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This is the 58th issue since the issue, Spring of 1971

EDITORIAL

The Holiday Season and AMA's New Emphasis

It is indeed a happy occasion on the part of the AMA management and staff to partake of the festive mood and greet the readers, contributors and co-editors with Happy Holidays! This is because the winter issue of AMA comes at this time of year when the Christian world celebrates Christmas and renews its faith that peace shall prevail on the face of the earth. And for both Christians and non-Christians alike, this time of year–year after year– is witness to family reunions in countless homes around the world – another beautiful gesture of humankind that the family, as a basic and most durable institution, shall endure as time goes by.

As the AMA bids 1987 adieu, it also greets 1988 with a firmer determination to continue to carry on – to reach everyone in the way of promoting agricultural mechanization as a means of increasing farm productivity, hence improvement of the farm families' economy.

For 1988 AMA will place special emphasis on the importance of achieving a balanced and coordinated growth in the agricultural machinery industry in developing countries. This is because there are empirical evidences to indicate that the level of farm mechanization, measured in available horsepower per unit area of land, in a given country is a function of that country's level of agricultural machinery industry development. What this relationship suggests is that so long as the level of agricultural machinery industry development remains at a low level, so long will farm mechanization continue to lag behind.

Therefore, the AMA solicits from readers, contributors, co-editors, researchers and development experts articles, research results and such other technical papers fo publication that will throw light on how best to achieve a balanced and coordinated growth in the agricultural machinery industry.

In thanking those who cooperate with and support AMA, the management and staff reiterate their wish for everyone to have a –

VERY MERRY CHRISTMAS AND A HAPPY NEW YEAR!

Yoshisuke Kishida
Chief Editor

January, 1988
Tokyo

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Farm Mechanization in West Java, Indonesia

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Abstract

A study on farm mechanization was conducted in Jatiluhur irrigation area of West Java, Indonesia. It included a farm survey and field measurements on 90 farm holdings which were grouped into human labor, animal, and tractor farms. The study emphasized land preparation operation. There were no significant differences found in the yield under three groups. The use of labor decreased with an increase in mechanization. With a decreased number of draft animals and timeliness constraints, the use of tractors increased in land preparation operation.

Introduction

Indonesia is predominantly an agricultural country with 58 % of the economically active population employed in agriculture. The share of agriculture in gross domestic product (GDP) declined from 47 % in 1970 to 34 % in 1982. During 1970 -80, the gross national product (GNP) of Indonesia grew at 7.8 % annually and the agricultural production grew at 4.2 % annually (Singh, 1984). The total cultivated area in Indonesia is about 19.5 million ha (10 % of total land area) and another 60 million ha are estimated to be potentially suitable for agriculture. The development of new areas into agricultural land is mainly through the transmigration program that aims to relocate farmers from the densely populated areas to the outer islands where labor shortage exists. About 28 % of the arable land is irrigated. Fertilizer consumption is about 65 kg/ha and rice yields are about 3320 kg/ha. Agricultural population per ha is about 4.5 and land per worker is only 0.6 ha.

Agricultural mechanization in Indonesia is in its early stages of development. The population of power-operated farm machines is given in **Table 1** (APO, 1983). Annual sales of 4-wheel and 2-wheel tractors are about 2 000 and 5 000 units, respectively. The population of draft animals in 1978 was estimated to be 1 million swamp buffaloes and 2.8 million cattle. Power available for agricultural operations in 1978 was only 0.20 kW/ha consisting of 0.12 kW/ha (60 %) from human labor, 0.07 kW/ha (35 %) from draft animals and only 0.01 kW/ha (5 %) from mechanical equipment (Singh, 1984).

The Study Area

The Jatiluhur Irrigation Project is located in West Java. Thirty-six percent of the 1982 rice production of West Java come from the Jatiluhur irrigation area. Sources of farm power, rice area and cropping intensity for this area are given in **Table 2**. The irrigation system is designed to provide sufficient water for 260 000 ha rice land in the dry season while the total rice area in five regencies of Jatiluhur is 319 000 ha. Tractor (mostly 2-wheel) population in the area has been increasing significantly. In 1982, 1865 tractors represented 53 % of the total tractors in West Java. The animal population decreased 3 % annually during 1971 to 1981. Land holding size in Jatihuhur area is given in **Table 3** (CBS, 1982). It is clear from the table that land holdings are really very small with 37 % of them below

Table 1 Population of Farm Machines in Indonesia

Item	1970	1975	1978	1984
4-weel tractors	415	582	1 740	20 000
2-wheel tractors	670	961	2 360	20 000
Power sprayers	7 215	25 420	44 441	–
Water pumps	2 015	2 732	3 424	–
Power threshers	124	338	1 343	–
Rice milling units	15 000	23 300	31 700	–

Acknowledgments: The financial support for the field study was provided by the Carl Duisberg Gessellschaft e.v. (CDG) of West Germany through a grant to the Asian Institute of Technology, Bangkok, Thailand. Additional financial support and field help was provided by the Ministry of Agriculture of the Republic of Indonesia. The authors are especially indebted to the cooperating farmers. This article has been excerpted from ASAE Paper No. 85-5502 presented at the December 1985 meeting of the American Society of Agricultural Engineers in Chicago, Illinois, U.S.A.

Table 2 Sources of Farm Power, Rice Area and Cropping Intensity in Jatiluhur, 1982

Regency	Farm workers	Draft animals	Tractors (2-wheels)	Rice area (ha)	Cropping intensity
Bekasi	24 148	7 738	364	76 335	1.50
Purwakarta	9 654	2 487	7	16 935	1.40
Karawang	58 394	13 117	701	102 198	1.91
Subang	120 137	27 573	475	81 667	1.87
Indramayu*	29 238	4 744	318	41 727	1.81
Jatiluhur	241 571	55 659	1 865	318 862	1.79

*Only 4 districts of Indramayu regency are covered by Jatiluhur.
Source: Agricultural Extension Service, West Java, 1982.

Table 3 Land Holding Size in Jatiluhur Area, 1980

Regency	Total number of holdings	Percent distribution by size		
		Less than 0.25 ha	0.25-0.50 ha	More than 0.5 ha
Becasi	99 580	44	27	29
Purwakarta	60 040	52	27	21
Karawang	118 650	24	32	44
Subang	145 700	44	28	28
Indramayn	129 450	30	31	39
Jatiluhur	553 450	37	29	34
West Java	1 603 350	50	27	23

0.25 ha. On an average, land holdings are even smaller for the whole of West Java with 50 % being less than 0.25 ha in size.

Synchronized planting is one of the integrated pest control policies being implemented in the Jatiluhur area. The Jatilhur Project Authority (JPA), in order to optimize the water distribution at farm level, has divided the whole area into six groups, where each group has a 30-day period to complete land prepatation. Farmers are looking at tractors as one of the possible alternatives to minimizing the risk of delay in land preparation and, subsequently, in planting of the rice crop. This study was undertaken to collect information on the status of mechanization in the Jatiluhur area to determine energy inputs on farms in rice production process and to determine the cost of land preparation using different sources of power.

Field Study

This study (Siswosumarto, 1983) was conducted in the Jatiluhur irrigation area in West Java, having 319 000 ha of rice land spread over five regencies of the province (**Table 2**). In the dry season 260 000 ha of rice land was covered by the Jatihuhur Irrigation Scheme. This irrigation facility provides sufficient water to grow two crops of rice per year. Most of the land preparation is done using 2-wheel tractors and bullocks and only a small part is done by manual labor. Data needed for the study were collected through farm surveys and field measurements using a stratified random sampling design.

Villages Studied

Four villages from two regencies were selected for the study. These were Rawamekar and Sukahadji in Subang regency and Pucung and Pangulak in Karawang regency. The locations of these villages and the area under study is shown in **Fig. 1**. The characteristics of these villages are given in **Table 4**.

The survey included 90 farm households and 117 rice plots located in four villages in Subang and Karawang regencies. Sample farms were categorized into three groups based on main source of power for land preparation, namely: human labor mainly; animal power mainly; and tractor power mainly.

The distribution of farm samples under each mechanization category is given in **Table 5**. There were 36 farms each under animal and tractor power categories and only 18 under the human labor category.

Field Measurements

According to the soil classification map published by the Bogor Soils Research Institute, the soil in the study area is alluvial. The depth of tillage in manual operation (7 cm) was significantly shallower than that in animal plowing (10 cm) and tractor rotary tilling (9 cm). The difference in depths using animal and tractor power was insignificant. The average speed of travel in land preparation using animals was 1.8 km/h while it was 2.8 km/h for rotary tilling operation using tractors. The average size of 2-wheel tractors (power tiller) was 5.9 kW with a range of 4.4 to 7.4 kW. The average fuel (diesel) consumption of these tractors was 1.5 l/h. It took 281 h of manual labor to prepare 1 ha of land. With the use of farm animals, land preparation took 36 h and 15 h for the first and the second pass, res-

Fig. 1 Map of the study area.

Table 4 Characteristics of Study Villages

Items	Subang regency		Karawang regency	
	Rewamekar	Sukahadji	Pucung	Pangulak
General:				
Total population	3239	5926	7169	6170
Number of households	852	1559	1675	1469
Agricultural power:				
Number of male workers	349	640	260	530
Number of female workers	378	693	270	550
Number of bullocks	20	49	36	12
Number of tractors	4	15	2	0
Agricultural land: (ha)				
Lowland rice	215	720	277	389
Holding size	0.25	0.47	0.17	0.26

Table 5 Distribution of Farms, by Farm Mechanization Category

Farm mechanization category	Surawang regency		Karawang regency		All Villages
	Rawamekar	Sukahadji	Pucung	Pangulak	
Human labor	9	0	9	0	18
Animal power	9	9	9	9	36
Tractor power	9	9	9	9	36
Total	27	18	27	18	90

pectively. Using a tractor, land preparation took 7.5 h for the first pass and 7 h for the second pass.

Socio-Economic Characteristics

Data related to socio-economic characteristics are given in **Table 6**. These data indicate that tractor farmers had higher formal education than the other farmers. The average number of family members engaged in agriculture seems to be highest for farms depending on human power mainly. Farms that depended upon animal power mainly had more family labor than farms that depended mainly on tractor power.

Data for two seasons regarding inputs of seeds, fertilizers, and pesticides as well as the yields are given in **Table 7**. There were no significant differences in the use of seeds, fertilizers (both nitrogen and phosphate) and pesticides by the farms under different categories. Average yields on "animal" and "tractor power" farms seemed to be slightly higher than those on "manual labor farms" but these differences were not statistically significant. In general, the yields were very high due to high inputs of fertilizers, efficient management and sufficient supplies of irrigation water.

Table 6 Socio-economic Characteristics of Sample Farms in Study Area, 1982

Items	Farm mechanization category		
	Human labor	Animal power	Tractor power
No. of sample	18	36	36
Head of household			
Age (years)	42	46	48
Education (%)			
1-6 years	100	82	78
6-9 years	0	18	22
>9 years	0	0	0
Household members			
– male	1.8	2.0	2.2
– female	1.7	2.0	2.0
Actively engaged in agriculture per household			
– male	1.3	1.4	1.1
– female	1.1	0.7	0.7
Holding size (ha)	0.3	0.9	1.2

Energy Input in Land Preparation

Energy input in land preparation was computed by adding the energy expanded by various power sources. A male adult was assumed to be equivalent to 0.07 kW and an adult woman equal to 0.05 kW. The average weight of draft animals in the study area was 400 kg with the average age of six years. Premi (1979) found that an animal can pull 13-16 % of its body weight. For this study 15 % value was used. Using the average speed of travel as 1.8 km/h, power developed by a draft animal is 0.3 kW. Power from a tractor for land preparation was estimated as 50 % of the rated horsepower (Singh and Yadao, 1979).

Energy inputs in land preparation

Table 7 Rice Yield and Inputs for Rice Production on Sample Farms, 1982

Items	Farm mechanization category		
	Human labor	Animal power	Tractor power
No. of farms	18	36	36
Yield (t/ha)			
– wet season	4.42	4.83	4.60
– dry season	4.24	4.43	4.58
average/season	4.33a	4.63a	4.59a
Fertilizer (kg/ha)			
Nitrogen			
– wet season	102.5	103.1	99.8
–dry season	91.4	106.6	105.1
average/season	97.0b	104.8b	102.4b
Phosphate			
– wet season	49.1	50.4	51.1
– dry season	53.4	52.6	49.8
average/season	51.7c	51.5c	50.4c
Seed (kg/ha)			
– wet season	33.5	32.8	29.1
– dry season	35.1	32.7	28.9
average/season	34.3d	32.7d	29.0d
Pesticides (1/ha)			
– wet season	3.8	3.1	2.7
– dry season	3.9	3.3	2.2
average/season	3.8e	3.2e	2.4f

Note: In a row, any means followed by the same letter are not statistically different at the 5% level of significance.

Table 8 Energy Inputs in Land Preparation by Farm Mechanization Category

Village	Farm mechanization category							
	Human labor		Animal power			Tractor power		
	man-h	kWh	man-h	animal-h	kWh	man-h	tractor-h	kWh
Rawamekar	405	28	284	66.7	40	179	12.4	49–
Sukahadji	na	na	280	57.7	37	177	14.2	54
Pucung	447	31	220	71.2	38	195	15.8	60
Pangulak	na	na	277	62.3	38	199	15.7	60
Average	426	30a	265	64.5	38b	187	14.5	55c

Note: In a row, any means followed by the same letter are not statistically different at th 5% level of significance.

Table 9 Correlation between Yield and Energy Inputs in Land Preparation at N Fertilizer = 100 kg/ha, by Source of Power

Main source of farm power	Inter-cept	Regres-sion coeffi-cient	F com-puted	R
Humans	2.21	0.0993	569**	0.998
Animals	2.16	0.061	934**	0.985
Tractor	2.64	0.036	221**	0.948

**Significant at the 5% level

under various farm mechanization categories are given in **Table 8**. It can be seen that the "tractor farms" used the highest amounts of energy in land preparation (55 kW/ha) followed by "animal farms" (38 kWh/ha) with lowest energy input (30 kWh/ha) on "human labor farms". Analysis of variance showed that at the 10% level, energy inputs in land preparation under various categories were significantly different from each other.

A regression model was developed to relate the yield with various levels of energy inputs in land preparation. Two steps were involved. First, a multiple linear regression model was developed for yield vs N fertilizer and energy input for each category. Second, the yield for each observation in all three categories was corrected for the same level (100 kg/ha) of N fertilizer. This corrected yield was used in the development of a linear regression model (**Table 9**). This result also indicates that the higher mechanical technology tended to use higher energy inputs to produce the same level of yield (**Fig. 2**).

