linear density of swaths left after combine harvesting of wheat ranged from 0.283 to 1.159 kgDM/m at about 40 cm height of cut and from 0.178 to 1.671 kgDM/m at about 28 cm height of cut. For paddy straw, the linear density of swaths ranged from 0.135 to 0.938 kgDM/m at about 32 cm height of cut.

The effective availability of paddy straw in swaths ranged from 1548 to 2362 kg DM/ha at heights of cut of 32 and 23 cm, respectively. The percentage recovery of paddy straw by baling with respect to potential straw yields was estimated as 31.5 % and 23.6 % for heights of cut of 23 and 32 cm, respectively.

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Present Status of Farm Machinery Fleet in Kyrgystan: Case Study


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Abstract

Kyrgystan is a recently emerged independent country from the former Soviet Republic in the heart of Central Asia. It is currently undergoing deep economic and political upheavals that should result in the establishment of a competitive market economy. The main pillar of the Kyrgyz economy is agriculture, particularly sheep and other livestock rearing. Cereals farming in the Northern Tchui Valley and cotton growing in Djal-Abad and Osh Governorates contribute also very much to the agricultural potential. Marginal potato, sugar beet and vegetable production in Issyk-Kul and Naryn Governorates complete the whole picture.

The flourishing agriculture in the past Soviet period was substituted by stagnation and, later on, a total collapse of agriculture in the early 90s. Especially, the sheep counting about 8 million head during the last years before the independence (1992), was decimated down to 2 million in 1997. Also, livestock farming decreased in both number of head and production of milk. Heavy heritage of rigid inefficient system of Soviet farming consisting of huge thousands-of-hectares kholkhozes and sovkhozes made it very difficult to pass from collective forms the Kyrgyz agriculture based on the past to the market-oriented profitable farms, either joint stock agricultural enterprises (replaced sovkhozes) or individual (family) farms. Problems of inputs, especially machinery and storing/handling equipment, have belonged to the most pressing burdens that were hindering the privatization process. The originally huge machinery fleet decreased in number and its technical status due to its age.

This present study offers a deep analysis of the agricultural machinery fleet availability in Kyrgyzstan as compared with current requirements and estimated future needs on different machinery types and models.

Current Machinery Fleet Available

In the first quarter of the current year (1999), the Kyrgyz agriculture disposed of some 23,305 tractors, of which 15,439 units were universal (mostly MTZ-80 and IUMZ-6 makes) and 7,896 special (crawler heavy duty units and row-crop tractors). The potential of the agricultural machinery fleet consisted of: 12,263 tractor trailers, 5,804 ploughs, 3,402 cultivators, 3,869 seeding and planting machines, 3,651 combine harvesters, 628 maize forage harvesters, 1,753 chopping machines (forage harvesters), 3,053 tractor mowers, 1,255 tractor rakes, 2,003 pick-up balers, 551 grain cleaning/grading units. Many other items of agricultural machinery were available for field farming.

Animal farms - mostly big farm units that are still partly (in a very reduced extent) working, were in possession of a high performance machinery, such as milking machines (1,014 units), freezing equipment (378 units), feeding and feeding distributors (781 units), farmyard manure handling conveyers (1,074), electric sheep shearing devices (1,830), crushing and milling centers (1,143).

There were still some 59.6 thousand electrical motors in agriculture, all together having power of about 614,400 kW. Another electrical equipment were available, such as electrical mains of (0.4 - 10 kW) and about 4,000 km, 3,237 transformer sub-stations with 540,000 kW of power.

Recent Evolution in Agricultural Machinery Inputs

During the past decades, the level of machinery inputs in the agriculture was growing year by year. However, due to a fierce fall of industrial production in the CIS and, especially, recent revolutionary upheavals in agriculture (disintegration of the old structural production base accompanied with hard insolvency of the agricultural producer), a smart reduction of supplies in agricultural machinery, spare parts and repair materials has taken place. For instance, in 1993 the Kyrgyz agriculture bought some only 112 tractors (4% of 1990), 117 trucks (also 4%), 74 combine harvesters (17%), and 18 seeding machines (4%), etc.

In the period 1994-97, the main supplier of the agricultural machinery - "Kyrgyzailkomok" (former Soiuzsel'khoztechnika), haven't supplied any tractors, combine harvesters, forage harvesters and many other items of machinery. Recently, the situation has improved a bit, however, a painful lack of machinery inputs survives up to now.

At present, in comparison with 1991, the agricultural enterprises had less machines and equipment, especially tractors (by 15%), trucks (by 9%), seed bed preparation equipment (by 12%) and seeding machines (by 17%). The number of combine harvesters and other harvesting equipment is less by 7 to 20% whereas their management and use got worse due to: privatization; fragmentation of big fields; lack of managerial skills and know-how at new private farmers; and worsening of the technical status of farm machinery.

The situation in farm machinery inputs is particularly precarious at recently emerged private farmers' community. The machinery fleet's recent evolution and the existing at private farmers is reviewed in **Table 1**.

Evaluation of Available Agricultural Machinery and Related Circumstances

The agricultural machinery inputs are, no doubt, the Achilles' heel of the Kyrgyz agriculture. Besides the lack of draw-bar power and, particularly, seeding and harvesting machines, many other constrains make the situation every year worse.

The situation in the agricultural machinery can be roughly characterized as:

1. The machinery park in Kyrghyzstan comprises an elderly fleet of medium to large-scale equipment which is in a near terminal state of deterioration;
2. As no significant supplies of new equipment for financial reasons can be expected in the near future (next 3 years), the only alternative are repairs of worn out machinery to the detriment of economic principles of machine use;
3. During the next 2 - 3 years an adequate supply of spare parts, repair materials and access to repair facilities will be the main factors that decide the technological level of the agriculture;
4. Without dramatic improvements in the supply situation for consumable items (spare parts, good quality lubricants and fuels and other repair materials) and access to repair facilities, the stock of used equipment will be virtually exhausted within 2 or 3 years;
5. The equipment, the farmers only have or must use, is nearly solely of the Soviet provenance (in relation to the Kyrgyz Republic of foreign origin) designed for use in an extensive agriculture industry, where to all intents and purposes, resources were infinite.
6. There is an inadequate coverage by agricultural machines, the major part of them being concentrated in the former kolkhoz/sovkhoz machinery pools that make the farmers' access difficult to. Especially, lack of draw-bar power is above the capacity of many farmers who are not able to farm their land
7. The machinery in the hands of private farmers is mostly improperly operated because they are usually unskilled to work with machines.

In relation to the new private agricultural sector mostly represented by small-scale farms, the up-to-date used machinery is, in the most part, unsuitable, unless the small farms are grouped (incorporated) into machinery cooperatives or machinery pools or contractor companies are set up. The process of farmers' reorganization in groupings and new farmers' structure establishment should be seen as the first and most important and effective step to the machinery input supply solution for new private agriculture sector.

Actual Availability of Agricultural Machinery

Farm Machinery for Field Operations in General

As stated above, the machines

Table 1. Agricultural Machinery in Private Farms

Item/Region	Kyrgyz Republic		Dzalal-Ab. region		Issyk-Kul region		Naryn region		Osh region		Talas region		Chui region	
Year	1996	1999	1996	1999	1996	1999	1996	1999	1996	1999	1996	1999	1996	1999
Trucks	1,556	1,942	552	571	87	87	281	335	256	555	134	131	246	263
Cars	1,060	1,033	32	37	78	78	462	462	196	350	36	32	256	275
Wheel tractors	1,697	2,092	474	504	116	117	231	381	344	547	160	174	372	369
Caterpillar tractors	551	831	128	149	31	40	113	201	79	146	55	166	145	129
Drills	320	448	85	95	16	18	50	80	48	141	50	46	71	68
Pick-up bailers	253	339	81	84	17	17	47	76	27	75	22	21	59	66
Plough	520	670	128	136	37	41	72	138	106	155	63	68	114	132
Mower	279	340	88	88	28	28	40	64	33	66	21	22	69	72
No. of farms	21,264	24,152	1,027	1,543	1,079	1,144	9,038	9,170	1,770	3,866	1,468	1,191	6,882	7,238

and equipment are usually over used and on actually very low level of reliability. This fact is reflected in their considerably reduced availability for field operations. In conformity with the above collected data, to the 1st of June 1998, there were some 5 880 tractors (23% of the whole fleet) out of service; the same was true for 4,646 trucks (31%). 741 forage harvesters, 1,339 combine harvesters and 487 maize forage harvesters representing a respective percentage of the whole fleet: 39%, 41% and 50%. There were other 312 windrowers (32%), 687 tractor mowers (31%), 282 tractor rakes (24%) and 558 pick-up balers (30%).

A particular situation has been found in NARYN Region where only some 68% of tractors are operational. The situation of other machinery looks no better, for instance: trucks - 61%, hay-making machinery - 52 - 61%. It is quite normal that the machinery availability varies within the same region, according to districts. For instance: **Tchon-Alajski and Alaiski Districts**: operable tractors - 47 and 53%, trucks - 50 and 49%, forage harvesting equipment - 40 and 53%; and **Kara-Kildjinski Raion**: operable tractors – 42%, trucks - 52%, tractor mowers - 19%, tractor rakes - 30%, pick-up balers - 48%.

Detailed information on other regions and their districts has also been gathered as follows:

Tractors' availability - 67%: in Talas Region (Batkenskii, Tchuiski and Tonskii Districts);

Trucks - 52 - 65%: in Talas Region (Batkenskii, Tchuiski, Tonskii and Manaskii Districts);

Forage Harvesters - 49 - 58%: in Djalalabad and Issyk-Kul Regions;

Tractor Mowers - 49 - 55%: in Uzgensk, Alamedinsk, Djailsk, Issyk-Kul and Tiup Districts;

Pick-Up Balers57 - 60%: in Ala-Bukinsk, Tchatkal'sk and Issyk-Atinsk Raions.

Brief Assessment of Main Farm Machines

Tractors

Tractors are the main power units in the Kyrgyz agriculture. They are especially possessed by the former kolkhozes/sovkhozes machinery pools that are going to be transformed into private service companies. Surprisingly, many tractors are found in the private farmers' sector.

Although some 20 different tractor models are currently in use only a few of them exist in remarkable quantity. The most popular ones are: wheeled MTZ-80 (and its 4DW modification MTZ-82) and DT-75 in some modifications. The biggest tractor units - wheeled K-700 and crawlers T-150 or T-4 are disappearing from farms for many reasons. On the contrary, up to now less used smaller performance tractors like T-40, T-25 or T-16 are getting more importance at private farmers, supposed their quality would be better. But other low-performance model classes of 20 and 30 HP, one- or two-axle mini-tractors and powered-hoes should be introduced into Kyrgyz agriculture.

The problems linked to today's use of tractors in Kyrgyz agriculture can be summarized as follows:

1. Most tractors are old and worn out. Their average service life largely exceeds the normative depreciation period (8 years);
2. They need costly repairs and adequate maintenance. Particularly, the repairs of tractor engines and tires will take more and more place getting very expensive (for example, rectification of crankshafts and cylinders.);
3. Their fleet is not more adequate to the new established economic situation – small-scale farms with reduced plot size and small-scale transport;
4. The most usual tractor model is MTZ-80 (75 HP) is suitable for farms with 30 and more hectares. Its use on small private farms gets uneconomic unless they co-operate together or co-exist within machinery pools (co-operatives);
5. There is insufficient range and quantity of smaller tractor models (from 16 to 40 HP) that could be of better (more economic) use for small farmers;
6. There are numerous heavy duty tractors, frequently crawler models, like T-150, K-700, DT-75, etc. that are not suitable for small farmers at all, unless they are not grouped or do not have possibility to hire these units;
7. Recently, some mini-tractors of Russian and Chinese makes have come into the country. Despite their reasonable prices (about 1 500 $US) and incontestable utility for small-scale specialized farmers (vegetable, potato, fruit growing), their sales are rather limited due to end-user's low purchasing power; and
8. There is lack of adequate working machines and equipment for tractor units smaller than MTZ-80, which potentially reduces their in-field use and management.

Furthermore, less experience and absence of proper farming practices at new emerging private farmers must be mentioned in context with low value of tractors field efficiency coefficient. The same problem is frequently met at service (contractor) companies and companies of the former Soiuzsel'khoztechnika.

But it is to point out that the tractors of the ancient Soviet design feature some useful characteristics like robustness and simplicity and they are well known at farmers, servicemen and managers.

Combine Harvesters

Difficult situation in cereal harvest is predicted for near future since lack of convenient combine harvester units has been stated all over the country. Besides, insufficient provision with fuel and spare parts exists since the early 90s. This is especially due to the new private sector. Although since 1990 the area under cereals has steeply decreased, the number of combine harvesters has fallen more quickly and their operation reliability reached a critical state. The operational readiness of combine harvesters is very low, on the average reaching only 59%. In some regions it is even less. For example, in the main production area (Tchui Region) has 47% but some its districts is already on a disastrous level - from 17 to 38% (Kara-Kuldjinski, Tchon-Alaiski, Bazar-Korgonski, Issyk-Atinski, Panfilovski and Djailski Districts).

The present number of combine harvesters (1998) is 3,561 units - by 1,400 units (40%) less than in 1986. The area to harvest is estimated for the current combine harvester fleet on some 158 ha per one combine harvester (class NIVA SK-5) which is by 1.4 times more than they actually can make (110 ha) with regard to their technical status. Actually, the NIVA's daily capacity cannot exceed 5 ha a day, which is due to its degree of serviceability, lack of repair services and other circumstances like, for instance, unskilled operators and unprofessional management. The above considerations highlight a very long period of cereal harvest in Kyrgystan (about 35 days), which consequently results in very high harvesting losses (about 10% in average).

This situation is even worse in the most productive areas like Djalal-abad Region where the cereal harvesting area per combine harvester is 1.8 times higher, Tchui Region (1.7 higher). In some districts of different regions this area goes up to 300 hectares. Consequent unacceptable delay of post-harvest operations is also one of the problems the farmers must face. Some figures concerning the situation are included in **Table 2**.

The actual harvest losses are difficult to measure since most combines are fitted with straw collecting devices or chopper blowers. However, because of low technological quality of Russian made combines (NIVA SK-5 or SK-6 KOLOS) the percentage of grain has always been estimated at 7 - 10%. In the case of crop cut with windrowers on windrows and threshed by combine harvesters with a pick-up header the harvest losses go up to 15%. It has been stated (by the World Bank) that due to delays, poor quality of harvesting and grain storing in Kyrghystan the losses go up to 25% of the total cereal grain. However, the information gathered and experience from the past evidence that this can be true only in some places and the average of losses can be estimated on the level of 15%.

Cotton Harvesters

The cotton harvesters still available in Kyrgystan were produced in Uzbekistan. New CASE cotton pickers are imported from USA and Tashkent but they have, up to now, a marginal importance. There are still many old (Soviet) harvesting units in Osh and Djalalabad regions where the percentage of unserviceable pickers reaches 70%. Private individually operating farmers rarely dispose of cotton harvesters and if so their harvesters are mostly old and unreliable. So they mostly have to seek help in hand picking. This, on the other hand, raises the quality of their cotton and improves its competitiveness.

Most (Soviet) cotton harvesters are carried on 3-wheel tractors having 2-row or 4-row vertical spindle picking units. Their picking capacity is quite satisfactory but the quality of picking (harvest losses) and quality of product is reduced due to improper handling and dirty cotton fibers. Moreover, these (vertical) picking units damage the fibers in contrast to the horizontal picking fingers (CASE design). Complicated post-harvest processing (cleaning, selection and packaging) is necessary in order to make the product marketable.

Sugar Beet Harvesters

There is one main sugar beet growing area - Tchui Valley in the North of Kyrgystan. Another very suitable area of good sugar beet prospects (Issyk-Kul Oblast) has no sugar factory. This has always limited sugar beet growing in the region because of transport costs (sugar beet was transported to the Kant sugar factory or even to Kazachstan (Burundai sugar factory). At present, this fact excludes at all sugar beet growing in Issyk-Kul Region.

During the 80s the area of sugar beet reached its top (1987) and its yields were steadily growing till the average 15.7 tons/ha (1986). However, in spite of the crop of good prospects and high rent ability potential (even now in this area), no convenient either seeding or harvesting equipment is available for

Table 2. Situation in Grain Combine Harvesters (CH) in 1999

Regions	Areas under cereals (1000's ha)	Grain CH available (pcs.)	Actual seasonal use (ha/CH)	Normative seasonal use (ha/CH)	Need for CH according to the normative use (pcs.)	Need for additional CH supply (pcs.)
Total in Kyrgystan	562.2	3,561	158	112	5,056	1,568
Osh Region	105.7	668	158	110	961	293
Jalal-Abad Gegion	69.3	385	180	100	693	308
Chui Region	203.6	1,096	186	110	1,851	755
Issyk-Kul Region	90.5	631	143	115	787	156
Naryn Region	58.7	433	136	120	489	56
Talas Region	34.4	348	99	125	275	

small-scale farming. Moreover, the farming practices do not suit the principles of modern sugar beet growing (seed bed preparation, inter-row cultivation and irrigation).

Despite some sugar beet growing area reductions (due to privatization and pest infestations of fields) the area under this crop is still quite large. The technology used on large kolkhoz/sovkhoz fields (4-row or 6-row toppers and root lifters accompanied with root loaders) is not more compatible with small farmers' fields. Some few available units are old and highly worn out.

The actual number of sugar beet harvesters is: 236 root lifters and 192 toppers, which is 46% less than in 1986. The harvesting area per combine harvester increased by 1998 to 58 ha – some 1.62 times more than the harvesters actually can harvest due to their technical status. With regard to their reduced operational reliability and lack of repair services the daily harvester capacity cannot exceed 1.5 ha. On the average, each root lifter should work at least 39 days a season. Consequently, high harvest losses must be considered.

Forage Harvesters

The Kyrgyz forage harvester fleet is composed of machines of Russian (Bialorussian) make and self-propelled German units (former East German company Fortschritt and new Land- und Transport Technik). The last ones are heavy-duty usually equipped with crushing device. The majority of machines are flail or double chop type.

The forage/hay harvesting technology in Kyrghystan is also a very old one. Only 40% of harvesters are serviceable in the first quarter of 1999. Except for very good German harvesters, the harvesting performance is generally much reduced. Because of their very bed technical status (namely, cutter bar and chopping drums), their work is unreliable and of low quality (chopping length varies considerably). There is nearly a total impossibility to adjust a fine cut (cutoffs up to 5 mm). There are almost no spare parts for forage harvesters all over Kyrghystan. This is true particularly for German harvesters because of financial difficulties of former supplying company (Kyrghyzailkomok). For example: a credit of 5 millions DM from German Government (given to Kyrghyzailkomok Co.) had been partly spent to buy spare parts for German forage harvesters. These spares can hardly solve the problem because their price at the distributor (Kyrghyzailkomok) is very high and cannot be purchased by the end-users.

Table 3 reviews the availability of the most usual forage combine harvester makes and calculates alternatives of needs of additional units to cope with a quality forage (hay) harvesting.