At the 1982 level of yield (4.6 t/ha) the proportion of energy inputs in land preparation on human farms, animal farms and tractor farms were 1 :1.3 :1.8. It is demonstrated that tractor power is less efficiently utilized compared to human and animal power. This is due to the high power used for tractors. Since the observed yields in each category are not more than 6 t/ha, these models are only valid for yields up to 6 t/ha. In order to determine the common regression line for a combination of human labor, animal power and tractor power categories, the weighted average was used. The values of weighted average of energy input were then plotted against the corrected yield to find the regression line. The regression line of the combination of human labor, animal and tractor power categories was expressed by:

$$Y = 2.494 + 0.048\,X,$$

where, Y : corrected yield (t/ha)
X : average energy input for land preparation (kWh/ha)

This regression is significant with the coefficient of correlation 0.99.

Fig. 2 Energy input in land preparation and corrected yield for 100 kg N/ha.

Cost of Land Preparaion

Results in **Table 10** show that the human labor farms incurred the highest cost in land preparation followed by the animal farms and tractor farms. These costs were computed for two cases. In Case 1, the family labor was valued at an opportunity cost as hired labor. Case 2 showed that there was no significant difference in the cost of land preparation for all three categories.

Choosing an alternative land preparation technique depends upon the availability and cost of power sources and timeliness constraints. Farmers, if possible, will naturally select the least cost alternative to reduce the cost of production. The cost of labor and animals has been increasing rapidly (**Table 11**). The population of draft animals has been decreasing due to increased meat consumption and the use of cropped area for food crops rather than for fodder crops or gazing lands. Irrigation authority in Jatiluhur area forbids the grazing lands. Irrigation authority in

Table 10 Cost of Land Preparation by Source of Farm Power Unit: Rp/ha

Village	Source of farm power					
	Case 1			Case 2		
	Human labor	Animal power	Tractor power	Human labor	Animal power	Tractor power
Rewamekar	63 900	54 300	50 900	49 900	51 500	49 900
Sukahadji	na	55 200	47 400	na	47 000	42 400
Pucung	68 500	59 600	50 800	53 400	53 900	47 900
Pangulak	na	54 900	45 300	na	49 500	42 600
Average	66 200a	56 000b	48 600c	51 700d	50 500d	45 700d

Note: In a column, any means followed by the same letter are not significantly different at the 5% level.

Table 11 Cash Wages Paid for Land Preparation Using Various Sources of Power

Years	Source of power		
	Humans Rp/h	Animals Rp/h	Tractors Rp/ha
1974-1975	37.4	162.4	na
1975-1976	39.5	171.2	na
1976-1977	41.7	191.8	15,000
1977-1978	46.7	236.9	17,500
1978-1979	54.9	259.4	20,000
1979-1980	61.5	295.8	22,500
1980-1981	70.8	338.9	22,500
1981-1982	83.4	375.0	25,000
1982-1983	100.0	425.0	28,000

US$1 = Indonesian Rupiah (Rp) 1 000 (1983).

Jatiluhur area forbids the grazing of animals on canal banks to protect the latter from being damaged. In contrast, even though the price of tractors increased rapidly, mainly due to inflation, the cost of tractor-hire did not increase as fast at the farm level. The average price of a tractor (5.2 to 7.5 kW) increased from Rp 1 900 000 in 1978 to Rp 2 900 000 in 1982. The optimum period for land preparation was about eight weeks each in both wet and dry seasons. During this period 95 % of the land area on the sample farms could be prepared. The cost of land preparation using a different number of working hours in a year was calculated as shown in Fig. 3. A tractor should work about 500 h annually to have the cost of land preparation equal to or less than that done using animal power.

Fig. 3 Cost of land preparation vs annual working hours using various power sources.

Conclusions

1. The labor input per ha in land preparation for rice crop on farms using human labor only (426 h) was significantly greater than the labor input on both the animal farms (265 h) and tractor farms (187 h).
2. Tractor farms used energy inputs in land preparation (55 kWh/ha) compared to animal farms (38 kWh/ha) and human farms (30 kWh/ha). Farms with higher energy inputs used higher levels of fertilizer in each farm category. However, fertilizer inputs were not statistically different at 5 % level.
3. The rice yields on farms in three categories were not statistically different from each other at 5 % level: human labor (4.3 t/ha), animal (4.6 t/ha), and tractor farms (4.6 t/ha).
4. In 1982, the costs of land preparation per ha, costing family labor as hired labor, were Rp 48 600 on tractor farms, Rp 56 000 on animal farms, and Rp 66 000 on human labor farms. These costs were significantly different from each other. If the cost of family labor was not included, the cost of land preparation using various power sources were not significantly different from each other.

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Cost of Operating Tractors on Quetta Farms, Pakistan

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Abstract

Tractor cost studies are important in making management decisions and for knowing the cost benefit ratio of owners. The field survey of all farm tractors was conducted in Quetta district of Baluchistan during 1980. One year data, from July 1979 to June 1980, were collected for all 65 tractors in the district. The various costs according to annual use, age and make of tractors and farm size were calculated, tabulated and analysed. The study shows that the average cost per hour was Rs. 38.26 for an average annual use of 1395 h for 45 to 65 hp tractors. The cost per hour decreased as the annual use increased. The cost per hour was high for the old tractors. Massey Ferguson, Belarus, Ford and Fiat tractor makes were used successfully in the area. Farm size had no effect on cost per hour as the tractors owned on small farms had enough work. The tractors were mainly used for seedbed preparation followed by transport and leveling operations. It is recommended that the number of medium size tractors be increased. Training facilities should be provided to the tractor owners, operators and mechanics. Tractor use and cost records should be maintained by the owners and further cost studies should be made.

Introduction

Baluchistan is the largest province of Pakistan in land area with the lowest population. The cultivated area is 25.7% of the total cultivable land which is quite insufficient to produce food for the population. The topographical conditions of land, scarcity of irrigation water and inadequate farm labour have made the use of tractors indispensable. A significant increase in clutivated area to obtain self-sufficiency in food production is needed. To achieve this goal, transition of traditional agriculture by mechanized agriculture is necessary. There is no perennial system of irrigation in Baluchistan. The only alternative is to conserve run-off of rainfall by constructing dykes ("bundats"). On rocky soils such as of Baluchistan, construction of these types of bundats is beyond the capability of animal power. The socio-economic conditions of the farmers are miserable due to non-development of agricultural land. Heavy investment for the purchase of farm tractor is inaccessible to a common farmer.

Contrary to this, remarkable expansion in the area under cultivation through tractor and resultant increase in income due to increased production is attracting the farmer to buy a tractor.

Considerable number of "bundats" which are constructed by government bulldozers remain uncultivated due to lack of draft animals and farm labour. It is also quite expensive to maintain draft animals in the province because these are mostly brought from other provinces and could not get ample feed. Under-feeding causes weakness, high mortality rate and inadequate farm power which, consequently, results in uneconomical farming and no increase in cultivable land area. The government has realized the importance of tractor and promotes farm mechanization as a means to improve and raise the socio-economic conditions of the farmers.

A world-wide study has concluded that for obtaining optimum yield, power input of 0.8 hp/ha is necessary. The population of farm tractors in 1980 in the province was 1159 for cultivable land area of 1401784 ha or about 0.04 hp/ha.

Farm tractor costs are divided into two categories: owning and operating costs. The costs of owning and operating a tractor are

important in evaluating the farmers' decision for the purchase of tractors.

This study has the main objective of assessing the overall cost per hour of the individual tractor owner and for a farmer hiring out tractor for custom work. Cost calculations are helpful for a farmer from the management point of view such as accounting and recording income and expenses, comparisons of crop production costs per unit area by substituting mechanical power in place of animal power. This study also pinpoints the factors responsible for unreasonable high cost and highlights the measures to be taken to reduce them.

Survey Procedure

The field survey of all farm tractors owned by farmers was conducted in Quetta district of Baluchistan during 1980. The area of the district is 2653 km^2 of which 294 km^2 is cultivated land area under Karez irrigation system and rainfed. The number of farmers maintaining tractors, cultivated area and addresses of all the tractor owners in Quetta district were collected from the office of the Extra Assistant Director of Agriculture Quetta and Agriculture Officers.

The survey of all the existing tractors was carried out. All of the 65 tractors in the district in 1980 were studied.

The cost of owning and operating tractors was collected and recorded on a pretested questionnaire. All the tractor owners of farm managers were contacted and data were collected from farm records and through personal interviews with them. The tractor operators were also interviewed about annual use and various costs incurred during the study period. The information given by the tractor owners, managers or operators was relied upon as all types of records were not maintained by them. Of the 65 diesel tractors surveyed in the district, 37 were Massey Ferguson (U.K.), 13 Belarus (U.S.S.R.), 10 Ford (U.S.A.), 2 I.M.T. (Yugoslavia), 2 Fiat (Italy) and 1 Zetor (Czechoslovakia). All the tractors were between 45 to 60 hp size. The hour meters in most of the new tractors were in working order and annual use was confirmed from the readings. At least one-year old tractors were included in the study.

As the main objective of the study was to determine the cost per hour of using a tractor, the following null hypotheses were developed and tested.

1. There is no significant correlation between age and repair cost per hour of a tractor.
2. There is no significant correlation between annual use in hours and cost per hour of a tractor.
3. There is no significant correlation between size of the farm and cost per hour of a tractor.

Tabulation and Analysis of Data

For the calculation of owning and operating costs per hour of the tractors, average annual use in hours, age in years, make and area in hectares are taken into consideration.

The owning cost includes charges for depreciation, interest, taxes and shelter. Depreciation per annum has been calculated by observing straignt line depreciation method, assuming 10 years total life of the tractor and 10% residual value (Lonnemark 1967, Bowers 1974, Hunt, 1977, Rahmoo 1979). The annual interest at the rate of 14% (normally charged for agricultural purposes) and taxes and shelter at 2% of the initial cost are used in cost calculations.

All of these items were aggregated to make a unit percentage of the initial cost to obtain annual owning cost.

$$D = \frac{C - R}{L} = 0.09C$$

$$I = \frac{C + R}{2} \times i = 0.7C$$

$$TS = 0.02C$$

Annual owning cost = D+I+TS

= 0.09C + 0.07C + 0.02C

= 0.18C or 18% of initial cost of tractor

Where:

D = Depreciation
C = Initial cost
L = Life of tractor
R = Residual value
I = Interest on investment
i = Interest rate
TS = Taxes and shelter.

Therefore, the total annual owning cost (fixed cost) of the farm tractor is equal to 0.18C or 18% of initial cost.

The annual operating costs include fuel, oil and lubricants, repair and maintenance and labour costs. The owning and operating cost per h was determined by dividing the annual owning and operating cost by annual use.

The data were tabulated, analyzed and summarized according to age of tractor, annual use of tractor, various makes of tractors and size of farm.

Results and Discussion

Costs for owning and operating farm tractors

Table 1 shows the average cost items for owning and operating tractors in the district. The costs are based on an average initial cost Rs 61746/tractor and average an-

Table 1 Average Cost per Hour for Owning and Operating Farm Tractors.

Cost items	Cost per hour (Rs.)	% of owning or operating cost	% of total cost
Owning costs			
Depreciation	3.98	48.13	10.41
Interest on investment	3.41	41.23	8.91
Taxes and shelter	0.88	10.64	2.30
Total	8.27	–	–
Operating costs			
Fuel	15.20	50.68	39.73
Oil and lubricants	1.26	4.20	3.29
Repair and maintenance	6.41	21.38	16.75
Labour	7.12	23.74	18.61
Total	29.99	–	–
Total cost per hour	38.26	–	–
Custom rate per hour	60.00	–	–

Note: Costs are based on an average initial cost of Rs.61746/ tractor and average annual use of 1395h.

nual use of 1395 h.

The average annual use was higher when compared with data from developed countries due to the fact that tractor per unit area was small in the district.

The tractor owners were compelled to use the tractor for more hours per day during peak period demand and earning income by hiring out the tractors. The demand for seedbed preparation with a moldboard plow and cultivator had increased in the area and the tractors were usually busy. The high annual use of tractors was reported by Kolawole (1972) Kitsopanidis and Martika (1969) and Chancellor (1971).

The hourly tractor hire rate was Rs 60/h which is almost double the total cost of operation per hour or per acre. The rise in prices of tractors and implements have prompted the tractor owners to increase the hire charges. Increased demand for seedbed preparation, intercultivation in the gardens, transport of fruits and vegetables and other goods to the market also influenced the custom hire rates of the tractor operations.

Costs affected by age of tractors

The cost per hour according to age of tractor is given in **Table 2**. The owning cost per hour decreased with age as old tractors were purchased at lower prices than the new ones. The operating cost, excluding repair cost, shows an increasing trend as age increased beyond 6 years as older tractors required more repairs. The oil leakages through various oil seals increased the oil consumption. The repair cost increased as the tractor became older. The repair cost shows a high rate of repair charges during the age of 4 to 6 years. This was due to the fact that the general overhauls of tractors, replacement of batteries, tractor tires, major repairs of fuel injection pumps, transmission, hydraulic system and replacement of other parts were carried out during this period. Again, a high increase in repair cost per hour of tractor occurred in the age group of above 10 years. **Fig. 1** shows the high repair cost per hour occurred due to second major overhauls and replacement of some major parts at different age groups of tractors. There is a high significant correlation between age of tractor and repair cost per hour.

The coefficient of correlation estimated was 0.82. This shows that the repair cost is directly related to the age of tractor. The relathioship between the age of tractor and repair cost per hour is shown in **Fig. 2**. The regression coefficient shows that for a unit increase in age of a tractor by one year, there is a corresponding increase in repair cost by Rs 0.69 per hour.

After 1970, the cost of spare parts increased due to high increase in fuel and oil rates and high rate of inflation. The prices of spare parts and materials were more than four times the rates during 1979-80 as compared to those of 1970-71. Shortage and non-availability of the genuine spare parts were the major causes of tractor breakdowns, requiring repairs and replacement within short periods. Adulteration of fuel, engine and lubricating oil had also resulted in frequent damage and major losses. Tractors beyond 3 years of age required engine overhauls after one or two years. The repair charges by service shops

Table 2 Age and Cost per Hour of Farm Tractor

Age of tractor (since purchase) Years	No. of tractors	Average purchase price of tractor Rs.	Average annual use h	Cost per hour (Rs.)				Repair & maintenance cost	
				Owning cost	Operating cost (excluding repair & maintenance cost)	Repair & maintenance	Total cost	% of purchase price (Average/ 100h)	% of total cost (Average/h)
Upto 2	19	81474	1758	8.34	22.67	1.10	32.11	0.14	3.43
2 - 4	10	70150	1590	7.94	22.47	2.71	33.12	0.39	8.18
4 - 6	12	62667	1292	8.73	22.75	4.66	36.14	0.74	12.89
6 - 8	13	52923	1146	8.31	25.62	5.39	39.32	1.02	13.71
8 -10	6	34333	1100	5.62	24.66	6.20	36.48	1.81	16.99
above 10	5	21200	880	4.34	28.93	13.06	42.06	6.16	31.05

Fig. 1 Cost per hour for different ages of farm tractors.

Fig. 2 Relationship between age of farm tractors and repair cost per hour.

had also substantially increased. Repair cost as percentage of total cost increased as the tractor became older. In the age group of 2 to 4 years, the repair cost as percentages of total cost was more than double and again it was double when the age of tractor was 10 years.

The findings of Esmay and Faidley (1973) that life expectency of tractors was 25% less and repair costs were 100% more than in the United States, are in agreement with this study. Bowers (1974) reported the accumulated repair cost as 90% of purchase price at full life for wheel type tractors. Bowers and Hunt (1970) also calculated the accumulated repair cost as 1.6 times the purchase price with inflation. Rahmoo *et al* (1979) and Bukhari (1982) stated that repair costs increased during 4 to 6 years use. Again the repair costs increased as age increased beyond 8 years. Bukhari (1982) also found that the older tractors had higher repair and maintenance cost per hour. However, field and simulated studies of tractor costs made in the developed and developing countries cannot be in general agreement with tractor costs in a certain selected area due to difference in tractor size and farming systems.

It was observed that tractor replacement policy depends upon the availability of financial resources for the purchase of a new tractor or non-repairable breakdown of the tractor. Accidents were also the causes of tractor replacement.

Costs affected by annual use

Table 3 shows the costs for various rates of annual use of tractors by the owners. The cost per hour of tractor operation is closely related to the amount of annual use.

The data was analysed and the correlation for annual use in hours and cost per hour ($r = 0.58$) shows no significant relationship and, therefore, the null hypothesis is accepted. Through the correlation coefficient between annual use in hour and cost per hour is not significant but there is a reduction in cost per hour as annual use increases. The owning cost is increasing as annual use increased due to the fact that new tractors with high new cost fall into the group of tractors with high annual use. The related reduction in total cost with increased annual use in hours shows an agreement with the views of Kitsopanidis and Martika (1969), Rahmoo *et al* (1979), Stone and Gulvin (1977). Kolawole (1974) also reported that low annual use resulted in high cost per unit of work. Moses and Frost (1965) reported that the annual use and age were both important aspects in explaining cost per hour of operating tractor. It was concluded that the season's use is much more important than the age of the tractor.

Costs for various makes of tractors

The costs per hour are given in Table 4. The owning cost per hour for Ford, Massey Ferguson and Belarus tractors was high due to the fact that these makes were purchased at high price after 1975 at a time of high rate of inflation and sudden rise in the cost of fuel which also influenced the prices of

Table 3 Annual Use and Cost per Hour of Farm Tractors

Annual use (h)	No. of tractors	Cost per hour (Rs.) Owning cost	Cost per hour (Rs.) Operating cost	Total cost per hour (Rs.)
Upto 500	1	6.30	50.50	56.80
501 – 1000	9	7.76	35.31	43.07
1001 – 1200	20	8.04	29.61	37.65
1201 – 1500	18	8.29	26.23	34.52
1501 – 1800	11	8.13	23.46	31.59
Above 1800	6	6.99	22.81	29.28

Table 4 Various Makes of Farm Tractors and Cost per Hour

Make of tractor	No. of tractors	Average annual use (h)	Cost per hour (Rs.) Owning	Cost per hour (Rs.) Operating	Cost per hour (Rs.) Total
Fiat	2	1900	6.16	21.71	27.87
Belarus	13	1631	7.50	26.58	34.08
Massey Ferguson	37	1300	8.07	26.76	34.83
IMT	2	1100	6.14	30.21	36.35
Ford	10	1420	9.32	28.40	37.72
Zetor	1	1200	3.75	38.71	42.46

other materials. Zetor tractor had the lowest owning cost per hour whereas the operating cost per hour was the highest among the six tractor makes studied. The lowest operating cost per hour and total cost per hour was for Fiat tractors. The average fuel consumption for Fiat, Massey Ferguson and IMT tractors was about 4 *l*/h, whereas it was 6.75 *l*/h for Belarus, 6 h for Zetor and less than 5 *l*/h for Ford tractors for similar field conditions and operations. As reported by the farmers maintaining tractors, Massey Ferguson, Ford, Belarus and Fiat tractor makes were successful and their performance was satisfactory. The number of Fiat tractors was less as few tractors of this make had been brought into the district. The Zetor and IMT tractors were not popular in the district. The number of Massey Ferguson tractors was the highest in the area. Belarus was the second popular make and Ford was the third commonly owned make of tractors.

Size of farm and cost per hour

Tractor costs per hour according to the size of farm is shown in **Table 5**. All the farms in the sample have one tractor and, therefore, the area per tractor has been considered as size of farm. The smallest farm with a tractor was 4 ha size and the bigggest was 809 ha. The tractors were only used for some operations like plowing, harrowing, levelling and transport. Thus, in no case is tractor power used for complete mechanized farming.

The coefficient of correlation ($r = 0.112$) for farm size and cost per hour is not significant. Therefore, the null hypothesis is rejected. The farm size has no effect on the cost per hour which resulted due to the fact that the size of the farm of 20 ha was sufficient and economical for optimum utilization of a tractor. It was observed that the tractor owners have realized the benefits of increased annual use and, therefore, small farms with less area used the tractors for more hire work. No hire work was performed by the farmers of big farms. They even hired tractors during the peak periods for planting the crops in time. The highest total cost per hour of tractor operation was incurred by the farms of 101 to 150, 151 to 200 and 401 to 500 ha size. Due to the fact that in farm group of 101 to 150 ha the majority of Ford, Massey Ferguson and Belarus tractors having high purchase price were owned by this group. In other farm groups of 401 to 500 ha farms the total operating cost was high due to more frequent berakdowns hence more repair charges.

Tractor-drawn implements owned by farmers

The numbers of tractor-drawn implements owned by each group of farm are given in **Table 6**. The number and availability of tractor-drawn implements on the farms indicates the level and standard of farm mechanization and economic position of the farm groups. The mouldboard plow, cultivator and leveller used for crops and gardens,

Table 5 Size of Farm Holding and Cost per Hour of the Farm Tractor

Size of farm (ha)	No. of tractors	Average annual use (h)	% of the custom work	Cost per hour (Rs.) Owning	Cost per hour (Rs.) Operating	Cost per hour (Rs.) Total
Upto 50	25	1372	82	8.23	26.34	34.57
51 – 100	9	1400	54	7.04	26.46	34.50
101 – 150	7	1243	32	9.52	30.46	39.98
151 – 200	3	1233	29	9.59	27.88	37.47
201 – 300	9	1544	36	8.13	25.24	33.37
301 – 400	3	1700	53	7.41	24.55	31.94
401 – 500	2	1600	25	4.73	33.65	38.38
Above 500	7	1543	17	6.92	28.41	35.33

Table 6 Details of Tractor-drawn Implements Owned on Farms

Farm size	No. of farms	Number of each kind of implement: Mould-board plow	Cultivator	Leveller	Front dozing blade	Trailer
Upto 50	25	23	25	21	1	24
51 – 100	9	8	9	8	–	9
101 – 150	7	7	7	7	1	7
151 – 200	3	3	3	3	–	3
201 – 300	9	8	9	6	2	9
301 – 400	3	2	3	2	2	2
401 – 500	2	1	2	1	–	2
Above 500	7	7	7	6	2	7

were the common implements onwed by all the tractor owners in the area, including trailers for transport of crops, fruits and vegetables.

The land is developed and levelled by the bulldozers. The front dozing blade for levelling the land and preparing dykes for water conservation were present on the big farms.

Annual use of tractors and implements

The annual use of tractors for on-and-off farm operations by different farm groups is shown in Table 7. The average "use hours percentages" were based on the verbal information given by the tractor owners and operators, as no such record was maintained by them. Seedbed preparation was the main job followed on the farms. The mouldboard plow and cultivator were used for the preparation of seedbed. The next major use of tractors on all the farms was for transport. The use of front dozing blade for levelling and planing and making dykes was made when found necessary for unlevelled land and dykes for water conservation. Somewhat similar percentage of annual use of the tractors for various field operations was reportted by Shivamagg (1972). The mean percentage work hours for seedbed preparation, levelling, transport were 66.66, 14.11 and 19.22, respectively.

Table 7 Size of Farm and Percentage of Annual Use of Tractors for Various Operations

Farm Size	Average annual use (h)	Percentage for each kind of operation		
		Seedbed preparation	Levelling	Transport
Upto 50	1372	67.76	12.39	19.85
51 – 100	1400	63.89	15.48	20.63
101 – 150	1243	62.64	17.82	19.54
151 – 200	1233	67.58	13.51	18.91
201 – 300	1544	69.06	8.63	22.31
301 – 400	1700	59.80	27.45	12.75
401 – 500	800	73.12	1.88	25.00
Above 500	1543	69.44	15.74	14.82
Mean	–	66.66	14.11	19.22

Summary

The average annual use of tractors in the district was 1395 h and cost per hour was Rs 38.26. The cost per hour showed a decreasing trend as the annual use increased but the negative correlation was not significant. The correlation between the age of tractor and repair cost was positive and significant.

The general overhauls of tractors involved large amounts during the age of 4 to 6 years making the repair cost a high percentage of purchase price and total cost of tractors.

The repair cost showed an increasing trend as the tractor became older. The repair cost as percentage of purchase price and total cost of old tractors was extremely high due to low purchase price and high cost of spare parts and service charges.

Six makes of the 65 tractors studied were used by the farmers of Quetta district: 37 Massey Ferguson, 13 Belarus, 10 Ford, 2 Fiat, 2 IMT and 1 Zetor. Except IMT and Zetor tractors, all of them were successful in the area.

Farm size had no significant effect on the cost per hour of tractor operation. As tractor owners with small farm size had sufficient optimum use of tractor and besides this, the farmers increased the annual use of the tractors by doing custom-hire work.

The farmers owned the different tractor drawn implements which included mouldboard plows, cultivators, levellers, front dozing blades and trailers. Except front dozing blade most of the tractor owners possessed all the implements stated above.

The tractors were ultilized for seedbed preparation, transport and levelling operations only. Seedbed preparation was the main job performed by the tractors for which an average of 66.66% of annual use of the tractors had been exercised. The transport and levelling operations made 19.22 and 14.11% of annual use of tractors.

Conclusions

1. Tractors of medium size of 45 to 65 hp were appropriate for soil conditions, crop pattern and farm sizes in the district.
2. The owners of new and old tractors were making reasonable profits from the tractors. The custom hire rates were double than those on the tractor owner's farms.
3. The tractor owners realized the benefits of increased annual use and the tractors were never left idle. The extent of annual use was governed by the demand and timeliness of operations. An increase in yearly cost did not influence the annual use. Despite the high yearly repair costs, the owners of some tractors used the tractors for more hours annually for getting more benefits through intensified cultivation or for more earnings from custom hire work. Thus the cost per hour of tractor operations was reduced.
4. The repair costs increased with the age of the tractors. High repair costs occurred due to high cost of spares, material and service charges. Non-qualified operators and untrained mechanics were also the main cause of breakdowns which increased repair costs.
5. The majority of tractor owners

were unaware of the benefits of maintaining records of use and expenses for proper planning of farm operations.

6. Selective farm mechanization was being practiced as the tractors were used for high power consuming operations like seedbed preparation, levelling and transport for which the animal power was inadequate and uneconomical.
7. The farm size had no significant relationship with cost of tractor operation as small farmers could also use the tractors for more hours by doing custom hire work.

Recommendations

1. The number of medium-sized tractors of 45 to 55 hp should be increased by financing the farmers through government loan schemes so that the demand of farm power could be met.
2. Considerating the rate of inflation, used tractor should be replaced when the accumulated repair cost becomes 1.5 times the initial purchase price.
3. Custom hire services provided by individual tractors and implements.
4. Comparative cost studies of the tractor hire services and bullock power use should be made in order to fully understand the benefits of each system of farming.
5. Short training course facilities should be provided for the tractor owners, operators and mechanics by the government institutes and tractor and implement dealers, so that the owners could acquire the proper knowledge of management, maintenance and repair of tractor.
6. Farmers should be guided through the network of agriculture extension services for keeping tractor cost records so that the real cost benefit ratio could be ascertained. The records will be helpful in economic appraisal of tractor use and future planning by the tractor owners and government also.
7. Further cost studies by maintaining tractor cost and use records should be conducted in the country in order to determine the actual cost benefit ratio of tractor owners and for planning by the government.

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Mechanical Transplanting of Rice in Pakistan

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Abstract

There is need for mechanical transplanting of rice in Pakistan. A farmers' survey carried out in the Northern Indus plains confirmed this observation as manual labor was found to transplant only 68 percent of the recommended plant population of 200 000 seedling hills per ha. The plant population along the border of field was also found higher and statistically significant different at the 0.05 level than in the center of field.

Introduction

Rice is both a staple food and cash crop in Pakistan. It occupies 10% of the cultivated area in the country. Pakistan earns about US$ 400 million annually from the export of rice. Rice is cultivated in four zones (Choudhri, 1978). Fig. 1 gives the location. Among the four zones, zone 2 has a typical climate which is very favorable for growing Basmati, one of the world's finest rice varieties. Zone 2 occupies 34% of 2 million ha of rice (PARC, 1983). Its share is about 50% of the total foreign exchange earnings from the export of this cereal. This study was focussed in zone 2 due to the economic importance of Basmati which is mainly grown in this zone.

Rice is, more than any other food crop, adapted to different cultivation methods, including direct seeding (drilling, dibbling and broadcasting) and transplanting.

Drilling is the most efficient direct seeding method in use because of low labor and seed requirements, uniform sowing in lines and uniform germination. Despite the fact that direct seeding with a drill reduces labor cost for rice sowing operation and gives higher grain yield as shown in studies conducted in some rice growing areas (Khan, 1975; Navasero, 1969; Jayasekera, 1966; and Adair et al, 1962), this method has two basic disadvantages.

1. There is more weed growth in direct seeded than transplanted fields. The weed problem can be more severe in direct seeding on dry soils than puddled soils (Jayasuriya and Price, 1979). Higher weed density and decreased tilling after 5 weeks was found in direct seeding as compared to transplanting (Pillainayagam, 1980). A need for 750-1250 man-h per ha

Fig. 1 Rice zones in Pakistan.

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was observed for weeding in direct seeding method against 450 man-h per ha in transplanting (Singh et al, 1983). More money was spent in weeding in other methods of sowing as compared with transplanting (Sankara, 1976). A decrease of 49 to 66% in grain yield was observed without weeding a rice crop sown by direct sowing methods against 13% in case of transplanting (Bhatnagar, and Sharma, 1975).

2. With direct seeded rice, there is uneven germination, initial stunting slow growth, and lodging of crop due to poor root development. Studies in the Philippines showed more prevalence of lodging with broadcast rice (Jesus, 1959) and even lodging ocurred earlier in direct seeded rice (Castillo, 1962). The need for a high standard of levelling and good water control system to ensure optimum yield for broadcasting also favors transplanting in most Asian countries (Padolina and Nichols, 1972).