Conclusions

1. There is lack of all kinds of agricultural machinery and equipment. The existing machineries are old and highly worn out and does not feature satisfactory operational reliability;
2. The situation in farm machinery inputs is particularly precarious at recently emerged private farmers' community, which is especially due to low purchasing power of the end-users;
3. The most precarious situation is the lack of draw-bar power, seeding and harvesting machines. Insufficient repair capacities and absence of management skills at the users (farmers) level are other constraints that make the situation more difficult;
4. Agriculture should get in the near future some 1,500 – 1,600 combine harvesters so that the cereal harvest is provided with sufficient harvesting capacity and

Table 3. Situation and Requirements in Forage Combine Harvesters (FCH) in 1999

Regions	Forage combines availability					The first cut of perennial grass		Forage combine capacity totally (ha/day)	Actual terms for the first cut fodder requirement	Requirements for additional FCH at alternatives of cutting period			
										for 10 working days		for 15 working days	
	KSK-100	E-281	Polesie	KPKU-75 and KPI-2.4	KUF-1.8	Totally within sason (ha/comb.)	Including for hay within season (ha/comb.)			KSK-100	KPI-2.4	KSK-100	KPI-2.4
Total in Kyrgystan	675	309	34	722	377	283.0	204.2	10,523	19	1,164	666	473	270
Osh	233	76	5		74	25.2	20.2	2,111	10				
Jalal-Abad	68	27	3	12	33	14.0	11.2	744	15	44	25		
Chui	113	108	10	421	119	96.0	76.8	3,648	21	470	269	172	98
Issyk-Kul	201	65	8	111	66	61.2	49.0	2,350	21	297	170	130	74
Naryn	39	15	6	108	58	55.7	22.3	1,026	22	140	80	54	31
Talas	21	18	2	70	27	30.9	24.7	644	38	213	122	117	67

NOTES:
1. Calculations were made on account of the fact that the first cut of perennial grass area for hay is 40% in Naryn Region and 80% in the rest of the country;
2. Daily harvester capacity: KCK-100 ... 6ha, E-281 … 6ha, "Polesye" … 7ha, KPKU-75 and KPI-2.4 … 4.5 ha, KUF-1.8 … 3ha.

harvesting losses are reduced;

5. The analysis proved that both the cotton pickers and sugar beet toppers and root lifters are not available in sufficient number. Being mostly of old (Soviet) design they feature low technological and reliability characteristics; and
6. Insufficient number of forage harvesting equipment makes forage (including hay) harvest very difficult. There are some 1,160 units of KSK-100 and 670 units of KPI-2.4 that are at present missed by Kyrgyz agriculture.

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Effect of Seating Attachment to a Power Tiller on Hand-arm Vibration

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Equipment and Power Input for Agriculture in Oman

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Abstract

Since 1970, the Sultanate of Oman has modernized agricultural production through the use of various inputs. Equipment and mechanical power are among the major inputs. Equipment input data for the 25-year period, 1976 to 2000, and census data indicating equipment and power input levels as in 1992/93 were been analyzed to determine what specific inputs have been made, assess the outcome of these inputs and to suggest ways of improving the use of equipment and power.

The results of the analysis show that 12 types of equipment were provided. Most of the field machineries are grouped as one. The major types are water pumps, pick-up trucks, tractors and sprayers. The trend in the inputs of pumps, tractors and sprayers and unit costs of these equipment for the period 1976 - 2000 were determined. The minimum level of tractor power input in terms of owner-operated tractors and grand total farm area in 1992/93 was 0.98 kW per ha. Mechanical services in the form of tractor hours were provided to the farmers. There had been a doubling of cultivated area for the period 1976 to 2000.

Suggestions on ways of improving the inventory recording, reporting, equipment and power application are presented.

Introduction

Since 1970, agricultural production in the Sultanate of Oman has been receiving a major thrust. The year was the start of an era of modernization in the country. For the past 30 years mechanized and irrigated agriculture have contributed to a successful economic and social development. This contribution has required inputs of equipment.

The Government of the Sultanate of Oman imported and distributed US$77 million (Rial Oman 30 million) worth of mechanically-powered agricultural machinery to farmers from 1977 to 1983 (Ampratwum, 1994), averaging about US$13 million a year. The input of power-driven equipment has influenced agricultural production activities and the increase of agricultural lands under cultivation. It is important to assess the performance of the equipment and power inputs in order to produce information that will guide future inputs.

The Oman statistical yearbooks (Oman Directorate General of National Statistics, ODGNS, 1973-1977, 2001), Arab agricultural publications (Arab Agriculture, 1991 and 1992) and the results of the 1992/93 Agricultural Census (Oman Ministry of Agriculture and Fisheries, OMAF, 1992/93) provide some data on agricultural equipment input. The data need to be analyzed and inferences drawn.

This paper reports on the analysis of the available equipment and power input data. The analysis was aimed at determining what specific inputs were made and their outcome with the end in view at making suggestions to improve equipment and power application.

Objectives of Analysis

The specific objectives of the equipment and power input data analysis are to:

1. Determine the range and trend of agricultural equipment input;
2. Assess the level of tractor power input to agricultural production and how the input has affected productivity;
3. Assemble equipment cost data essential for equipment cost analysis;
4. Determine the magnitude of mechanical services offered to farmers; and
5. Suggest on more relevant ways of input inventory keeping and ways of improving equipment application.

Literature Review

The introduction of power and machinery between man and materials in an agricultural production system is essential for the success of agriculture. In the process, mechanical and electric power-driven machinery is applied for the improvement of land, hence the economic production of crops. The importance of the application of equipment lies in replacing manual labor, improving labor productivity, increasing efficiency in operations, enabling economic production, reducing drudgery in operations and improving product quality (Goering, 1992; Srivastava, et al., 1993).

Positive correlation between yield and power input to crop production (Giles, 1975 cited by Owende and Ward, 1999), indicates the inherent advantage of increasing available power. A minimum disposable power of 0.75 kW per ha has been recommended (Davie, 1973 quoted by Owende and Ward, 1999). The total available power for agriculture in Arab countries is estimated at about 0.15 kW per ha (FAO, 1982 quoted by Sabah, 1990). In India, farm power availability in 1997 was 0.986 kW/ha, 81% of which was provided by mechanical power units mainly tractors (Singh and De, 1999). In the USA, a farmer uses about 3 kW/ha in a plowing process (Kepner et al., 1982). The tractor is a major power unit used in agricultural production. A study of field power and equipment trends in agricultural production in Kenya indicates the dominance of 30 - 60 kW tractors (Owende and Ward, 1999). The extent of cultivated land in Oman in the early 1970s was about 30,000 ha. In an effort to encourage greater cultivation of land in Oman, 55 tractors were supplied to agricultural farms between 1970 and 1975, 35 in 1971 and 20 in 1974 (ODGNS, 1973 – 1997, 2001). Tractor sizes in Oman range mostly from 30 - 80 kW (Ampratwum, 1994).

Equipment Input Data Analysis

The Oman Directorate General of National Statistics is responsible for compiling and publishing data on various aspects of the economy. Data on number and value of agricultural equipment distributed to farmers, hours of tractor services provided to farmers and on areas of cultivated land are compiled (ODGNS, 1973 to 1997, 2001; Arab Agriculture 1991, 1992). Results of the 1992/93 Agricultural Census including data on type, ownership or source and number in use, of agricultural equipment and on various areas of cropped land as in 1992/1993 are also available (OMAF, 1992/93).

The data were collected, examined and analyzed. The analysis was carried out for a period of 25 years starting in 1976, the year that marks the start of the first five-year development plan period (1976 - 1980) when the agriculture sector started receiving major inputs of agricultural equipment. The analysis of the census data focused on the position of inputs at the beginning of the fourth five-year development plan period (1991 - 1995).

Results of Analysis

The various types of equipment employed in agricultural production are catalogued in the 1992/93 agricultural census, namely; tractors, pickup trucks, trailers, lorries, carts, combine harvesters, hay equipment, sprayers, hatching chambers, electric and engine-powered water pumps and other farm machineries. The types, number and source of equipment used are shown in **Table 1**. The distribution of owned and rented equipment is shown in **Figs. 1a and 1b**. The distribution of farm holdings and land areas for the various types of equipment in 1992/93 is shown in **Table 2a**. The grand total area for all farm holdings by 1992/93 was estimated at 60672 ha. The calculated values from the data in **Table 2a**, namely; total number of equipment per holding, total or cropped area per holding or per equipment, percent cropped area, and total or cropped area as percent of grand total area, are presented in **Table 2b**. The distribution of holdings and land areas for various types of equipment are shown in **Fig. 2**. The number of tractors used on various land areas is given in **Table 3**. Calculated percent owned or rented equipment and total number of equipment as percent of grand total are also shown in **Table 3**. The distribution of tractors (total number and percentage) for various land ar-

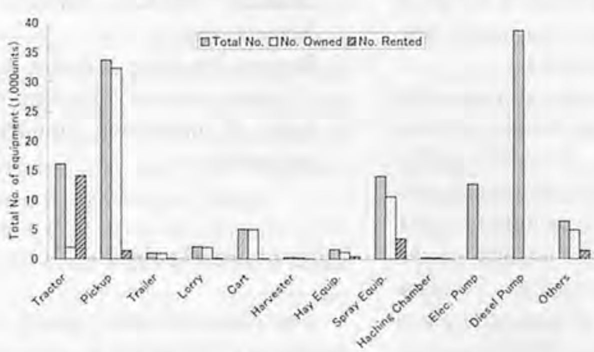

Fig. 1a Distribution of farm equipment.

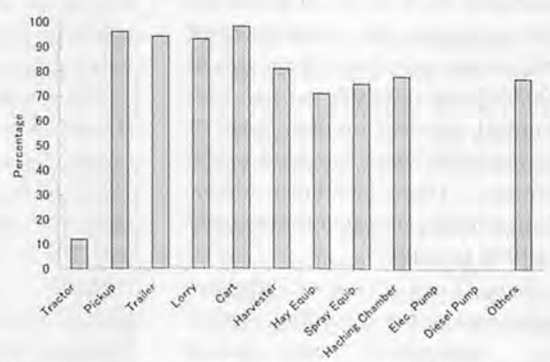

Fig. 1b Percent distribution of owner-operated farm equipment.