In order to cope with the problems of weed control, poor seedling growth, poor lodging resistance, and bird damage, a new cultivation system called direct seeding with coated rice in submerged paddy (DSSP) system has been developed in Japan. This system currently requires rice drilling equipment, coating machines and chemicals necessary for the preparation of rice seeds, and pyrazolate herbicide for the initial weed control. The seeding depth of 1 cm for this system is highly critical since both the lodging and emergence strength depend upon it.

Initial trials of the DSSP system in Japan have shown a reduction in labor input by more than 20% and almost double the net income as compared with conventional transplanting (Nakamura et al., 1983). As the DSSP system is being developed in Japan, which has a cold climate, the Asian Institute of Technology (AIT) is conducting studies to determine its suitability under tropical conditions. Two initial studies have shown promising results of this system (AIT, 1983).

Rice is transplanted under rainfed and irrigated lowland rice cultures. The rainfed crop is known as *kharif* (monsoon) crop and is sown in India, Bangladesh, Indonesa, Nepal, Pakistan and Thailand. In irrigated crops, the supplementary canal and tube-well irrigation facilities in addition to providing water for the growing crop also prevent risks of delayed planting which might result in poor stands in early varieties (Rao and Pradhan, 1973).

In transplanting, if healthy and vigorous seedlings are used, a uniform stand results. Additional advantages are effective weed control and no lodging of the crop. Plant spacing is an important production factor in transplanted rice (De Datta, 1981). Planting rice closer than necessary increases the cost of transplanting and increases the probability of lodging. On the other hand, too wide spacing results in lower yeild.

Transplanting at the right time of the season has a pronounced influence on the rice yield. A delay in transplanting of one month reduced the yield by 25% and a delay of 2 months reduced the yield by 70% (Rao and Pradhan, 1973).

Zone 2 in Pakistan has a clayey and silt loam soils and are generally flat. It is a double-cropped area with rice grown as a monsoon crop and wheat or burseem (fodder crop) as a "*rabi*" crop. Transplanting is practised in this zone. Experiments on direct sowing both in dry and puddled soil conducted at the Rice Research Institute, Kala Shah Kaku, Pakistan were not conclusive. Farmers use the translplanting method as the *rabi* crop occupies the land until the end of May and if the farmers prepare their land in June, they can sow their crop in July when the monsoon starts. Because of poor surface drainage of these lands, there might be chances of failure of the crop if heavy rain falls immediately after sowing. Using the conventional transplanting method, farmers prepare their land in June/July and also sow rice seedlings on small plots in June. This not only decreases their water requirements for a one-month period but also gives them sufficient time for land preparation.

On the basis of agro-climatic condition, present cultural practice and lack of sufficient research on direct seeding and problems associated with it, transplanting seems an appropriate rice sowing method for the zone 2 area of Pakistan, especially for Basmati which is tall and more susceptible to lodging.

Transplanting of the rice crop is done by manual labor in Pakistan. Manual transplanting of paddy crop is one of the most laborious and time-consuming practices in rice production. Transplanting requires about 25% of the labor input. Moreover, it is a highly tiring task. The hired manual labor tend to transplant a lower plant population in the center of the field. The average plant density of 119 000 to 148 000 plants per ha is much lower than the recommended plant population of 200 000 plants per ha (Khan et al., 1979).

In the past few years, due to the migration of rural youth to urban areas for better emoluments, the shortage of labor during peak transplanting season has resulted in increased labor wages and delayed transplanting operations. The inadequate number of seedling hills per hectare transplanted by manual labor and the delay in transplanting due to labor shortage during peak transplanting season have pushed the demand for the development of suitable equipment needed to mechanize this operation.

Objectives of Study

In order to assess the quality of hand-transplanted rice crop and the labor availability situation during the peak rice transplanting season, a farmers' survey in rice zone 2 of Pakistan was undertaken during the summer of 1985. A questionnaire was designed to answer the question: Is mechanical rice transplanting needed? The questionnaire examined the following areas: 1. Labor shortage, particularly during the peak rice transplanting season. 2. Effect of potential rice area and distance of a rice farm from nearest town on labor availability. 3.The plant population of hand transplanted rice crop. 4. The distribution of plant density within the field.

Is plant population higher around the edges of field than in the center of field? 5. The trend in cost of hand transplanting in relation to paddy price.

Materials and Methods

The questionnaire was prepared at Cornell University and sent to the Farm Machinery Institute (FMI) of the Pakistan Agricultural Research Council, Islamabad for conducting the survey. The survey was undertaken in five main districts namely; Gujranwala, Sialkot, Sheikhupura, Lahore, and Kasur which are the main rice growing areas in zone 2. Five main roads were selected, one in each of these districts and then two towns were randomly selected on each main road. Using each town as a bench mark, 12 farmers from each of 12 categories made by various combinations of three levels (0-5, 5-10, 10-15 km) of distance from a nearest town and four levels (0-5, 5-10, 10-20 and over 20 ha) of potential rice area of farms were randomly selected and interviewed.

Results and Discussion

One questionnaire of a farmer from a category of 0-5 ha potential rice area and 5-10 km distance in the questionnaire packet received from Pakistan, 11 questionnaires, one from each of the remaining 11 categories were randomly selected and discarded. The analysis was made of 108 farmers, 9 from each of 12 categories mentioned in section 2.3.1. The three levels of distance from a nearest town (0-5, 5-10, and 10-15 km) will be written as distance 1, 2 and 3, whereas four levels of potential rice area. (0-5, 5-10, 10-20, and over 20 ha) are identified as area 1, 2, 3 and 4 in the tables and figures of this study. The farmers were numbered from 1 to 108 from category 1 through 12.

Potential Rice Area

There was a total potential rice area of 1946 ha in the surveyed rice farms. IRRI-6 and Basmati 370 are the main rice varieties grown on these farms. The Basmati 370 area was found to decrease during 1983-85, whereas the IRRI-6 area was found to increase slightly from 1982 to 1983. A 20% increase in IRRI-6 area was found from 1984 to 1985 and 56 to 58% of the total potential rice area was sown under rice during 1981-85 as shown in **Fig. 2**. The farmers gave various reasons for non-sowing of the whole potential rice area (**Table 1**). The main reasons are shortage of water (64%) and area needed for fodder production (27%).

Labor Situation

Labor is not easily available for rice transplanting as reported by 78 (72%) of the interviewed farmers. The effect of both distance and area was found significant at 0.05 level of significance (**Table 2**) on difficulty of labor availability. The

Fig. 2 Percent varietal distribution of potential rice area sown in Pakistan during 1981-85.

Table 1 Reasons of Non-sowing of Potential Rice Area

Reasons	No. of Interviewees	Percent
Fodder Production	32	27
Vegetable Production	3	3
Other Crops	7	7
Water Shortage	69	64
High Labor Charges	1	1
Non-suitability of Land	4	4
Labor Shortage	6	6
High Production Cost	3	3
Diseases and Pest Attack	1	1
No Reasons	12	11

Note: There are 28 interviewees who reported two reasons and 1 interviewee reported 3 reasons.

proportion of farmers reporting difficulty in labor availability generally increased with an increase in area and distance as shown in **Fig. 3**. The main reasons for the difficulty in labor availability shown in **Table 3** are: 1. Higher wage rates in towns; 2. Migration of rural labor to urban area and foreign countries; and 3. Higher wage rates and permanent nature of jobs in factories.

There were only 39 farmers (36%) who reported labor shortage during the 1984 peak rice transplanting season. The results of analysis of variance for labor shortage shown in **Table 4** indicate only a significant effect of area at 0.05 level. There seems some interaction between area and distance as shown in **Fig. 4**, but this is not statistically significant at 0.05 level.

There were 145 ha (7.4% of potential rice area), comprised of 64, 78 and 3 ha of IRRI-6, Basmati and other rice varieties, respectively, which were sown late during the 1984 rice transplanting season. The number of days of late sowing were found to be 10-20, 10-30 and 10 for IRRI-6, Basmati and other rice varieties, respectively. A total of 56 ha (3% of potential rice area) were not planted due to labor shortage in 1984.

Table 2 Analysis of Variance Difficulty in Labor Availability

Source of Variation	df	Sum of Squares	Mean Square	F-value
Distance	2	808.70	404.35	5.92
Area	3	1202.90	400.97	5.87
Distance* Area	1	1.60	1.6	0.02
Error	5	341.70	68.3	
Corrected Total	11	2354.90		

Table 3 Reasons of Difficulty in Labor Availability Reported by Surveyed Farmers

Reasons	No. of Inter-viewees	Percent
Migration of Labor to Urban Area and Foreign Countries	17	16
Preference of Work in Factories for Higher Wages and Permanent Jobs	23	21
Higher Wages in Towns	31	29
Labor Shortage	3	3
Hard Work and Low Wages	4	4

Table 4 Analysis of Variance Percent Farmers Reported Labor Shortage

Source of Variation	df	Sum of Squares	Mean Square	F-value
Distance	2	286.9	143.45	0.98
Area	3	1606.1	535.40	3.66
Distance Area	1	3.5	3.50	0.024
Error	5	731.1	146.22	
Corrected Total	11	2627.6		

Density of Plant Population

The plant population per m^2 of hand-transplanted rice crop was measured at eight locations: four along the edges and four in the center of the fields of each of interviewed farmer. Plant population per m^2 was then averaged both for edges and center of fields. The

Fig. 3 Farmers' response to labor access.

Fig. 4 Farmers' response to labor shortage.

Table 5 Analysis of Variance Plant Population/m² for Various Rice Area Levels

Field Location	Source of Variation	df	Sum of Squares	Mean Square	Prob > F
Along Border	Between Levels	3	11.36	3.8	0.415
	Within Levels	104	409.41	3.94	
	Corrected Total	107	420.77		
Center	Between Levels	3	10.30	3.43	0.653
	Within Levels	104	647.70	6.23	
	Corrected Total	107	658.00		

Table 6 T-test: Mean Plant Population/m² Along Border vs Center

Null Hypothesis (H_O): X bar = Y bar
Alternate Hypothesis (Ha): Not H_O

Parameter Statistic:

X bar (Mean plant population/m² along field border)	= 14.95
Y bar (Mean plant population/m² in field center)	= 12.00
Sx (Standard deviation of X bar)	= 1.98
Sy (Standard deviation of Y bar)	= 2.48
nl (No. of observations along field border)	= 108
n2 (No. of observations in field center)	= 108
SP^2 (Pooled Variance) = (Sx^2) (nl - 1) + (Sy^2) (n2 - 1) / (nl+n2 - 2)	
= $(1.98)^2$ (107) + $(2.48)^2$ (107) / (108+108 - 2)	= 5.035
T - statistic = (X bar - Y bar) / (sqrt (SP^2 (1/nl+1/n2)))	
(calculated) = (14.95 - 12) / (sqrt (5.035 (1/108+1/108)))	= 9.66
Value of T from table with df of 214 at 0.05	
Significance level	= 1.96

Since T - calculated > T - table, so we reject H_O and conclude that there is a statistically significant difference between mean plant population/m² along the border and in the center of field.

analysis of variance results shown in Table 5 indicate no significant effect on area level on mean plant population per m² both for edges and center of fields.

Mean plant population per m² (13.53) obtained from the average of edges and center of fields gave a plant population of 135 300 plants per ha which is only 68% of the recommended plant population per ha. Mean plant population per m² along the edges of field was higher and statistically significant at 0.05 level from mean plant population per m² in the center of field (Tables 6 and 7).

The above results indicate poor quality of hand-transplanted rice crop and the need to improve this operation. This is also confirmed as 90 (83%) of the surveyed farmers indicated thin plant population of the rice crop transplanted by manual labor.

Cost of Manual Transplanting

Hand-transplanting is done on a contract hiring of manual labor per acre basis in the surveyed area. This cost includes uprooting, transportation and transplanting of the rice seedlings. The questionnaire data on cost per acre was converted to per (ha). The average cost per ha was then computed for the years 1981-85. Since the paddy procurement per 40 kg was only available up to 1984, this price was estimated using a linear regression technique. The percentage increase in the cost per ha of hand-transplanting and procurement price per 40 kg was then computed as shown in Table 8. The average percent increase in manual transplanting cost per ha (6.5) was much higher than the average percent increase in procurement price per 40 kg (2.7) during 1981-85.

Table 7 Mean Plant Population/m² for Various Rice Area Levels

Area (Level)	Location in Field: Along Border	Location in Field: Center	Field Average
1	15.5 (2.12)	12.1 (2.75)	13.8 (2.43)
2	14.8 (1.80)	12.4 (2.75)	13.7 (2.02)
3	15.0 (2.17)	11.8 (2.47)	13.4 (2.17)
4	14.6 (1.83)	11.6 (1.90)	13.1 (1.65)

Note: The numbers in parenthesis are standard deviations.

Other Issues

Hand-transplanting of the rice crop is mostly done 1-2 days after the last puddling as reported by 98 farmers (91%) in the surveyed area. Because of poor land levelling conditions in the surveyed farms, high temperature (up to 110 F) and weekly access to canal irrigation water, most of the farmers apply more water than needed in the fields at the time of transplanting. Water depth at the time of transplanting was reported at 2.5-5.0, 5.0-7.5, 7.5-10.0, 10.5-12.5 and 12.5-15.0 cm by 3, 26, 39, 24 and

Table 8 Percent Increase in Manual Transplanting Cost/ha vs Paddy Procurement Price/40 kg during 1981-85

Items	Year: 1981	1982	1983	1984	1985	Average
Manual transplanting cost/ha (Rs.)	231	247	264	278	297	263
Increase in manual transplanting cost /ha (%)	-	6.9	6.9	5.3	6.8	6.5
Paddy procurement price/40 kg (Rs.)	85	88	90	92	94.5*	90
Increase in paddy procurement price/ 40 kg (%)	-	3.5	2.3	2.2	2.7	2.7

* Estimated on the basis of previous years prices.

16 farmers, respectively. Therefore, more than 50% of the farmers keep a water depth greater than or equal to 7.5-10.0 cm at the time of transplanting.

Canal and tube-well water are the main irrigation sources in this area. A majority of the farmers (56%) in the surveyed area reported use of both canal and tube-well water to irrigate their rice crop. The rest of the farmers use either canal or tube-well water for irrigation.

Wheat and burseem (fodder) or only wheat are sown as major *rabi* crops in this area. The numbers of farmers who grow wheat and fodder and only wheat as Rabi crop were 70 and 29, respectively.

Eighty percent of the farmers were eager to buy a transplanter, particularly the riding type. The rest of the farmers preferred to use a transplanter on a rental basis. All the interviewed farmers showed willingness to adapt nursery raising and field preparation practices needed for mechanical transplanting.

Conclusions

On the basis of results of this study, the following conclusions were drawn.

1. A small precentage of the potential rice area (10.4) sown late and non-transplanted in 1984 rice transplanting season indicated that there was no apparent shortage of labor. This is also substantiated by the fact that 91% of the farmers transplanted rice within 1-2 days of the last puddling of their fields. However, farmers are experiencing serious difficulties in getting labor for rice transplanting as reported by 78 (72%) of the interviewed farmers.
2. Manual labor transplanted only 68% of the recommended plant population of 200 000 seedlings per hill. The plant population along the border of field was also high and statistically significant at 0.05 level than in the center of field.
3. Average percent increase in manual transplanting cost per ha was much higher than the average percent increase in procurement price per 40 kg during 1981-85.
4. Eighty percent of the interviewed farmers indicated willingness to buy a transplanter. The rest of the farmers showed willingness to use a mechanical transplanter on rental basis. Farmers also showed willingness to raise their nursery crop and prepare fields according to the requirements of mechanical transplanter.

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Design and Development of a 6-Row Korean Transplanter

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Abstract

In an effort to mechanize the rice transplanting operation in Pakistan, a Korean rice transplanter was found appropriate for the country's condition as it uses root washed seedlings grown by the traditional method. However, this machine needs improvements in both feeding and transplanting mechanisms before its adaption in the country. Design improvements such as a positive unloading mechanism, seedling box with pressure plate and planting fork in the transplanter decreased the maximum number of rice seedlings in a hill from 8 to 4 and improved its seedling distribution pattern.

Introduction

Rice is both a staple food and cash crop in Pakistan. It is grown by manual transplanting of rice seedlings in well prepared puddled soil. The non-uniform distribution and inadequate number of rice seedling hills per hectare transplanted by manual labor (Khan, 1987) has pushed the demand for the development of suitable equipment needed to mechanize the rice transplanting operation.

In an effort to mechanize the rice transplanting operation in Pakistan, both root washed seedling and mat seedling transplanters from China, Korea, India, Philippines, and Japan were tested for their suitability. A 6-row Korean transplanter using root washed seedlings and the Japanese Chung Yuan and Yanmar planters using mat type seedlings gave the best results in terms of missing and floating hills (Rahman and Amjad, 1983). The Japanese machines were not suitable for Pakistan because the transplanters required: (i) great precision of field levelling, (ii) good water management practices, and (iii) high technical skills for growing mat type seedlings. The Korean transplanter (Fig. 1) uses root washed seedling grown by the traditional method, therefore, further testing and modification of this machine were carried out in Pakistan in 1978 (IRRI-PAK, 1978 and Jameel, 1981). The modified machine increased the planting depth to 5 cm and worked well in fields having water depth up to 10 cm. However, this machine still had problems in releasing the seedlings in the soil. These seedlings remained in the fork prongs of the transplanter in its upward movement. The fork on entering the seedling box of the machine in the next stroke disturbed the seedlings in it and caused some missed seedling hills. The seedlings in the seedling box were also disturbed by a pair of pushers which entered near the base of the seedling box and pushed the seedlings towards the comb wires as the

Fig. 1 6-row Korean paddy transplanter.

planting fork entered to pick them.

During testing of the transplanter in Pakistan, the seedlings per hill varied from 0 to 11 with an average of 3 plus seedlings per hill. This seedling distribution is not desirable in growing fine rice varieties like Basmati because of its high tilling capacity. Therefore, more development work is needed in the transplanting and feeding mechanism of this machine before its adaption in the country. This study was undertaken to make design improvements, development modifications in both the transplanting and feeding mechanisms of the Korean transplanter to improve its seedling distribution pattern.

Materials and Methods

The feeding and transplanting mechanisms of the transplanter were mounted on a stationary frame. The transplanter PTO shaft was powered with a variable speed electric motor. Metal containers (soil boxes) of 20x20x275 cm (WxHxL) mounted on two pairs of rubber wheels were placed on a rail made from aluminum C-channel. A variable speed, right angle gear drive motor was mounted on a frame with two rubber wheels provided for the soil box travel. A sprocket attached to motor shaft ran on a chain placed in the groove of the aluminum C-channel coupled to the rail. The soil box was connected to the motor frame and could move back and forth by the motion of

Fig. 2 Laboratory apparatus for evaluting seedling distribution of Korean transplanter.

Fig. 3 Linkage configuration for the motion of the planting fork.

motor. A control box with a time delay relay switch was constructed to simultaneously run both the transplanter and the soil box motors. **Fig. 2** shows the various components of this laboratory apparatus used for evaluating the performance of the transplanter.

Linkage configuration for the transplanter fork movement shown in **Fig. 3** gives it an elliptical motion. A locus of planting fork tip displacements of the transplanter with 0.175 rad (10°) intervals was traced on a tracing paper **(Fig. 4)**. An average planting displacement of 36 cm during the 5 cm vertical penetration of the planting fork into the soil was found from the displacement locus for each revolution of transplanter crank. This relationship was used in determining the transplanter fork speeds from the transplanter crank revolutions per sec. Since the transplanter is designed for a planting fork speed of 3 revolutions per second, this can give it a vertical penetration planting speed up to 108 cm/s.

Improvements in Transplanting Mechanism

A positive unloading mechanism was developed and installed on the fork mounting shaft to release the seedlings at the lowest position of

Fig. 4 Locus of planting fork tip displacement.

the planting fork into the puddled soil. This mechanism consists of a spring loaded shaft mounted on the fork mounting hollow shaft. A flat spring steel piece stiffened at one end (ejector) with two slots for its forward and backward motion is attached to a bracket coupled to the shaft. A flat bar with a curved end (cam) is mounted on the crank arm. A bent spring steel piece (follower) with matching bend to the cam is connected to the spring loaded shaft. **Figs. 5A** and **5B** show

Fig. 5A Positive unloading mechanism (disengaged). (a) Planting fork, (b) Seeding ejector, (c) Cam, (d) Spring-loaded shaft, (e) Follower.

Fig. 5B Positive unloading mechanism (engaged).

the details of this mechanism. The cam comes in contact with the follower just before the fork reaches its lowest position in the soil. This gives a clockwise rotation to the spring-loaded shaft through the follower. The shaft rotation pushes the ejector forcing the rice seedlings out of the fork prongs. The ejector also gives a push to the seedlings in the soil and this increases their standing capability.

Effect of Soil Aging and Planting Speed on Seedling Distribution

A preliminary investigation on seedling distribution of the modified (with positive unloading mechanism) transplanter without actually transplanting seedlings into the soil indicates that the transplanter should be used with the seedling root lengths of 1-2 cm and up to a fork planting speed of 50 cm/s. Since seedlings with 2-cm root lengths gave larger seedling withdrawal force (an index of seedling anchorage into the puddled soil after transplanting) than seedlings with 1-cm root lengths (Khan, 1987), paddy seedlings with 2-cm root lengths were used in this study.

Saturated puddled soil was prepared and poured in the soil boxes. The soil boxes were kept undisturbed for 2, 3 and 4 days to obtain puddled soil of these aging. Greenhouse grown Labelle rice seedlings of 35 days old with 2-cm root lengths after aligning their root bases were placed in the seedling box of the transplanter and were transplanted in the puddled soil of the soil boxes. Three planting speeds (30, 40 and 50 cm/s) were used for these tests. This arrangement gave a 3^3 factorial experiment with three levels of soil aging (2, 3 and 4 days) and three planting speeds (30, 40 and 50 cm/s). Each test was replicated three times. Data was collected on the number of seedlings transplanted per stroke. The average number of seedlings per hill, percent missing hills and percent of hills improperly transplanted are shown in **Table 1**.

The proportion of hills improperly transplanted was higher for soil aging of 2 days as compared with 3 and 4 days aging. The effect of planting speeds was inconsistent on the percentage of improperly transplanted hills. These findings agreed with results obtained in another study on puddled soil and rice seedling characteristics (Khan, 1987) in which the only main effect of soil aging was significant on the seedling withdrawal force. Seedling distribution data was lumped together for various planting speeds and plots of seedlings per hill versus percentage of hills planted, an indicator of seedling distribution pattern, are shown in **Fig. 6**. Not much effect of planting speeds was evident on the distribution pattern, but on the basis of percent hills up to 3 seedlings per hill, planting speed of 50 cm/s seems better as compared with planting speed of 30 and 40 cm/s. If these results are compared in terms of

Table 1 Seedling Distribution Statistics for Various Combinations of Soil Aging and Planting Speed

Soil aging (days)	Planting speed (cm/s)	Test replication	Average seedling per hill (No.)	Missing hills (%)	Hills with improperly planted seedlings (%)
2	30	R1	2.17	16.67	33.33
		R2	2.00	16.67	16.67
		R3	1.67	16.67	33.33
	40	R1	2.40	20.00	10.00
		R2	1.50	20.0	10.00
		R3	2.10	10.00	0.00
	50	R1	2.00	0.00	33.33
		R2	1.67	26.67	33.33
		R3	1.60	13.33	13.33
3	30	R1	2.86	14.29	14.29
		R2	2.29	14.29	14.29
		R3	1.57	14.29	0.00
	40	R1	2.60	10.00	0.00
		R2	1.80	10.00	20.00
		R3	2.20	10.00	10.00
	50	R1	2.80	0.00	20.00
		R2	1.93	20.00	0.00
		R3	1.53	26.67	0.00
4	30	R1	3.12	12.50	0.00
		R2	3.00	0.00	12.50
		R3	3.25	0.00	25.00
	40	R1	2.36	0.00	18.18
		R2	2.54	9.09	18.18
		R3	3.27	18.18	9.09
	50	R1	1.91	18.18	0.00
		R2	2.54	18.18	9.09
		R3	3.00	9.09	9.09

Fig. 6 Seedling distribution pattern for various planting speeds.

percent missing hills, then planting speed of 30 cm/s gave the lower percentage missing hills. There is not much difference in percentage missing hills between planting speed of 30 and 40 cm/s. Therefore, on the basis of percentage missing hills and planting efficiency (as planting speed is directly related to machine forward speed and hence its field capacity), planting speed of 40 cm/s was appropriate for this study.

Improvements in Feeding Mechanism

One of the few possible solutions to the problem of non-uniform seedling distribution is to separate and singularize the seedlings by a crew of workers sitting on a platform behind the machine. Investigations of manual seedling singularization have been conducted for several types of agricultural transplanters (Graham and Rohrbach, 1983). The speed of singularization and accurately supplying seedlings to a conventional tobacco transplanter was 54 plants per person per minute and 72 plants per two persons per minute (Suggs, 1979). Increased demand for singularization speed substantially increased planting errors and necessitated the need for some automatic mechanical singularization technique (Splinter and Suggs, 196*). Italian researchers tried to develop rice transplanters for working in flooded as well as dry soil conditions in which a group of workers, one for each row separated seedlings and placed them between rotating discs for transplanting (Low, 1969; Singh and Kishore, 1979; and Kurup and Datt, 1981). Due to their high operational cost, these machines did not gain widespread acceptance.

Another possibility is to separate rice seedlings by water or air streams before they are conveyed to the planting forks. The separation of rice seedlings can also be done by the projections of a rotating hollow cylinder. Various air, water and rotating cylinder concepts were tried at Cornell University and were found non-suitable for the following reasons:

1. Rice seedlings are biological material with considerable variations in their length and spread measurements.
2. The roots of rice seedlings tend to stick to each other.
3. The rice seedlings are susceptible to damage by mechanical handling.

The third possibility is to improve the feeding mechanism of the transplanter by exerting pressure behind the seedlings by placing a mild steel plate in the seedling box to provide a positive feeding to the planting forks. As seedlings are picked near their stem bases by the planting forks, this plate should have provision to apply more pressure near their stem bases, especially when the seedling box is nearly empty. The pair of seedling pushers in each seedling box of the transplanter should be removed to avoid seedling disturbance. This approach being simple in construction and operation was also tried at Cornell University. A mild steel plate (pressure plate) supported at the top on a round bar frame was attached to the seedling box as shown in Fig. 7. The pressure plate moved down by gravity towards the comb wires and exerted pressure on the seedlings in the box. A mild steel sheet was hinged to the top of the pressure

Fig. 7 Pressure plate assembly. (a) Frame, (b) Pressure plate, (c) Pressure adjusting screw, (d) Rice seedling.

plate and pressure near the seedlings stem bases was varied by changing the distance between the pressure plate and mild steel sheet by means of a pair of screws.

After installing the pressure plate, the transplanter was tested for its seedling distribution pattern with 35-day old Labelle rice seedlings. Seedling distribution data was collected for three planting speeds (30, 40 and 50 cm/s) with four replications. The average number of seedlings per hill and percentage missing hills are shown in **Table 2**. Replication data of each planting speed was lumped together and plots of seedlings per hill versus percentage of hills planted are shown in **Fig. 8**.

Planting speed had no influence on the percentage of missing hills. The average seedlings per hill are lower with planting speeds 30 and 40 cm/s as compared with planting speed of 50 cm/s. There was no difference in the average number of seedlings per hill between planting speed of 30 and 40 cm/s. On the basis of the percentage of hills up to 3 seedlings per hill, a planting speed of 30 cm/s gave better results as compared with planting speeds of 40 and 50 cm/s. For transplanting efficiency, the planting speed of 40 cm/s was again found feasible for this machine.

Use of the pressure plate instead of a pair of pushers decreased the maximum number of seedlings per hill from 8 to 6. It also decreased the percentage missing hills and improved the seedling distribution. In order to further decrease the maximum number of seedlings per hill and improve seedling distribution, changes were made in the planting fork tip, and gap and the rigidity of comb wires.

Table 2 Seedling Distribution Statistics for Different Planting Speeds

Planting speed (cm/s)	Test replication	Average seedling per hill (No.)	Missing hills (%)
30	R1	3.0	0.00
	R2	2.5	10.00
	R3	1.8	20.00
	R4	1.7	10.00
40	R1	2.6	10.00
	R2	2.5	10.00
	R3	1.7	20.00
	R4	2.4	10.00
50	R1	2.4	0.00
	R2	3.4	10.00
	R3	2.6	20.00
	R4	2.7	20.00

Fig. 8 Seedling distribution pattern for various planting speeds with pressure plate.

A new planting fork with a more curved tip and tapered grooves of 3.5 mm as compared with an almost uniform width groove of 4.5 mm in the original planting fork was designed, constructed and tested. The improved planting fork is 3 mm longer than the original fork and thus can penetrate deeper into the seedling box. This helps it in picking up the seedlings even in the disturbed seedling area. Because of the narrow and tapered grooves, the improved planting fork has rounded edges and this causes less damage to the seedlings as compared with the original fork. The curved tip of this fork also aids in wiping off the excessive seedlings as it exits from the seedling box. **Fig. 9** shows both the improved and original planting forks.

There was a gap of 3.01 mm between the original wires in the comb and this was too wide to permit blocking of excessive seedlings picked by the forks, especially small diameter seedlings. A new seedling box with a comb wire holder shown in **Fig. 10** was designed and constructed to accommodate wires from 1.7 to 2.31 mm diameter. This holder has a provision to vary the gap between the brush end and comb wires in both the vertical and horizontal directions and, therefore, the entry height and the angle of planting fork in the seedling box can be varied.