Table 1. Distribution of Agriculture Equipment, 1992/93

Type	Number		Percent owned	Number rented	Percent rented
	Total	Owned			
Tractor	16,114	1,977	12	14,137	88
Pickup truck	33,732	32,301	96	1,431	4
Trailer	1,036	970	94	66	6
Lorry	2,106	1,959	93	147	7
Cart	5,092	5,007	98	85	2
Combine harvester	289	234	81	55	19
Hay equipment	1,659	1,171	71	488	29
Spray equipment	14,012	10,533	75	3,479	25
Hatching chamber	253	198	78	55	22
Electric water pump	12,647	-	-	-	-
Diesel/petrol water pump	38,710	-	-	-	-
Others	6,402	4,936	77	1,466	23

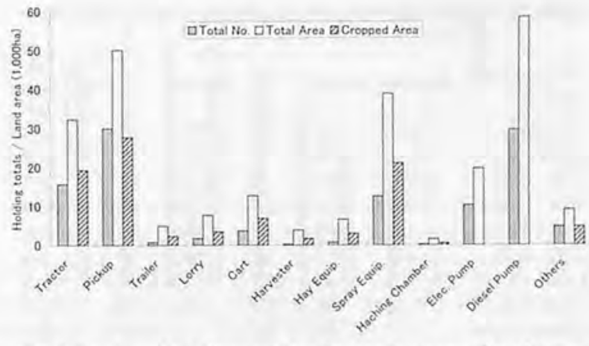

Fig. 2 Profile of holdings and land areas, by type of equipment.

Table 2a. Holdings and Land Areas for Various Types of Equipment, 1992/93

Type	Total number	Number of holdings	Cropped area (ha)	Total area (ha)
Tractor	16,114	15,699	19,338	32,337
Pickup	33,732	30,034	27,750	50,121
Trailer	1,036	793	2,347	4,960
Lorry	2,106	1,768	3,528	7,718
Cart	5,092	3,738	6,951	12,760
Combine harvester	289	208	1,759	3,917
Hay equipment	1,659	780	3,023	6,652
Spray equipment	14,012	12,624	21,140	38,973
Hatching equipment	253	174	605	1,561
Electric water pump	12642	10,334	-	19,763
Diesel/petrol water pump	38,710	29,749	-	58,510
Others	6,402	4,742	4,765	9,135

Table 2b. Calculated Values from Data in Table 2a.

Type	Total No. per Holding	Total Area ha per Holding or Equipt.	Croppped Area ha per Holding or Equipt.	Percent Cropped Area	Total Area as % of Grand Total Area	Cropped Area as % of Grand Total Area
Tractor	1	2.1	1.2	60	53	32
Pickup	1	1.7	0.9	55	83	46
Trailer	1	6.3	3.0	47	8	4
Lorry	1	4.4	2.0	46	13	6
Cart	1	3.4	1.9	54	21	11
Combine	1	18.8	8.5	45	6	3
Hay equipment (harvester and baler)	2	4.2	1.8	45	11	5
Spray equipment	1	3.1	1.7	54	64	35
Hatching equipment	1	9.0	3.5	39	3	1
Electric water pump	1	-	-	-	33	-
Diesel/petrol water pump	1	-	-	-	96	-
Others	1	1.9	1.0	52	15	8

eas are shown in **Figs. 3a** and **3b**.

The distribution of tractors, water pumps and sprayers provided to farmers from 1976 to 2000 and their unit values are shown in **Tables 4a** and **4b**, respectively. The provision of sprayers and water pumps ceased in 1999 and 2000, respectively. The distribution of equipment provided to farmers in various 5-year periods up to 1995 is shown in **Fig. 4**. Tractor services have also been provided to farmers. The number of tractor hours provided by the Ministry of Agriculture and Fisheries from 1976 to 1998 are shown in **Table 5**. The distribution of tractor services provided in various 5-year periods up to 1995 are shown in **Fig. 5** whose total hours of operation averaged 55,848 hours per annum between 1976 and 1995. This figure declined sharply to 9,259 hours per year in 1996, 1997 and 1998.

The total area under cultivation in 1975 was 36,000 ha that increased to 72,835 ha by the end of the year 2000. The data on cultivated areas from 1975 to 2000 together with corresponding number of tractors and calculated yearly values are shown in **Table 6**. In **Fig. 6** tractor inputs are contrasted with cultivated areas from 1976 to 2000.

As indicated by the inventory of farm equipment stated earlier, there had been a wide range of distribution and use for agricultural production. The most dominant equipment input is electrical and engine-powered water pumps reflecting their great need in an arid region. This is followed by pickup trucks, tractors and sprayers in that order. Though not indicated in the census data, it may be assumed from the ownership proportion that the pumps were all owner-operated. Ninety-six percent of the pickup trucks and 75% of the sprayers were owned by the farmers. Only 12% of the tractors were owner-operated against 88% which were rented.

From the numbers of holdings reporting on various equipment inputs (**Table 2a**) there is one piece of equipment per holding except for hay equipment (**Table 2b**). The two units of hay equipment shown per holding may actually consist of forage harvester and hay baler. Various land areas with an equipment ranged from 1.7 ha total area

Table 3. Distribution of Farm Tractors by Size of Holdings, 1992/93

Cropped Land Area, ha	Total No.	Owned	%	Rented	%	Total No. as % of Grand Total
< 0.004	685	126	18	559	82	4.3
0.004 - 0.41	5,698	376	7	5,322	93	35.4
0.42 - 0.83	3,501	300	9	3,201	91	21.7
0.84 - 2.09	4,007	478	12	3,529	88	24.9
2.10 - 4.19	1,466	300	20	1,166	80	9.1
4.20 - 8.39	418	125	30	293	70	2.6
8.40 - 12.59	88	46	52	42	48	0.5
12.60 - 16.79	42	26	62	16	38	0.3
16.80 - 20.99	37	30	81	7	19	0.2
21.00 - 41.99	51	49	96	2	4	0.3
42.00 - 83.99	16	16	100	0	0	0.1
84.00 +	105	105	100	0	0	0.7
Grand Total	16,114	1,977	12	14,137	88	100.0

Table 4a. Equipment Distributed to Farmers in Every Five Years

Period	Tractors	Water pumps	Sprayers
1976 - 1980	446	2,388	2,604
1981 - 1985	641	3,598*	8,675
1986 - 1990	108	986	4,656
1991 - 1995	296	256	3,490
1996 - 2000	280**	16***	-

* Data for 1983 – 1985.
** Excludes input for 1998.
***Data for 1996 only.

Table 4b. Unit Value of Equipment Distributed to Farmers (Unit: US dollar)

Period	Tractors	Water pumps	Sprayers
1976 - 1980	**	1,184	85
1981 - 1985	1,976*	921*	136
1986 - 1990	9,982	2,255	317
1991 - 1995	12,294	2,309	330
1996 - 2000	1,677	2,903#	-

* Data for1983 – 1985 only.
** Data not available.
\# Data for 1996 only.

Table 5. Tractor Services Provided to Farmers in Oman

Period	No. of tractor hours	Average No. of tractor hours/year
1976 - 1980	243,232	48,646
1981 - 1985	370,753	74,151
1986 - 1990	353,744	70,749
1991 - 1995	149,225	29,845
1996 - 1998	27,775	9,259

Table 6. Area under Cultivation and Corresponding Number of Tractors

Year/period	Total area, ha	Increase in area, ha	Yearly increase, ha	No. of tractors distributed to farmers	Yearly tractor input
1975	36,000				
1980	41,024				
1976-80		5,024	1,005	446	90
1982	42,278				
1981-82		1,254	627	216	108
1985	53,586				
1983-85		11,308	3,769	425	142
1988	55,756				
1986-88		2,170	723	37	13
1990	58,310				
1989-90		2554	1,227	71	36
1992	67,565				
1991-92		9,255	4,628	235	118
1993	68,020				
1993		455	455	48	48
1995	68,640				
1994-95		620	310	13	7
1996	69,103				
1996		463	463	10	10
1997	70,202				
1997		1,099	1,099	8	8
1998	72,329				
1998		2,127	2,127	142	142
2000	72,835				
2000		506	506	120	120
Total		36,835		1,771	

and 0.9 ha cropped area for pickup truck to 18.8 ha total area and 8.5 cropped area for combine harvester (**Tables 2b**). For a tractor the figures are 2.1 ha total area and 1.2 ha cropped area. These area values correspond to cropped land area associated with the greatest number of owner-operated tractors (**Table 3**). The second highest number of rented tractors is also associated with this range which is 0.84 - 2.09 ha. The range for the highest number of rented tractors is 0.004 - 0.41 ha. Eighty-six percent of the total number of tractors is associated with cropped land areas of up to 2.09 ha. This consists of 78% for rented tractors and 8% for owner-operated tractors.

The trend in equipment inputs over a 25-year period (1976 - 2000) is indicated by the number of tractors, water pumps and sprayers distributed to farmers. The input peaked during 1981 - 1985 (**Table 4a** and **Fig. 4**). After this period the input of water pumps and sprayers declined. The input of tractors declined after the peak period until 1990 when the number of inputs started to rise again until 1995. The lack of tractor input in 1998 resulted in a slight decline by the year 2000. By the end of 1992, 75% of owner-operated tractors in the country was equivalent to the number of tractors distributed to farmers by the government up to that period.

The level of tractor power input in terms of owner-operated tractors with average output of 30 kW and grand total area of holdings was 0.98 kW per ha in 1992/93. This is higher than the recommended minimum disposal power of 0.75 kW per ha.

The unit cost of tractors, water pumps and sprayers increased considerably from a low level in the first decade (1976 - 85) to a higher value in the second decade (1986 - 95) (**Table 4b**). The average unit values for the decade 1986 - 95 were US$11370, US$2265 and US$ 323 for tractors, pumps and sprayers, respectively. These figures are 6 times, twice and 3 times the values for tractors, pumps and sprayers, respectively from 1976 to 1985. The unit cost of tractors for 1996 to 2000 is at a level similar to that for 1983 – 85.

The area under cultivation increased from 36,000 ha in 1975 to 72,835 ha in 2000 representing a doubling of the 1975 figure. In the same period, 1,771 tractors were distributed to farmers. The three highest yearly increases in hectares

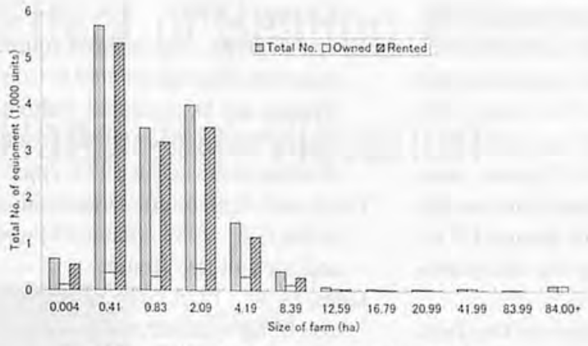

Fig. 3a Distribution of tractors, by farm sizes.

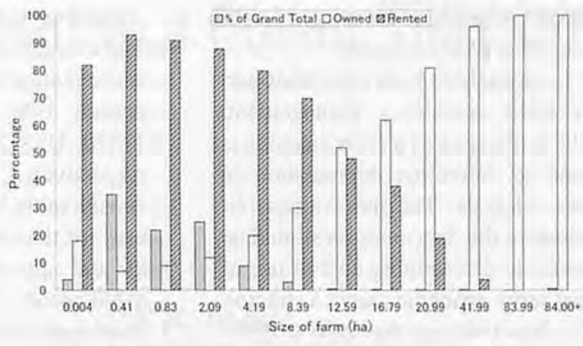

Fig. 3b Percentage of tractors used, by farm sizes.

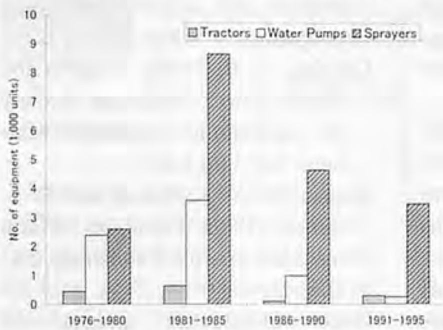

Fig. 4 Distribution of equipment provided to farmers, 1976-1995.

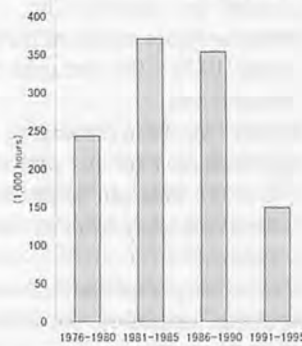

Fig. 5 Trend in tractor hour utilization.

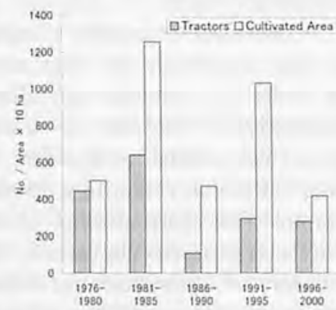

Fig. 6 Comparative tractor numbers and cultivated areas (× 10ha) 1976-2000.

were in 1983-85, 1991-92 and 1998. These coincided with the years when the largest numbers of tractors were distributed (**Table 6**). There is a positive relationship (r = 0.70) between tractorization and more land being cultivated.

The total number of equipment in a country has commonly been the main inventory figure used as index of the level of farm machinery use. However, such an index has its limitations since it does not indicate the sizes of equipment, type of usage and extent of on-farm application as a percentage of total annual use. A better index is that of units of power input, that is, kW per unit area of arable land (Sabah, 1990). To be able to calculate such an index and provide performance data on equipment, kilowatt levels of power units and sizes of field machinery should be recorded during inventory keeping and reporting.

As agriculture develops it becomes increasingly dependent on equipment to sustain production. Equipment-related expenditures may be the greatest single item in a modern farm's production costs.

In order to improve equipment and power use the following should be observed:

1. Defining the equipment use needs in the country;
2. Selecting the available equipment that best meets these needs;
3. Providing adequate servicing facilities and making spare parts more readily available; and
4. Stabilizing equipment prices to enable improved equipment use and cost management.

Discussion of Results

The average farm size in Oman is 2 ha. The low tractor ownership level of 12% indicates that there are prospects for greater purchase of tractors by farmers. However, the small farm size makes ownership uneconomical and has resulted in a high level of tractor hiring.

The existence of one piece of equipment per holding is to be expected since the census data are from holdings which report usage of equipment reflecting usage rather than ownership. However, the high input and owned proportion of pickup trucks indicates that almost every farm had one whose usage may not be limited to farm production activities.

The decline in the number of water pumps seems to have been the result of initiating the establishment of centrally controlled water use systems during the fourth five-year plan period 1991 - 95 (OMAF, 1990). However, farmers might have acquired water pumps themselves. A similar decline in the distribution of sprayers might have been due to purchases by farmers themselves. The distribution of water pumps, sprayers and tractors to farmers was carried out through the Oman Bank for Agriculture and Fisheries which started operations in 1981 (OMAF, 1990) under subsidized and soft-loan scheme by the Government. The level of calculated tractor power input is a conservative estimate due to the low value of the range of tractor power in the country.

Cost analysis is an important part of farm machinery management. The initial cost of a farm machine is used to determine depreciation in cost analysis. The unit values obtained in the data analysis should be useful in determining cost of use of the farm machine, say, a tractor. The low unit cost for 1976 to 1985 and 1996 to 2000 are likely to be subsidized values.

A considerable number of inputs of farm equipment has been made in order to promote agricultural productivity. The use of tractor power has resulted in doubling the area under cultivation in a 25-year period. The sharp decline in the provision of tractor services by the Ministry of Agriculture and Fisheries from 1996 to 1998 indicates a phasing out of such provision of machinery services by the Ministry.

Conclusion

Farm equipment input data for the 25-year period, 1976 to 2000 and census data indicating farm machinery and power input levels as in 1992/93 were analyzed the results of which show the following conclusions:

1. A wide range of farm equipment inputs has been provided to agricultural productivity. The range includes 12 types of equipment such as water pumps, pickup trucks, tractors and sprayers;
2. The trend in the number of pumps, tractors and sprayers for the period 1976 - 2000 reached a peak in 1981 - 85. After 1985 the number of water pumps and sprayers declined. The tractor input declined until 1990 and rose again to reach another peak in 1995;
3. The level of tractor power input in terms of owner-operated tractors in 1992/93 was 0.98 kW per ha. This is higher than recommended minimum disposable power of 0.75 kW per ha for increased agricultural productivity;
4. The average unit cost of tractors, water pumps and sprayers for the decade 1986 - 95 were US$ 11370, US$ 2265 and US$ 323, respectively. The figures were considerably higher than the figures for the earlier decade 1976 - 85 and appear to be non-subsidized costs;
5. Machinery services in the form of tractor hours have been provided to farmers. The annual tractor hours provided for the period 1976 - 95 averaged 55,848 hours; and
6. There has been a doubling of cultivated area for the period 1976 to 2000. This can be attributed to the availability of farm mechanization.

In order to improve further use of farm mechanization, the followings are suggested:

a. The recording of the capacity of power units in kilowatts and the sizes of field machineries during inventory keeping and reporting should be observed;
b. The farm equipment and power use needs of the country should be defined;
c. Available farm machineries that best meet these needs should be selected;
d. Adequate service facilities should be provided;
e. Spare parts should be made more readily available; and
f. Farm machinery prices should be stabilized.

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Effect of Seating Attachment to a Power Tiller on Hand-arm Vibration


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Abstract

Vibration characteristics were studied in transportation and rotatilling operation in I-Low, II-Low and III-Low gears at engine speeds of 1600, 1700, 1800, 1900, and 2000 rpm. Tests were conducted in the experimental farm of Agricultural and Food Engineering Department, Indian Institute of Technology, Kharagpur, India. It was found that vibration intensity was more in vertical direction than in longitudinal direction and in all cases vibration intensity was maximum in transportation followed by rotatilling and puddling. Seating attachment has improved exposure time to a maximum level of 69 % in transportation for 30 percentile of exposed population and 42.8 % for 40 percentile of exposed population in rotatilling.

Introduction

Agricultural farm mechanization is the most important tool in meeting the demand of a rapidly growing population of India. For increasing cropping intensity from 130% to about 170% in the next 25 years to compete with the population outburst, the power availability on farm will have to be increased from its present level of 1.08 kW/ha to about 2-2.5 kW/ha mainly through mechanical sources (Singh, 1997). The small land-holding size and scattered location of farms has been an inhibiting factor in the efficient utilization of four-wheel sized big tractors in rice growing regions. Rather, it emphasizes the use of small size power tillers. It appears that only 2 % of the operational holdings are in the size group of 10 ha or more, whereas the area operated under the size group of 1 ha or less is (marginal) as high as 65 % (Singh, 1996). In all these contexts, power tillers are the most appropriate in Indian agriculture.

The versatility of the power tiller can be seen in it's operation of tilling, puddling, harvesting, water pumping, threshing, plant protection and transportation. Because of it's diversified application, the power tiller can be used as an alternative power source. In regard to economical and income generating aspects, it can be used as replacement for bullock power. Power tiller farming system gave a benefit cost ratio of 2.3 as against 2.08 with tractor farming system, mainly because of increased crop yield due to better quality of puddling and less water loss through percolation and lesser weed growth (Tiwari, 1997).

With the advent of technology, much consideration is given to the human factors or ergonomical aspects of the operator while using different tools and equipment. The operator has to walk 15-20 km for rotatilling a hectare of land by 0.6 m width tyne (Mehta, 1997). To achieve more work output with desired efficiency, it is required to design tools, equipment and machines in favor of the operator's safety and comfort. Vibration is one of the major factors of drudgery in power tiller operation. It has been observed that in conventional power tiller or walking type tractor, intensive vibration is transmitted to the operator through the handles.