The comb wire holder was attached to the seedling box to give a gap of 11.5 mm between the seedling box brush and the tip of the wires. The improved planting fork was bolted on its holder with a distance of 60.3 mm between holder end and the tip of the fork which gave the fork an entry height of 49.4 mm. Seedling distribution data of the transplanter at a planting speed of 40 cm/s with the modified planting fork and seedling box was collected with 35-day Labelle rice seedlings. Mild steel wires of 2.03,

Fig. 9 Planting forks: (a) Original version and (b) Modified version.

Fig. 10 Improved seedling box with wire comb: (a) Seedling box, (b) Pressure plate, (c) Wire comb.

2.18 and 2.31 mm diameters were used in the seedling box comb for this test.

The average number of seedlings per hill and percentage missing hills were computed and are shown in **Table 3**. The average number of seedlings per hill were 2.25, 2.08 and 2.00 with 2.31, 2.18 and 2.03 mm diameter wires, respectively. The maximum number of seedlings in a hill decreased from 8 to 5.

Table 3 Seedling Distribution Statistics for Different Comb Wires

Comb wire dia. (mm)	Test replication	Average seedling per hill (No.)	Missing hills (%)
2.31	R1	1.32	8.3
	R2	2.25	8.3
	R3	1.83	16.7
	R4	1.83	8.3
	R5	2.00	8.3
	R6	1.75	8.3
2.18	R1	2.00	8.3
	R2	2.08	8.3
	R3	1.50	16.7
	R4	1.67	25.0
	R5	1.33	16.7
	R6	1.92	8.3
2.03	R1	1.50	16.7
	R2	1.50	8.3
	R3	1.25	16.7
	R4	1.25	8.3
	R5	2.00	8.3
	R6	1.50	8.3

Both the average number of seedlings per hill and percentage missing hill were improved substantially by the incorporation of changes in the planting fork and seedling box of the transplanter. Replication data of this test was lumped together and plots of seedlings per hill versus percent hills are shown in **Fig. 11**. On the basis of the percent of hills up to 3 seedlings per hill, there is no difference between 2.31 and 2.18 mm diameter wires but 2.03 mm diameter wire gave the highest percent as compared with 2.31 and 2.18 mm diameter wires. The percentage of hills up to 3 seedlings per hill varied from 92 to 97 with these large diameter comb wires against 75 with the original comb wires at a planter fork speed of 40 cm/s.

Fig. 11 Seedling distribution pattern for various diameter comb wires.

The improved planting fork after removing 1 prong (with 2 prongs) was intalled on the transplanter to further reduce the maximum number of rice seedlings in a hill and hence the average seedlings per hill and percent missing hills. The transplanter gave 1-2 seedlings per hill only for the first few planting strokes immediately after filling the seedling box. The 2-prong planting fork skipped every alternate wire gap because of fixed indexing of the seedling box per planting stroke and increased the number of hanging seedlings through these gaps. A decrease of 1/2 of the present indexing of the seedling box needs redesigning of the transplanter gear box. Because of financial and time constraints, changes were not made in the gear box and further investigation on the possible use of a 2-prong planting fork was not undertaken in this study.

The improved planting fork tip was made more curved to penetrate deeper into the seedling box and pick up fewer seedlings which might have affected its seedlings placement capability into the soil. In order to assess the effect of this change in the planting fork, seedling distribution data was taken with 35-day old Labelle rice seedlings in puddled soil of 4 days aging. The modified planting fork placed seedlings into the soil even better than the original as not a single seedling was found improperly planted in this test. The average seedlings per hill and percent missing hills shown in **Table 4** were found similar to the results of seedling distribution shown in **Table 3**. The maximum number of seedlings in a hill decreased to 4 in this test.

Table 4 Seedling Distribution Statistics for Different Comb Wires with Puddled Soil of 4-Day Aging

Comb wire dia. (mm)	Test replication	Average seedling per hill (No.)	Missing hills (%)
1.98	R1	1.69	15.4
	R2	1.77	0.0
	R3	1.85	15.4
	R4	1.61	7.7
2.03	R1	1.54	7.7
	R2	2.08	7.7
	R3	1.77	0.0
	R4	1.46	7.7
2.18	R1	1.45	25.0
	R2	1.80	0.0
	R3	1.50	15.0
	R4	1.95	5.0

Discussion of Results

The seedling distribution pattern of the transplanter mainly depends upon the proper placement of rice seedlings in the seedling box and adequate seedling root lengths. The seedlings with large root lengths (root areas) increase their standing capability into the soil. However, the degree of entwining of adjacent rice seedling roots also increases with large root lengths and this affects their separation by planting fork. The root lengths also affect the stem base position in relation to the entry point of the planting fork in the box and hence seedling distribution pattern of the transplanter. The results of this study indicated that rice seedlings with 1-2 cm root lengths should be used with this transplanter for better seedling distribution.

A minimum penetration speed of the planting fork is needed to pick up the rice seedlings from the box. An increase in planting speed eases the seedling picking but disturbs the orientation of the seedlings in the box. A planting speed up to 50 cm/s was found suitable for the transplanter. The results shown in **Tables 1** and **2**, as well as **Fig. 6** indicate that the machine should be used with a fork penetration speed of 40 cm/s for better performance.

The installation of a positive unloading mechanism helped to clear the seedlings from the planting fork and improve their standing capabilities. The seedling box pressure plate improved the seedling distribution by decreasing both the maximum number of seedlings in a hill from 8 to 6 and percentage of missing hills.

The installation of the improved planting fork further reduced the maximum number of seedlings in a hill and increased their standing capabilities. The new seedling box with provision for changing comb wires facilitated the comb wire gaps according to stem size of the seedling stock. These modificaitons further reduced the maximum number of seedlings in hill to 4.

The design and development improvements made in the transplanter in this study has substantially improved its performance. There is still need for further modifications in the transplanter gear box to investigate the effect of a 2-prong planting fork on its seedling distribution pattern.

The results of this study have clearly indicated that the performance of the transplanter depends upon thorough washing of rice seedlings, trimming of their stems and roots to 20 and 2 cm, respectively, and their careful placement in the box. Its use will require considerable manual labor which is already scarce in the country. Therefore, there is need to investigate the possibility of adaption of the mat type transplanters and other rice growing methods which need less manual labor, besides, continuing design improvements on the Korean transplanter.

Conclusions

On the basis of results of this study, the following conclusions were drawn:

1. The planting fork of a 6-row Korean transplanter can transplant seedlings up to a vertical planting speed of 108 cm/s while travelling at a forward speed of 60 cm/s. A better seedling distribution was found with a

planting speed of 40 cm/s and rice seedlings of 2 cm root lengths.

2. The percentage of seedling hills with improperly transplanted seedlings increased with a decrease in soil aging which indicates a definite effect of soil aging on seedling anchorage into the puddled soil.
3. Installation of a positive unloading mechanism to release rice seedlings in the soil at the lowest position of the planting fork worked satisfactorily and improved the seedling distribution pattern of the machine. The incorporation of a pressure plate, changing of planting fork tip angle, and rigidity and gap between comb wires decreased the number of seedlings per hill from 8 to 4 and hence improved the seedling distribution pattern of the machine.

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Field Performance of Seeding Devices in Rainfed Situation in Orissa, India

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Abstract

Placement of seeds at proper depth results in a better crop stand. Thus, six seeding devices have been tested under dryland condition broadcasting. In each case the amount of energy utilization in drilling the seeds and seed distribution efficiency have been determined and grain yield on the experimental fields has been observed. The overall efficiency of seed-cum-fertilizer drill developed by the Department of Agriculture, Government of Orissa, is the highest and thus it is recommended the farmers of Orissa use seed drill to sow the paddy seeds under dryland situation.

Introduction

The State of Orissa is situated in the northeastern section of India and extends over a geographical area of 15.54 million ha between 17°50′ and 22°30′ N latitude and the medians of 81°21′ to 87°38′E longitude. The major source of water available for agriculture is obtained from rainfall. The rainfall pattern in Orissa is very erratic and its distribution is quite uneven. Despite the average annual rainfall of 1 500 mm Orissa observes drought period once in three years. Conservation of moisture is one of the solutions to such a problem. Conservation of moisture can be considered from two angles – one aspect may relate to the field conservation practices and other aspect may relate to the utilization of available moisture before it is lost. Thus placement of seeds at proper depth in soil for better plant stand is very important under dryland situation. Therefore, field experiments on dryland agriculture research project are being conducted at two sites (upland and medium land) at the Central Research Station of the Orissa University of Agriculture and Technology, Bhubaneswar. The upland site in Bhubaneswar is a typical oxisol found in parts of the coastal districts of Orissa. The surface soil is coarse textured, well drained, strongly acidic in reaction, low in nutrient status and is underlain by sandy clay loam type soil. The soil in the medium land site may be termed as inceptisol having a sandy clay loam texture up to 30 cm deep.

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Table 1 Physical and Chemical Characteristics of Soil (0–22 cm depth) in Experimental Sites

Items	Upland	Medium land
Mechanical Composition		
Sand (%)	78.7	64.0
Silt (%)	7.8	7.0
Clay (%)	13.5	29.0
Texture	Sandy loam	Sandy clay loam
Colour	Raddish brown	Pinkish grey
Bulk density (g/cm^3)	1.8	1.82
Porosity (%)	35	32
Field capacity (cm^3/cm^3)	0.16	0.24
Infiltration rate (cm/h)	2.0	1.0
pH	5.1	5.8
Organic carbon (%)	0.55	0.39
Total nitrogen	0.05	0.03
Electrical conductivity (mmhos/cm)	0.05	0.09

The detailed characteristics are presented in **Table 1**.

Seed Drills and Treatments

Six seed drills were used in the test. Broadcasting and covering by *desi* (village) plough was taken as one of the treatments for comparison. A brief description of each seed drill is given in **Table 2**. The detailed dimensions of the implement-factory seed-cum-fertilizer drill with its different views are shown in **Fig. 1**.

Table 2 Main Features of Seed Drills

Name of seed drill	Width (cm)	Source of power	Seed metering device	Capacity of hopper/ drum (kg)	Row spacing (cm)	Type of furrow opener	Number of furrow opener
Implement Factory Seed drill	45	Human	Plastic roller with small round depressions	1.5	15	Cultivator type	3
Implement Factory seed-cum-fertilizer drill	30	Human	Plastic roller with small round depressions	2.0	15	Cultivator type	2
Annapurna seed drill	75	Human	Drum with holes on the periphery. Circular iron belt regulates the size of openings	4.5	15	Hoe type	5
Annapurna seed-cum-fertilizer drill	35	Human	–do–	2.5	15	Hoe type	3
CAET 3-row seed drill	52	Bullock	Wooden roller with small round depressions mounted on the shaft	6.0	20	Cultivator type	3
CAET 5-row seed drill	70	–do–	–do–	10.0	15	–do–	5

The field trials were conducted on the plot of a net area of 200 m^2 (20 m x 10 m) laid out in a randomized block design with three replications. The land preparation was done by tractor-drawn plough and farm yard manure of 5 ha was added during land preparation. Paddy seed (variety DR 92) was sown on 24.6.85 and harvested on 25.9.85. Seed rate of 75 kg/ha was maintained for all the treatments. Fertilizer was added at the rate of 60 kg N, 30 kg P_2O_5 and 30 kg K_2O/ha.

Results and Discussion

Table 3 shows the kind of power sources utilized in various activities of operation of the seeding devices.

Energy utilization by different seeding devices is given in **Table 4**. The calculations are based on a ratio of one adult man-hour that is equivalent ot 1.96 MJ and one pair of bullock-hour to 14.05 MJ.

The energy utilization for the broad-casting and bullock-drawn three-row seed drill is almost similar.

Fig. 1 Implement Factory seed-cum-fertilizer drill.

Table 3 Time Taken by Different Power Sources to Operate Seeding Devices per Hectare of Land

Treatment	Power	Time taken by man-power in h/ha			Time taken by one pair of bullock in h/ha
		Man-hour for broad-casting/ drilling	Man-hour for operat-ing the plough	Total number per ha	
A	2 man	16	16	32	–
B	2 man	19	19	38	–
C	2 man	11	11	22	–
D	2 man	19	19	38	–
E	One man and one pair of bullock	13	–	13	13
F	One man and one pair of bullock	9	–	9	9
G	One man and one pair of bullock	3	13	16	13

Table 4 Energy Components of Different Sources for Computing the Total Energy Utilization by Different Seeding Devices

Treatment	Energy utili-zation by man-power	Energy utili-zation by animal power	Total energy utilization	Percentage of energy utilization as compared to broad-casting	Less energy utilization
	MJ/ha	MJ/ha	MJ/ha		%
A	62.72	–	62.72	29.3	70.7
B	74.48	–	74.48	34.8	65.2
C	43.12	–	43.12	20.1	79.9
D	74.48	–	74.48	34.8	65.2
E	25.48	182.65	208.13	97.2	2.8
F	17.64	126.45	144.09	67.7	32.3
G	31.36	182.65	214.01	100.0	–

The five-row seed drill is preferred as compared to three-row seed drill in view of less energy utilization as seen from **Table 4**. The energy utilization for the implement factory seed-cum-fertilizer drill and in case of the Annapurna seed-cum-fertilizer drill is similar. These two seed drills sow the seeds in two rows and are operated by two persons and they take almost the same time to sow the seeds per unit area. Among all the seed drills the Annapurna seed drill sows the seeds in five rows and thus the coverage is greater per unit time compared to other seed drills. Column 6 of **Table 4** shows that less energy per ha is utilized by different seeding devices as compared to broadcasting. The maximum energy of about 80 % is saved when seeds are drilled by the Annapurna seed drill and 71 % when drilled by the implement factory seed drill as compared to broadcasting. From the **Table 4**, it is very evident that the farmers should use the seeding devices to drill the seeds and abandon the traditional method of sowing seeds by broadcasting.

Depths of seed placement at number of points were measured and the average value for each treatment is given in **Table 5**.

The seed drills developed by Department of Agriculture, Government of Orissa and Annapurna seed-cum-fertilizer drill put the seed at almost the same depth, i.e., at 2.85 cm. For the broadcasting system the seeds remain within a depth of 1 cm. Three row bullock-drawn seed drill puts the seeds below 3 cm depth whereas the five-row bullock-drawn seed drill puts the seeds within a depth of 2 cm.

Table 5 Average Depth of Seed Placement

Treatment	Depth, cm
A	2.85
B	2.87
C	1.43
D	2.85
E	3.20
F	1.70
G	0.86

Table 6 Average Plant Population per Meter Length of Row

Treatment	Average population per meter length of row
A	25
B	28
C	20
D	23
E	24
F	26
G	120/m²

The maximum number of plant population has been established when seeds are sown by the seed-cum-fertilizer drill.