These perceived vibrations are a source of discomfort and reduced operator's efficiency. Vibration exposure to hand often produces a disease in hands known as '*Raynaud's Phenomenon of Occupational Origin*' or vibration induced white finger (vibration syndrome), a finger disorder (Reynolds, 1977). Hand-arm vibration causes vascular disorders, bone and joint disorders, peripheral neurological disorders and muscle disorders, etc. Hand-arm vibration may reduce sensations in controlling by the operator's fingers. Vibration directed into the hand can be felt all the way up to the shoulder and progressively becomes more localised to the hand and then to the fingers. To improve the comfort in operation and to increase work efficiency, a seat (**Fig. 1**) has been designed from ergonomic considerations.

The nature of the energy directed into the hand is a function of direction of vibration. For constant displacement amplitudes, the instantaneous energy supplied to the hand in the lateral direction is less than the corresponding energy directed into the hand for the vertical and longitudinal directions (Reynoulds, 1977). According to the present study (Karmakar, 1998), vibration intensity was measured in vertical and longitudinal directions.

The vibration of a power tiller system is very complex and at any location, several predominant frequencies could be observed (Salokhe, 1995). Hence, much emphasis was not given to frequency measurement; only the vibration intensity was observed.

This paper deals with the values of hand-arm vibration in two different orthogonal directions (longitudinal: Z_h and vertical: X_h) in three operating conditions, viz., transportation on tar-macadam road, rotatilling on hard surface and puddling in lowland with and without seat and their effect on operator's physiological and operational behavior.

Methodology

In this investigation, experiments were conducted on a KAMCO-Diesel power tiller. For measurement of vibration intensity, the orientation of the co-ordinate system (**Fig. 2**) has been followed as suggested by ISO 5349-1986 (E) with reference to an appropriate basicentric coordinate system (ISO, 1986).

The seat assembly comprises of a seat pan and supporting structure. The seat pan is made of steel sheet strong enough to support the weight of the operator. A leaf spring supports the seat, which acts as a shock absorber. It has a small backrest of 20 cm high with seat depth of 36 cm.

The experiments were conducted for transportation on tar-macadam road, rotatilling on hard surface and rotapuddling in lowland condition with and without seating attachment. For transportation and rotatilling, pneumatic wheel inflation was kept as 1.5 kg/cm^2. The 'C-type' tyne was used for rotatilling and 'L-type' for rotapuddling. A skilled power tiller operator was used as the subject of all sets of experiments in field.

The vibration intensity was measured by an Integrating Vibration Meter with piezo-electric accelerometer. Observations were taken in terms of root mean squared (r.m.s) value. For taking vibration measurements according to the standard ISO 5349-1986 (E), a clamp was devised and mounted at the middle of the handle grip. Vibration intensity was observed as weighted r.m.s. acceleration.

Experiments were conducted in the low gears of I, II and III (L_1, L_2 and L_3, respectively) at the engine angular speeds of 1600, 1700, 1800, 1900 and 2000 rpm in transportation on tar-macadam road, rotatilling on hard surface and puddling in lowland with and without seating attachment.

Vibration Evaluation

The assessment of vibration exposure is primarily based on daily

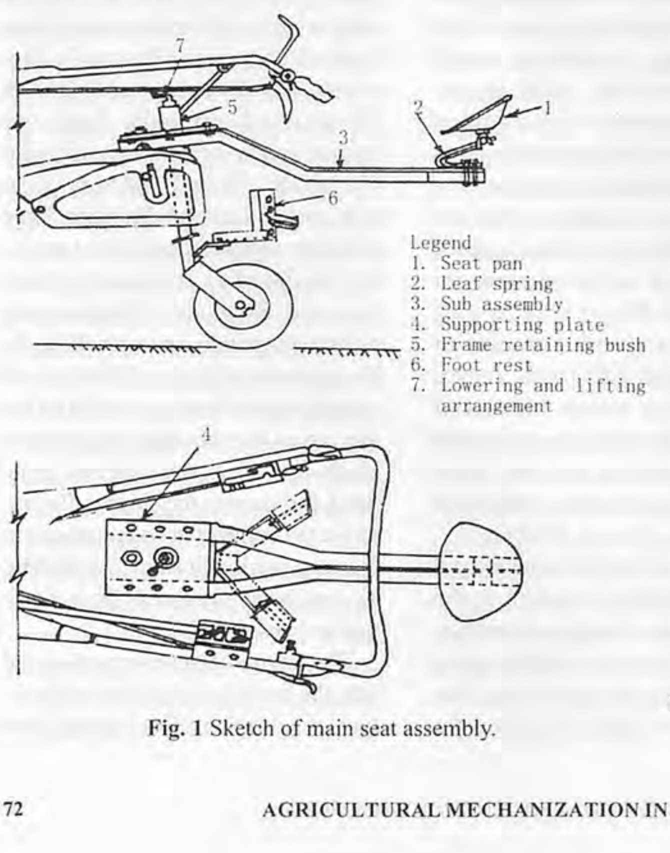

Fig. 1 Sketch of main seat assembly.

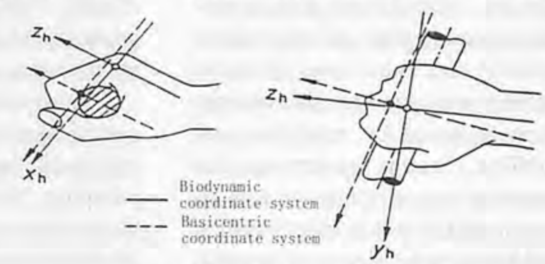

Fig. 2 Sketch of handgrip position.

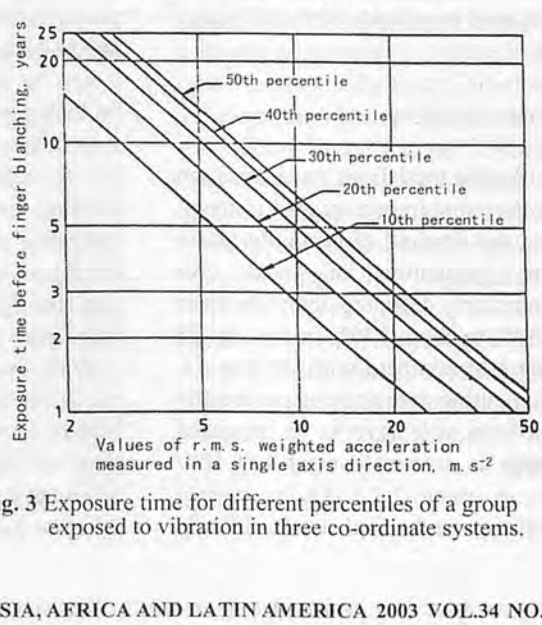

Fig. 3 Exposure time for different percentiles of a group exposed to vibration in three co-ordinate systems.

exposure. The dose-effect relationship used for evaluation was in terms of frequency-weighted-energy-equivalent acceleration in (**Fig. 3**) which shows the duration of exposure necessary before the vascular symptoms, characterized by finger blanching as a function of r.m.s. weighted acceleration, for selected percentiles of an exposed population.

In order to facilitate comparisons among different durations of exposure, the daily exposure was expressed in terms of energy equivalent frequency weighted acceleration for a period of four hours. If the total daily exposure to vibration is other than 4 h, the energy equivalent acceleration for a period of 4 h was determined by the integration of the square of frequency weighted acceleration over the whole of the daily exposure. This was determined by the following relationship (ISO –5349):

$$[a_w]_{eq(4)} = [1/T_4 \int_0^\tau \{a_w(t)^2\, dt\}]^{1/2}$$

where,

$[a_w]_{eq(4)}$ is energy equivalent acceleration for a period of 4 h, metres per second squared.

$a_w(t)$ is the instantaneous value of weighted acceleration;

τ is the total duration of the working day, hr;

T_4 is 4-hour duration of work.

Results and Discussion

Effect of Forward Speed

The variations in hand-arm vibration intensity (acceleration, r.m.s level) with change in forward velocity in different operating conditions are shown in **Figs. 4** and **5**. For transportation (**Fig. 4**) and rotatilling (**Fig. 5**), it is seen that with an increase in forward velocity, vibration intensity first decreased and then increased at a particular gear setting. The minimum vibration intensity was observed at the velocity equivalent to engine speed of 1750 to 1850 rpm. This trend may be attributed to the dynamic vibration absorption. Also, in these two operating conditions vibration intensity was be minimum in all respects in the II-Low speed.

Effect of Seating Attachment

The effect of seating attachment on vibration intensity is shown in **Fig. 6** suggesting that in all the operation conditions, vibration intensity was less with a seating attachment than without the seat attachment.

In all cases the vibration intensity is greater in the vertical direction (X_h) than that in longitudinal direction (Z_h). There was no appreciable

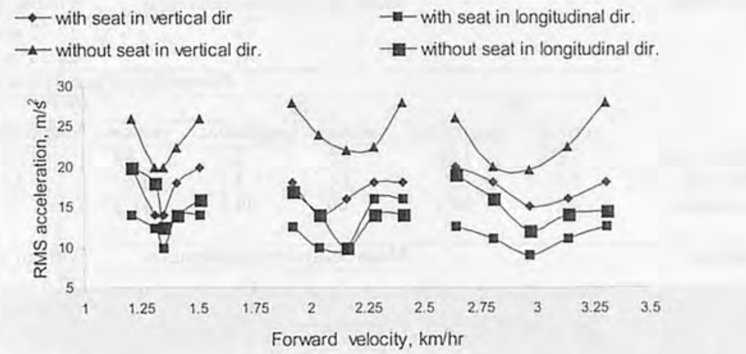

Fig. 4 Effect of forward velocity on vibration intensity in vertical and longitudinal directions with and without seat in transportation.

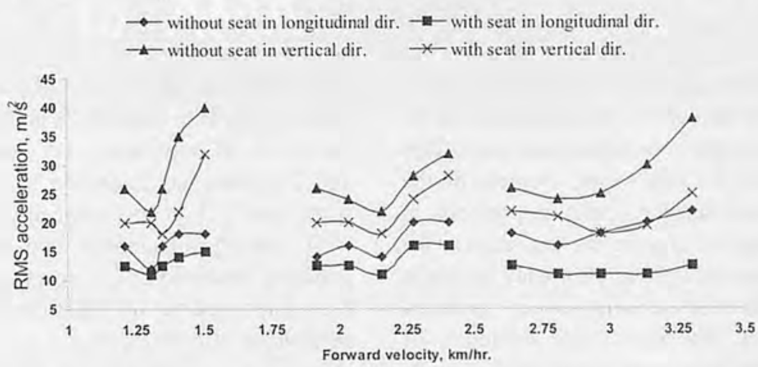

Fig. 5 Effect of forward velocity on vibration intensity in vertical and longitudinal directions with and without seat in rotatilling on undisturbed field.

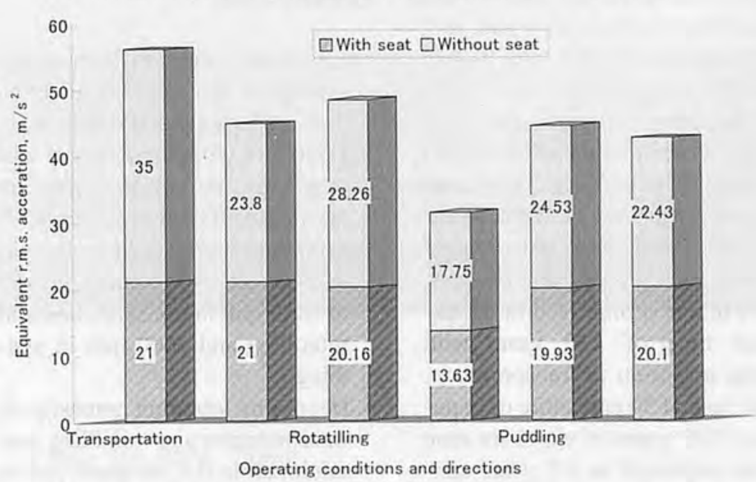

Fig. 6 Variation of vibration intensity with and without seating attachment in vertical and longitudinal directions.

Table 1. Exposure Time before Finger Blanching for Different Percentiles of Population Group Exposed to Vibration

Operation	Exposure time (years)									
Transportation				Mean equivalent acceleration		Without seat		With seat		
				Z_h		23.8 m/s^2		21 m/s^2		
				X_h		35 m/s^2		21 m/s^2		
	Percentiles of population exposed									
	10		20		30		40		50	
	vertical	longitudinal	vertical	longitudinal	vertical	longitudinal	vertical	longitudinal	vertical	longitudinal
Without seat	0.85	1.06	1.21	1.5	1.48	1.84	1.72	2.12	1.92	2.4
With seat	1.43	1.43	2.02	2.02	2.5	2.5	2.86	2.85	3.2	3.2
% increase	68	35	67	34.6	69	35.8	66.2	35	66.6	33.3
Rotatilling				Mean equivalent acceleration		Without seat		With seat		
				Z_h		17.75 m/s^2		13.63 m/s^2		
				X_h		28.26 m/s^2		20.16 m/s^2		
	Percentiles of population exposed									
	10		20		30		40		50	
	vertical	longitudinal	vertical	longitudinal	vertical	longitudinal	vertical	longitudinal	vertical	longitudinal
Without seat	1.06	1.69	1.5	2.4	1.84	2.9	2.1	3.4	2.37	3.8
With seat	1.5	2.2	2.6	3.1	2.6	3.8	3	4.4	3.3	5
% increase	41.5	30.2	40	29.2	41.3	31	42.8	29.4	39.2	31.6
Puddling				Mean equivalent acceleration		Without seat		With seat		
				Z_h		22.43 m/s^2		20.1 m/s^2		
				X_h		24.53m/s^2		19.93 m/s^2		
	Percentiles of population exposed									
	10		20		30		40		50	
	vertical	longitudinal	vertical	longitudinal	vertical	longitudinal	vertical	longitudinal	vertical	longitudinal
Without seat	1.22	1.34	1.73	1.9	2.12	2.32	2.45	2.67	2.7	3
With seat	1.5	1.49	2.13	2.11	2.6	2.6	3	2.9	3.4	3.34
% increase	23	11.2	23.1	11	22.6	12.2	22.4	8.6	26	11.3

difference between vibration intensity in vertical and longitudinal directions in puddling operation. This may be due to the wetness of the field surface, causing problem in forward movement and reason for less vertical vibration may be due to vibration absorption in puddled soil. The percentage reduction of vibration intensity due to the incorporation of the seat in vertical and longitudinal directions are 40 and 29 in transportation, 29.3 and 23.2 in rotatilling and 18.5 and 10.4 in puddling, respectively.

Comparing the average r.m.s weighted acceleration (**Fig. 6**) with the standard graph (**Fig. 3**), without the seat, 10 percentile of the working population will have finger blanching within 0.85 year of exposure while it is improved to the exposure time of 1.43 years with seating provision in transportation. In the case of 50 percentile of population, 1.92 years of exposure time can be improved to 3.2 years considering the worst exposure to vertical direction. For rotatilling operation without the seat, the restricted exposure time for 20 and 50 percentile of population, 1.5 years and 2.4 years has improved to 2.1 years and 3.3 years, respectively, with seating attachment and for puddling operation, 2.7 years has been improved to 3.4 years for 50 percentiles of population.

Conclusions

1. Hand-arm vibration intensity is greater in the vertical direction than the longitudinal direction.
2. Hand-arm vibration intensity was maximum in transportation on tar-macadam road in all cases.
3. Minimum vibration intensity was at the engine speed range of 1750 to 1850 rpm in transportation and rotatilling and 1600 rpm in puddling.
4. Hand-arm vibration intensity in transportation and rotatilling was minimum in II-Low speed and in puddling in III-Low speed.
5. The seating provision reduced vibration intensity 40 and 29 % in transportation, 29.3 and 23.2 % in rotatilling and 18.5 and 10.4 % in puddling operation in vertical and longitudinal directions.
6. The seating attachment improved the exposure time to a maximum of 69 % in ransportation for 30 percentile of exposed population, 42.8 % for 40 percentile of exposed population in rotatilling and 26 % for 50 percentile of population puddling operation.

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ABSTRACTS

The ABSTRACT 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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Sorting Tomatoes According to Colours Using Optical System. **Levent Taseri**, Research Assistant, Department of Agricultural Machinery, Faculty of Agriculture, University of Trakya, Tekirdag, TURKEY. **Bülent Eker**, Professor of the same.

This research aimed at manufacturing a prototype machine for colour classification used in the standardisation of tomatoes in Turkey. The machine consists of five sub-units, namely; a band conveyor, a lighting system, a directing mechanism, an optic-electronic system and a computer unit. These units were assembled and organized as a whole system and tested as one unit.

The system is capable of sorting into two colours of tomatoes: red and green. In order to grade the surface colours or ripeness rate of the tomatoes, the accuracy in colour sorting was calculated. The average accuracy in colour sorting was 75%.

Further development of the system is needed to increase the capacity.

149

Paddy Transplanting – a Thirst Area for Farm Mechanization in West Bengal State, India. **S. Karmakar**, Lecturer, Department of Farm Machinery and Power, Faculty of Agricultural Engineering, BCKV, Mohanpur, West Bengal, 721 302, INDIA.

Appropriate machinery is required for ensuring timely field operations and effective application of various crop production inputs utilizing human, animal and mechanical power sources. A suitable machine also reduces drudgery in farming besides being cost effective and eco-friendly. West Bengal State, though significantly contributes to the national agricultural production, does not stand in a perspective way in agricultural mechanization, the application of which could utilize the natural resources. Rice production in West Bengal is mostly traditional. Rice is the staple food for Begalis which is grown in three seasons in the state. Since time immemorial, paddy seedlings are manually transplanted which is a time-consuming and strenuous job. In developing India, farm mechanization is being given much consideration, and West Bengal should not lag behind. In this paper, efforts are made to promote the mechanizing paddy transplanting.

152

Eeffects of Tire Type, Size and Pressure on Traction for Tillage Operations in Cambodia. **S. Om**, Research Assistant, Cambodian Agricultural Research and Development Institute, PO Box 1, Phnom Penh, CAMBODIA. J. N. Tullberg, Senior Lecturer, Crop Production Technology University of Queensland Gatton Campus, Lawes, Qld, 4345 AUSTRALIA. J. F. Rickman, Head, Agricultural Engineering Unit, International Rice Research Institute, Los Banos, Laguna, PHILIPPINES.

The tractive performance of common rear tire options was evaluated under four surface conditions typical of those encountered in rice production on the sandy soils of Cambodia. Three different tires -- radial and bias ply of the same nominal size, and an oversize bias ply of 10% greater dimensions -- were tested at three levels of inflation pressure and constant tractor weight. Using coefficient of traction (CT) as the criterion of performance, the greatest traction always occurred at the lowest tire pressure, but the effect of inflation pressure was reduced in firm (untilled dry) and very soft wet conditions. Radial ply tires provided better traction than bias ply tires of the same dimensions in all except wet untilled conditions. Radial ply tires were also slightly superior over the oversize bias ply tires in dry conditions, and noticeably better in wet conditions. Oversize bias ply tires were better than the standard bias ply tires in dry conditions but the effect was reversed in wet conditions. The difference between tire types and sizes was less pronounced in dry, firm conditions.

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Mechanization of Rice Production in Sierra Leone. **N. G. Kuyembeh**, Njala University College, University of Sierra Leone, Private Mail Bag, Freetown, SIERRA LEONE.