Uniform placement of seeds along the line is one of the important factors which affects the crop growth and thus the yield. Uniform placement of seeds by the seed drills depend on their metering devices. Therefore, the design of metering devices is one of the most important aspects of seed drills. To quantify how uniformly the seeds are placed in the soil along the line, the following equation was used.

$$Se = 100\left(1 - \frac{y}{d}\right) \quad \ldots . (1)$$

Where,

Se = seed distribution efficiency of the seeding device

y = average numerical deviation of number of plants per meter length of row from average number of plants per meter run

d = average number of plants per meter length of row

The above formula evaluates the extent to which the seeds are uniformly distributed in the soil along

Table 7 Seed Distribution Efficiency

Treatments	Se (%)
A	80
B	81
C	65
D	67
E	77
F	78
G	62

Table 8 Grain Yield in Quintal per hectare

Treatment	Average yield g/ha	Percentage increase as compared to broadcasting
A	13.69	98
B	17.15	149
C	8.25	20
D	9.10	32
E	9.95	44
F	11.80	71
G	6.90	–
S.E.(m) ±	0.89	
C.D.(0.05)	0.79	

the line by the seeding device which can also be called the uniformity coefficient of metering device of the seed drill. Plant population per meter length along the row was taken at a number of places and the seed distribution efficiency of the seeding device was calculated using the Equation (1) as shown in **Table 7**.

Both Annapurna seed drills distributed the seeds very poorly along the row as compared to other seed drills. The Annapurna seed-cum-fertilizer drill is 14% less efficient than the implement-factory seed-cum-fertilizer drill in drilling the seeds uniformly in the soil. As the metering devices of both the implement factory seed drills are of the same type, the seed distribution efficiency values obtained in these two cases are almost the same.

Table 8 records the grain yield per ha of land with respect to different treatments. The percentage of increase of yield per ha for each treatment as compared to broadcasting is also been shown in **Table 8**.

The implement factory seed drill has caused 98% higher yield than broadcasting. The Annapurna seed drill and Annapurna seed-cum-fertilizer drill have caused 20% and 32% higher yield, respectively, over broadcasting. Five-row bullock-drawn seed drill has resulted in 71% higher yield than broadcasting but 45% less yield than the implement factory seed-cum-fertilizer drill which has produced a maximum grain yield of 17.15 quintals per ha which is 149% higher than broadcasting. When comparison is made between implement factory seed-cum-fertilizer drill and implement factory seed drill, the former has produced 25% higher yield per ha than the latter.

Table 9 Overall Efficiency Factor for Performance Comparison among Seeding Devices

Treatment	Energy utilization factor	Seed distribution efficiency factor	Grain yield factor	Overall efficiency factor
A	1.707	0.80	1.98	2.70
B	1.652	0.81	2.49	3.33
C	1.799	0.65	1.20	1.40
D	1.652	0.67	1.32	1.46
E	1.028	0.77	1.44	1.34
F	1.323	0.78	1.71	1.76
G	1.000	0.62	1.00	0.62

In order to evaluate the overall performances of different seeding devices, the combined effect of energy utilization, distribution efficiency and grain yield per ha well taken into consideration. Each factor, i.e., energy utilization factor, seed distribution efficiency factor and grain yield factor was given a numerical value for different treatment as compared to broadcasting as shown in **Table 9**. The implement factory seed-cum-fertilizer drill has attained maximum overall efficiency factor, i.e., 3.33. The next best seeding device is the implement factory seed drill which has received 2.7 as its overall efficiency factor.

Conclusion

Conservation of moisture and the best utilization of available moisture in soil need better care in rainfed agriculture for better crop stand and high yield. The solution to the latter problem can be accomplished by use of seeding devices. From the field experiments it can be concluded that the farmers of Orissa can use the implement factory seed-cum-fertilizer drill for sowing the paddy seeds under dryland condition for better crop stand and higher yield. Though the Annapurna seed drill utilizes minimum energy during its operation, considering the combined effect of energy utilization, seed distribution efficiency and grain yield, the implement factory seed-cum-fertilizer drill proved to be better. Manually-operated seed drills perform better in the field than the animal-drawn seed drill. The performance of the latter is low because of the operational difficulties encountered during operation of the seed drills.

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The AMRI Sugarcane Planter

by
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Abstract

The AMRI sugar cane planter plants 53 000 to 87 000 sets per hectare. It saves 80 man-h per ha which is otherwise required for set cutting. The best planting can be achieved while operating the planter in 1st low gear at 1 200 rpm and in 2nd low gear at 1 200-1 400 rpm. It costs approximately U.S.$36.80 per ha while planting with this planter, which is about 43% less than the indigenous planting method.

Introduction

Sugarcane is one of the most important cash crops grown in Pakistan. In 1983-84 the area under sugarcane cultivation was 0.90 million ha or about 4.5% of the total cultivable area of the country. The annual increase in sugarcane acreage and yield per ha is still very low even with the expansion of sugarcane industries in the country. Sugarcane cultivation requires labour intensive operations such as harvesting, stripping and planting. Inadequate farming techniques lack modern and versatile equipment for sugarcane cultivation and small numbers of sets per ha are the main causes of low yield.

The shortage of timely labour and exhorbitant labour hiring rates force the farmers to limit their sugarcane acreage. Hence, there is an urgent need to mechanize these operations fully or partially in order to cut down man-h, reduce operational cost, but plants more seed. The research division, AMRI, Faisalabad has designed and developed a semi-automatic sugarcane planter which fulfils all the above requirements. The planter is capable of planting 53 000 to 78 000 sets per ha at different tractor ground speeds, whereas with manual planting only 45 000 to 50 000 sets per ha can be achieved. The planting man-h per ha with this planter was almost 3 times less than that required in manual planting. The set cutting and planting cost with this machine was calculated at U.S.$36.80 per ha as compared to U.S.$63.35 per ha for manual planting method.

Available Sugarcane Planting Machines

Different private and public agencies have tried to design and develop sugarcane planters and some of them have come up with different types of designs, but still there were some technicalities due to which those planters are not very well accepted by the farmers.

An Australian sugarcane planter was a single row PTO-driven, tractor mounted, which opened the furrow, cut the sets and placed them into the furrow properly. The fertilizer arrangement was also available with that planter. Two men sitting on the trailer attached to the rear of the planter for carrying of canes, were engaged to feed the canes into the planter. The planter cut the canes into sets of predetermined length and dropped them into the furrow. That planter along with the trailer was available for U.S. $4 320 approximately from Millat Tractors Ltd., Lahore. The high initial investment and a long field for an efficient operation were the main problems in the adoption of that machine.

An Indian sugarcane planter was a billet type, two-row and semi-automatic, tractor-mounted. The sets were dropped manually through chutes into the furrow opened by the planter. Hoppers were provided to store sets and fertilizer. The machine was also equipped with set covering and soil compacting system. Its field capacity was measured at 0.26 ha/h with double set placement method. Its row-to-row distance could be varied from 760 mm to 910 mm. The design was copied and developed by some of the manufacturers due to its low

initial cost, but the non-uniformity in the placement of sets and labour needed for cutting and transportation of the sets were the major problems in that planter.

The FMI two-row planter consisted of set cutting mechanism, cane hopper, furrow openers and fertilizer applicators. The set cutting mechanism of the planter was significantly different and ideal in performance from the other mechanism. It was powered from tractor rear wheel through chain and sprockets firstly, but later on was modified and replaced with PTO drive system with the help of worm gear. This was done to improve and get faster cutting speed. In this planter the cane of 1.5 m to 1.8 m long were fed horizontally to the rotating finger wheels, which held the cane and pressed it against the three equally spaced stationery curved knives. The knives cut the cane into four pieces and dropped two sets into one furrow through diverting chutes, which in turn positioned and placed the sets into the furrow according to the double set placement method. To maintain set length uniform in this planter was difficult because the two inner sets were cut 0.45 m long each due to fixed position of the curved knives. The length of outer two sets depended on the actual length of individual cane, efficiency and accuracy in feeding. Straight and 1.5 m to 1.8 m long canes, accuracy and activeness in feeding and proper set cutting speed with respect to tractor forward travel speed were the main drawbacks in this design.

AMRI Sugarcane Planter

The main parts of the AMRI sugarcane planter are main frame, furrow openers, cane feeding chutes, set cutting mechanism, feeder seats and space for storing of canes (**Figs. 1 and 2**). The machine is mounted behind the tractor with three-point linkage and is powered through tractor PTO shaft. Two spur gears were used to reduce PTO speed and a cam mechanism was utilized to deliver this speed to the horizontal sliding frame on which the cutters were fitted (**Fig. 3**). The sugarcane stalks are fed vertically through feeding chutes. The men drop the canes into the chutes, which help to guide the canes toward cutters and also provide support for effective and positive cutting and shearing of canes. The feeding and cutting of canes at faster PTO speed was based on free fall principle, but at slower PTO speed it was controlled under constant fall length. Under the chutes metal plates called deflectors were provided to divert and position the sets accurately into the furrow.

Set Cutting Speed

The cutting of sugarcane sets were based upon free fall principle. The time required to cut one set of 457 mm length is calculated by using equation $S=ut+\frac{1}{2}gt^2$. Where S represents the distance of travel by the sugarcane before next cutting or length of one set (S=457 mm), u represents the initial velocity of cane at the time of first cutting (U=0), g represents acceleration due to gravity ($g=9.81$ m/sec^2) and t represents the time between first and second cutting. Substituting the above given values in the equation

Fig. 1 Main components of AMRI sugarcane planter.

Fig. 2 AMRI sugarcane planter.

Fig. 3 Power drive and cutting mechanism of AMRI sugarcane planter.

Table 1 Cane Wait-time and Total Drop Time before Cutting at Different PTO Speeds.

Tractor PTO.* RPM (N_p)	Cutter frame RPM (N_c)	Time to complete one revolution of cutter frame (t_{td})	Drop time from reference point to divertor plate. (t_{fd})	Cane wait time on divertor before cutting (t_{cw})
200	50	1.2	0.3	0.9
300	75	0.80	0.3	0.5
400	100	0.60	0.3	0.3
500	125	0.48	0.3	0.18
540	135	0.44	0.3	0.14
600	150	0.40	0.3	0.10
700	175	0.34	0.3	0.04
800**	200	0.30	0.3	0.00

Remarks: * Tractor Fiat-640 was used. ** Theoretical maximum PTO rpm at which cane wait time on diverter plate becomes zero, with PTO to cutter frame speed ratio equal to 4.

gives t equals to 0.31 sec.

According to the cutter frame configuration the cutter frame completes one revolution in cutting of one set or 0.31 sec are required to complete one revolution of the cutter cam. Thus the cutter cam requires approximately 193 rpm to cut 457 mm cane set under the free fall principle.

To achieve cutter speed equal to 193 rpm is not difficult, but it created the following problems.

a) Different combination of gears are required to get desirable constant cutter speed (193 rpm) with different PTO speeds. The free fall feeding of cane in this planter is independent of its cutter speed and forward travel speed. An efficient planting can only be done with the best combination of cutter speed, forward travel speed and seed feeding speed.

b) Faster forward speed with higher engine rpm is required to operate the planter with cutter speed equal to 193 rpm, which results in inefficient and non-uniform feeding of canes.

Fig. 4 Cane feeding and set cutting mechanism.

Thus the free fall cutting was modified into the free fall feeding and controlled cutting with the addition of metal plate below the cutter at a distance of 457 mm in line with the feeding chute (Fig. 3). This plate performs two functions: stops downward fall of cane (to maintain required length of set) until the cutter cuts it and to divert and drop the set into the furrow accurately. With this arrangement the planter worked accurately even at slower PTO speed. Again, at faster PTO speed cutting happened under free fall principle but at slower PTO speed controlled cutting with constant length of fall occured.

The two spur gears of 15 teeth and 60 teeth were used to reduce PTO speed and delivered it to the cutter frame through cam mechanism (Fig. 4).

While operating the planter at slower PTO speed, the cutter frame does not complete its one revolution (or cutting of one set of specific length) in the specified time, which a cane takes to move from reference point (cutter) to the

diverter plate. In other words, the cutter frame takes longer time to complete its cutting revolution. Therefore, the cane stops on the diverter plate and waits for cutter to come and cut it. The diverter stop or waiting time for cane can be calculated by using following equation.

$$t_{cw} = t_{td} - t_{fd}$$

$$t_{cw} = 1/N_c \times 60 - t_{fd}$$

Where

t_{td} = Total drop time before cutting

t_{cw} = Cane waiting time on diverter plate before its cutting

t_{fd} = Free fall drop time from reference point (cutter) to diverter plate

N_c = Cutter frame rpm.

At higher cutter frame speed the dropping and cutting of canes occur almost under free fall principle, because the cane waiting time on diverter plate approaches to zero.

Field Performance

The sugarcane planter was tested in the field (**Fig. 5**) at different forward and PTO speeds to determine the best combination between tractor forward speed and planting speed of the planter. The best combination of the speeds would be the one at which the planter will plant 53 000 to 87 000 sets per ha with a uniform and efficient feeding without any miss (**Fig. 6**). **Table 2** shows the number of sets per row of 670 mm length, sets per ha and average set length while operating the tractor at different gear speeds with different engine rpms.

Fig. 5 AMRI sugarcane planter working in the field.

Fig. 6 A uniform planting and placement of sugarcane sets into the furrow without missing.

Fig. 7 Planter is working in 1st low gear at 1200-1400 engine rpm.

The variation in number of sets among the rows in the same gear speed and engine rpm was due to the different feeding efficiency and capacity of each feeder. It is apparent from the data given in **Table 2** and **Fig. 7** that the best tractor forward speed for the best planting (greater number of sets per ha) with this planter was achieved with the 1st low gear at 1 000-1 200 engine rpm or with 2nd low gear at 1 200-1 400 engine RPM.

The data in **Table 3** show that the planting time per ha can be reduced by increasing the engine rpm within the same speed gear, but it also reduces the number of sets per ha. Increase in the engine rpm gives more increase in forward travel speed as compared to PTO speed.

The total planting cost of U.S. $400.09 per ha was calculated along with 142.50 bullock-h per ha and 589 man-h per ha in case of indigenous method of planting. Whereas the mechanized method of planting (especially with AMRI designed sugarcane planter) gave 47

Table 2 Number of Sets per Row, Sets per ha and Average Set Length at Different Gear Speed and Engine RPM

Gear position	Engine RPM	No. of sets per row (670 mm row length)			No. of sets per ha	Average set length(mm)
		I Right row	II Middle row	III Left row		
1st low gear	1000	393	332	415	87427	454
	1200	382	371	387	87427	454
2nd low gear	1200	194	224	200	47504	457
	1400	231	209	261	53568	457
	1500	183	176	297	50536	452
	2000	209	217	221	49525	431.8
3rd low gear	1500	108	184	164	34869	431.8

Table 3 Planting Time per ha and Planting Speed of Tractor at Different Gears

Gear position	Engine RPM	Tractor field speed (km/h)	Planting time* per ha (h)
1st low gear	1000	0.77	7.59
	1200	0.80	7.30
2nd low gear	1200	1.11	5.57
	1400	1.42	4.58
	1500	1.48	4.46
	2000	2.08	3.47
3rd low gear	1500	2.80	2.83

Remarks: * Planting time includes minor stoppage and cane loading time during field operation.