The use of tractor power in Sierra Leone started in 1946 when the first agricultural tractor, plough and harrow were brought into the country by the Department of Agriculture. Since then the use of tractor power in mechanical cultivation of rice in the country steadily increased and by 1974, the Ministry of Agriculture had a total of 300 operational tractors that were actively engaged in ploughing the riverain grasslands and bolis in the country.

Problems, however, arose from the mechanical cultivation operations due to short supply of spare parts. In addition the mechanical cultivation operations were severely restricted due to administrative difficulties at the Ministry of Agriculture's offices, which resulted in the short supply of fuel, lubricants and spare parts that were urgently needed at the cultivation sites. Also, the mechanical cultivating operations were badly planned and poorly managed with lack of transparency and accountability.

154

Adapting a Tunnel Ventilation for High Density Broiler Production in Tropical Conditions. **M. E. Corria**, Doctoral Student, State

University of Campinas, Campinas-SP, BRAZIL. I. A. Nääs, Professor of the same.

In order to optimize broiler productions, Brazilian farmers have adopted high bird density associated with auxiliary management such as the use of tunnel ventilation system to provide thermal comfort for the lodged birds. This research studied a tunnel based on positive and negative pressure on the side walls closed with curtains. Broilers were housed at a density of 18 birds/m2, compared to a conventional lodging system using 13 birds/m2. Variables such as dry bulb temperature and relative humidity were recorded as well as broiler weight gain. Results showed that the weight gain was not statistically different, however, due to the larger number of birds in the higher density housing, but nevertheless, the poultry meat was profitable.

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Development and Evaluation of a Manually-operated Single Row Sunflower Planter. **Sukhbir Singh,** Asst. Agric. Engineer, Department of Agric. Engineering, CSKHPKV, Palampur-176062 (H.P.), INDIA. D. N. Sharma, Professor, Department of Farm Power and Machinery, College of Agric. Engg. and Technology, CCSHAU, Hissar-125004 (Haryana), INDIA. D. K. Vatsa, Research Engineer, Department of Agric. Engineering, CSKHPKV, Palampur-176062 (H.P.), INDIA.

A single-row, manually-operated sunflower planter was developed and evaluated. Trials were conducted at the research farm of CCS Haryana Agricultural University, Hissar to compare technical feasibility over broadcasting and dibbling methods for sunflower sowing. The average field capacity of the planter was 0.10 ha/h with average draft 15.0 kg. The seed-rate obtained with the machine was 4.32 kg/ha in MYCO-8 hybrid and 3.88 kg/ha in HS-1 composite variety. The operating cost of the machine was Rs181.26/ha and required 19.34 man-hrs/ha. The adoption of planting sunflower using the planter results in net savings of 57.16 man-hrs/ha and 1.50 tractor-hrs/ha over the broadcasting method, and 57.91 man-hrs/ha and 2.25 tractor-hrs/ha over the dibbling method. Therefore, the manually-operated sunflower planter has good potential for reducing the labor requirement and cultivation cost in sunflower farming.

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Canola Seed Germination Changes during Drying and Storage. A. K. Fujii, Graduate Student, Agricultural Engineering Department, Michigan State University, 210 A.W. Farral Hall, East Lansing, MI 48824, U.S.A. R. C. Brook, Professor of the same.

Canola seed producers have faced problems of viability loss, when crops are harvested at high moisture content and need to be dried. Drying conditions may affect seed quality.

A useful mathematical model of viability prediction was applied to a grain drying program that gives the final viability, depending on the initial seed conditions (viability and moisture) subjected to a certain drying conditions (air temperature and relative humidity).

Canola seed at an initial moisture content of 21% wb, was dried at 67 C, with an airflow of 0.4 m/s. After drying, germination was evaluated. The first layer of seeds, at the plenum (relative depth, d=0.0) , close to the entrance of the drying air, reached final moisture content of 3 %, after 6 hours and the final germination was 78%. The layer of seeds situated at the exit air (d=1.0) reached final moisture content of 8% after 6 hours and germination of 90%. ■■

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INSTRUCTIONS TO AMA CONTRIBUTORS

The Editorial Staff of the AMA requests contributors of articles for publication to observe the following editorial policy and guidelines in order to improve communication and to facilitate the editorial process :

Criteria for Article Selection

Priority in the selection of articles for publication is given to those that -

a. are written in the English language ;
b. are relevant to the promotion of agricultural mechanization, particularly for the developing countries ;
c. have not been previously published elsewhere, or, if previously published are supported by a copyright permission ;
d. deal with practical and adoptable innovations by small farmers with a minimum of complicated formulas, theories and schematic diagrams ;
e. have a 50 to 100-word abstract, preferably preceding the main body of the article ;
f. are printed, double-spaced, under 3,000 words (approximately equivalent to 6 pages of AMA-size paper) ;
g. are supported by authentic sources, reference or bibliography ; and those that
h. are written on floppy disc

Rejected/Accepted Articles

a. As a rule, articles that are not chosen for AMA publication are not returned unless the writer(s) asks for their return and are covered with adequate postage stamps. At the earliest time possible, the writer(s) is advised whether the article is rejected or accepted.
b. When an article is accepted but required revision/modification, the details will be indicated in the return reply from the AMA Chief Editor in which case such revision/modification must be completed and returned to AMA within three months from the date of receipt from the Editorial Staff.
c. The AMA does not pay for articles published. However, the writers are given collectively 2 free copies (one copy air-mailed and the other sent by surface/sea mail) of the AMA issue wherein their articles are published. In addition, a single writer or a responsible writer is given 20 off-prints of the article along with 2 more free copies of the issue and joint writers are given 5 off-prints (also sent by surface/sea mail).
d. Complimentary copies: Following the publishing, three successive issues are sent to the writer(s) .

Procedure

a. Articles for publication (original and one-copy) must be sent to AMA through the Co-operating Editor in the country where the article originates. (Please refer to the names and addresses of Co-operating Editors in any issue of the AMA). However, in the absence of any Co-operating Editor, the article may be sent directly to the AMA Chief Editor in Tokyo.
b. Contributors of articles for the AMA for the first time are required to attach a passport size ID photograph (black and white print preferred) to the article. The same applies to those who have contributed articles three years earlier. In either case, ID photographs taken within the last 6 months are preferred.
c. The article must bear the writer(s) name, title/designation, office/organization, nationality and complete mailing address.

Format/Style Guidance

a. Article must be sent on 3.5 inch floppy disk with MS DOS format (e.g. Word Perfect, Word for DOS, Word for Windows... **Absolutely necessary TEXT FORMAT**) along with two printed copy (**A4**).
b. The data for graphs and the black and white photographs must be enclosed with the article.
c. Whether the article is a technical or popular contribution, lecture, research result, thesis or special report, the format must contain the following features :
   i) brief and appropriate title ;
   ii) the writer(s) name, designation/title, office/organization ; and mailing address ;
   iii) an abstract following ii) above ;
   iv) body proper (text/discussion) ;
   v) conclusion/recommendation ; and a
   vi) bibliography
d. The printed copy must be numbered (Arabic numeral) successively at the top center whereas the disc copy pages should not be numbered. Tables, graphs and diagrams must likewise be numbered. Table numbers must precede table titles, e.g., "Table 1. Rate of Seeding per Hectare". Such table number and title must be typed at the top center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e.g., "Figure 1. View of the Farm Buildings".
e. **The data for the graph must also be included (e.g., EXCEL for Windows).**
f. Tables and figures must be preceded by texts or discussions. Inclusion of such tables and figures not otherwise referred to in the text/discussion must be avoided.
g. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
h. Express measurements in the metric system and crop yields in metric tons per hectare(t/ha) and smaller units in kilogram or gram(kg/plot or g/row).
i. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
j. Convert national currencies in US dollars and use the latter consistently.
k. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
l. When numbers start a sentence, such numbers must be written in words, e.g., "Forty-five workers..." or "Five tractors..." instead of "45 workers..." or "5 tractors..."

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Farm Machinery Yearbook 2003

It includes the data about Farm Machinery Statistic of JAPAN

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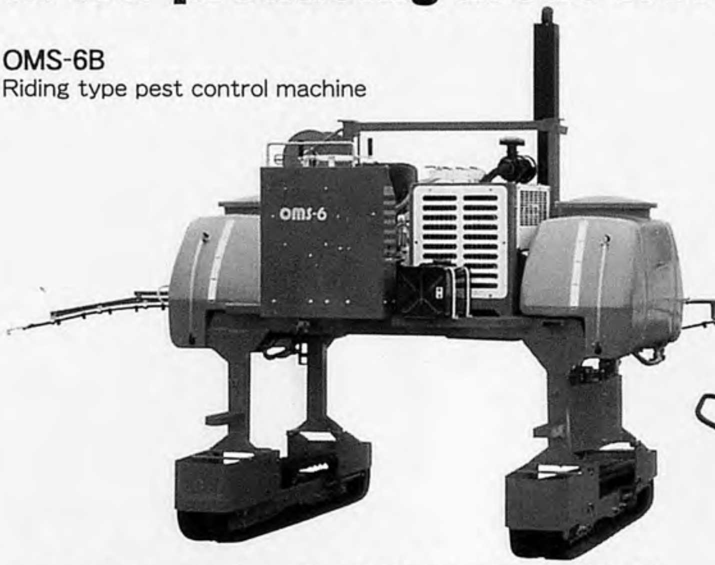

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- Succeeded in devising Japan's first automatic tea-leaf picker in 1959.
- Received the Director of the Board of Scientific Technology Award i n 1967.
- During the intervening period(1959-1967)obtained a number of patents, as well as receiving a variety of awards and prizes in the domain of science and technology.
- The top-ranking tea-leaf picker and tea-tree trimmer producer,holding 60% of the shares in the same line of business in Japan, surpassing the other manufacturers in sales and product, and leading the related business worlds in its expansion and development.

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