Table 4 Sugarcane Planting Cost and Man-hour per Hectare

Indigenous planting	Bullock-h	Man-h	Cost U.S. $
1 Land Preparation			
Raja-hal 6–8 ploughing per ha at the rate of 12 man-h/ploughing/ha	72–96	–	61.00
Planking 4 times/ha 1.25 man-h/plank/ha U.S. $ 7.62/ha for one ploughing and planking	5	–	–
2 Irrigation			
8 h/ha U.S. $ 0.93/h	8	–	7.44
3 Farm yard manure(F.Y.M.) and fertilizer 25 carts load F.Y.M./ha			
U.S. $ 1.23/cart F.Y.M. Purchase charges	–	–	30.75
U.S. $ 1.54/cart F.Y.M. transportation charges including loading and unloading	39	124	38.50
F.Y.M. spreading 2 men for 10 h/ha (U.S. $ 1.85 per 8 man-h)	–	20	4.62
Fertilizer dose per ha			
DAP=5 bags U.S. $ 9.20/bags	–	–	41.00
Urea=2.5 bags U.S. $ 7.09/bags	–	–	17.72
K_2SO_4 = 2.5 bags U.S. $ 3.20/bags	–	–	8.00
Fertilizer spreading	–	5	1.15
4 Seed			
Seed rate 5.92t/ha or 45000 to 50000 sets/ha. U.S. $ 0.55/40 kg	–	–	82.22
5 Seed harvesting, cleaning and shifting 12 man for 16 h/5.4t	–	192	44.44
6 Set cutting			
10 man for 8 h/ha	–	80	18.51
7 Planting			
20 man for 8 h/ha	–	160	37.03
2.5 bullock-h/ha for ridging	2.5	–	7.71
Total	142.5	589	400.09
Mechanized Planting	**Tractor h**	**Man-h**	**Cost U.S. $**
1 Land preparation			
1.1 Chisel, 2 + Cultivator, 3 or	7	–	40.50
1.2 M.B.plow, 1 + Cultivator, 4 or	6.75	–	33.54
1.3 Cultivator, 8	10.00	–	42.4
U.S. $ 12.34 for one ploughing of chisel or M.B.plow per ha. U.S. $ 5.30 for one ploughing of cultivation per ha			
2 Irrigation			
8 h/ha U.S. $ 0.93/h	–	8	7.44
3 Farm yard manure and fertilizer 12 trollys F.Y.M./ha			
U.S. $ 3.08/trolly F.Y.M. purchase cost U.S. $ 3.08/trolly F.Y.M.	–	96	36.96
Transportation cost including loading and unloading	–	–	36.96
F.Y.M. spreading	–	20	4.63
Fertilizer dose per ha			
DAP=5 bags. U.S. $ 8.20/bag	–	–	41.00
Urea 2.5 bags U.S. $ 7.09/bag	–	–	17.72
K_2SO_4 2.5 bags U.S. $ 3.20/bag	–	–	8.00
Fertilizer spreading	–	5	1.15
4 Seed			
Seed rate 7.92t to 9.88t per ha or 75000 to 100000 sets/ha. U.S. $ 0.55/40 kg	–	–	137.22
5 Seed harvesting, cleaning and shifting 20 man for 8 h/9.88t	–	160	37.03
and shifting with trolly	8	–	–
6 Seed planting with AMRI Sugar Cane Planter			
Cane loading into planter 3 man for 8 h/ha	–	24	5.55
Cane feeding into planter 3 man for 8 h/ha	–	24	5.55
Planting time/ha. Planting cost with planter U.S. $ 3.21/h**	8	–	25.68
Total	47.00	337	405.47

* These items are not included in the total.
** Tractor plus planter operational cost per h.

tractor-h/ha, 337 man-h/ha and U.S. $405.47 total planting cost/ha. The total planting cost per ha for the mechanized method was a little higher than that of the indigenous method, which was due to higher seed rate per ha. The man-h in mechanized planting was almost half than that of the indigenous method. With the use of AMRI planter a greater number of sets per ha can be planted and about 80 man-h/ha can be saved which otherwise can be used for set cutting.

Summary

The AMRI sugarcane planter was tested in the field and its performance was found satisfactory. The planter cuts down the problem of shortage of timely labour and exhorbitant hiring rates of labour. The planter provides higher yield per ha by planting 53 000 to 87 000 sets per ha as compared to indigenous method of planting, which plants only 45 000 to 50 000 sets per ha. The planter saves 80 man-h which is otherwise required for cutting of sets manually. The manual planting needs 160 man-h to plant 1 ha of sugarcane crop, which is about 3 times higher than that required while planting with AMRI sugarcane planter (planter takes 48 man-h per ha). The best performance of the planter was found when the tractor was operated in 1st low gear at 1 200 engine rpm or in 2nd low gear at 1 200 to 1 400 engine rpm with 300 to 400 PTO rpm. The non-uniform and inefficient cane feeding, less number of sets per ha and missing in planting occurred while the planter was operated in higher gear speeds. Sometime feeding of the crooked canes produced problems and cut unequal sets due to narrow chute near cutter. The sugarcane planting cost with AMRI planter was calculated U.S.$36.80 per ha which was about 43% less

Specifications and Features of the AMRI Sugarcane Planter

Planter type	Semi-automatic tractor rear mounted
Source of power	Tractor PTO driven
Number of rows	3
Row to row distance	762 mm
Overall length	2180 mm
Overall width	1530 mm
Overall height	1750 mm
Weight	250 kg (without sugarcanes and feeder men)
Cane cutting mechanism	Horizontal sliding frame, with gears and cam mechanism
Feeder men	3
Cane loading capacity	150 kg per batch
Planting time	8 h per ha with 2nd low gear at 1200 rpm
Number of sets	53000 to 78000 sets/ha
Men-h per ha	48
Cost of planter	U.S. $ 465

than the manual planting cost (U.S.$63.25 per ha).

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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. The requests from the readers for publishing the whole contents among the articles introduced here may also be sent to editorial staff. Regarding the article of many requests, the publication of whole contents will be reconsidered.

Design and Operation of Subsurface Irrigation System in Humid Area: N.A. Memon, Asst. Prof., Faculty of Agric. Engg., Sind Agric. Univ., Tandojam, Pakistan; R.S. Broughton, Professor, Dept of Agric. Engg., McGill Univ., S.A. de Bellevue, H9X 1CO, Quebec, Canada; C.A. Madramooto, Lecturer, Ditto.

A suitable combined subsurface irrigation and drainage system was designed on a 10-ha field with automated water control structures in order to provide adequate moisture control in the root zone. Based on the requirement of water for crop and leakage losses due to sub-surface irrigation, the amount of irrigation water to be delivered was determined. All the components of head loss were computed based on theoretical and practical approach on which shapes of water table were determined from Hooghoudt's steady state equation. Profiles of water table elevation were drawn which helped in deciding the water level to be maintained in the control chambers. Guidelines and recommendations for the operation of sub-surface irrigation in humid region are given.

Evapotranspiration from Wetland Rice and an Experience with Microlysimeters: Md. Bazlur Rahman Khan, Senior Scientific Officer, Agric. Engg. Div., Bangladesh Agric. Res. Institute, Joydebpur, Gazipur, Bangladesh; Jens Rounso Jensen, Assoc. Prof., Agric. and Food Engg. Div., Asian Institute of Technology, Bangkok, Thailand.

The study was carried out at the Asian Institute of Technology (AIT) from February 19 through June 21, 1985. Eight microlysimeters were used in two plots

(Continued on page 54)

Mechanization of Sugarcane Ratoon Culture in India

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Abstract

A tractor-mounted PTO shaft operated multi-purpose equipment was designed and developed as an important aid for mechanizing sugarcane ratoon culture. With the help of this equipment, all the main cultural operations, namely; stubble shaving, off-barring, tilling in the interspace between two rows and fertilizer application can be carried out simultaneously in one pass. During field trials, the equipment gave an output of 3.5 ha to 4 ha/day of 8 h working at 1/5th to 1/6th of the cost of the conventional system. The equipment is an important aid for raising a better sugarcane ratoon crop.

Introduction

The economics of sugarcane cultivation largely depends on the returns from a ratoon crop. Raising of a ratoon crop in sugarcane is vital not only from the point of view of saving in energy input for land preparation, etc. and cost of seed but also ensures high sugar recovery in the early part of the crushing season. Generally, more than one ratoon is not taken in India barring an isolated instance of 10 ratoons on the farm of the Indian Institute of Sugarcane Research, Lucknow. Some 4-5 ratoons are quite common in other cane growing countries of the world.

Not only is the number of ratoons low in India, but the average yield from ratooned field is also low as compared to yields obtained in other cane growing countries. The low return per unit time and input is attributed to many factors which when combined together, adversely affect the overall economics of cane cultivation. The average ratoon yeild in various states in India is 46.8 t/ha in U.P., 41.7 t/ha in Haryana and as low as 22.1 t/ha in Bihar. On the other hand, the average plant cane yield ranges between 50-55 t/ha.

It is thus obvious that there is a plenty of scope for boosting yeilds from ratoon crop of sugarcane. The essential requirement is to give due care and do the various cultural operations on time. Simple time and labour saving devices are required to carry out agricultural operations such as application of inputs not only timely but precisely regulated, too. There is thus a need to mechanize cultural operations in ratoon in a manner suiting the socio-economic conditions of the Indian farming community.

Desirable Cultural Operations

Basal Harvesting

The cultural operations in a ratoon field normally start from harvest of the plant crop. It is desirable that harvesting of cane be done flush with the ground and no stubbles are left. But generally, where harvesting is done by paid labourers, it has been observed that 10-15 cm high stubbles are left. This not only reduces the yield from the plant crop at the rate of about 3-4 t/ha but there are indirect losses, too. The lower portion of the canes being rich in sugar remains in the field uncut and thus the overall sugar recovery is reduced. The ratoon yields are also poor because of the fact that buds above ground on left over stubbles tend to sprout. Tender shoot roots from the sprouting base do not reach the soil for long and in most of the cases the sprouts from such buds do not grow into healthy shoots. Therefore, the first essential requirement is that the cutting of the plant cane at harvest be done close to the ground level and there should be no left over stubbles. To achieve this end, some improved harvesting knives have been developed at IISR, which facilitate basal harvesting of sugarcane with reduced energy inputs.

Stubble Shaving

Harvesting of sugarcane is generally done in a manner that 10-15 cm high stubbles are left. These stubbles should be shaved close to the ground to enable the buds below ground level to have a chance to sprout and develop into healthy shoots. The stubbles, if shaved manually with the help of a conventional tool such as 'spade', 'khurpi' etc., is time and labour intensive. On an average, 30 man/day are required for stubble shaving operation in 1 ha. A tractor-mounted PTO shaft operated stubble shaver has been designed and developed for this purpose.

Off-Barring

Off-barring is an operation carried out to cut old roots and improve aeration through tilling. Developing shoot roots become functional at a faster rate as a result of off-barring operation. This operation can be carried out by using a conventional 'kudal' and requires 18 man/day/ha. Attachment has been provided with the IISR tractor-mounted stubble shaver to do this operation with the help of two tynes and reversible shovels. The distance between the tynes is adjustable as per requirement depending upon row-to-row spacing.

Fertilizer Application

Between 100 and 200 kg N/ha are applied each crop of ratoon fields in a split manner. Fifty percent of nitrogen is applied as basal doze. Normally, fertilizer is broadcast in the field by labourers. It takes 2 man/day to complete fertilizer application in 1 ha. The main problem with broadcasting is that the fertilizer is not placed in the root zone and as a result it is not utilized immediately. Further, the application is not uniform. To avoid these problems, a fertilizer dispensing system has been designed and developed as an attachment with the IISR tractor mounted PTO shaft operated stubble shaver. Fertilizer is placed in the root zone in metered quantity uniformly.

Technical Details

The IISR has designed and developed a single-row and a double-row PTO shaft-operated tractor mounted stubble shaver with attachment for off-barring and fertilizer application system. **Fig. 1** gives the details of the equipment. The technical description is given below.

Frame

The frame of the modified single-row stubble shaver is made of M.S. angle iron of 62.5 mm x 62.5 mm x 9 mm and overall dimensions are 1400 mm x 1000 mm x 750 mm. The frame is properly strengthened by M.S. angle iron supports. A three-point linkage system is provided on the frame to hitch the equipment with the tractor. The frame of the two-row unit is 1350 mm x 1400 mm x 750mm.

In the centre of the frame, a gear unit having a pair of bevel gear with 16 teeth in the driving and 21 teeth in the driven gear, is also provided. The drive to the gear unit is given from tractor PTO shaft through universal cross joints and a telescopic shaft. The drive from the gear unit is transmitted to the shaving blades.

Shaving Elements

In the single-row unit, the shaving disc consists of 3 trapezoidal shaped cutting elements in one blade and all blades are bolted on a concave disc. The disc rotates at a speed of 700-800 rpm and is 500 mm in diameter. In the two-row unit, the wheel spacing of the tractor is increased to 1 800 mm so that the four wheels remain in furrows. Two 300 mm-long blades are bolted on 150 x 100 x 9 mm blade holders which are welded on a 300 mm dia x 9 mm thick M.S. disc. The disc remains in the centre of two rows and the blades cover both the rows while in operation.

Off-barring System

An auxiliary frame is provided at the rear and of the main frame. On this frame, two tynes with double point reversible shovels are provided (single-row unit). These shovels work on both sides of the ridge and cuts the old roots along with tilling

Fig. 1 Two-row tractor-mounted stubble shaver with off-barring and fertilizer application system.

operation. Shaving is also done simultaneously. The distance between two tynes is adjustable and the shovels penetrate to a depth of about 150-200 mm. In the two-row unit, 7 tynes with reversible double points shovels are provided to do the tilling on both sides of the ridge and in between the rows as well to minimize weed population. The distance between the tynes is adjustable as per the recommended row-to-row spacing.

Fertilizer Application System

Two wooden boxes of 550 x 250 x 300 mm having trapezoidal section with side walls inclined at an angle of 30, based on the angle of repose of urea, are provided on the auxiliary frame. The fertilizer is agitated and metered through a disc having three holes of 9, 11 and 12.5 mm diameter. Desired hole is selected as per the requirement. The drive to the agitator system is given with the help of two lugged wheels (single-row unit) and a rear spring loaded wheel for double-row unit. It has been calibrated for applying nitrogen through urea at the rate of 50 kg, 75 kg and 100 kg N/ha as basal doze, where nitrogen is applied in two equal dozes of fertilizer. **Fig. 2** shows the equipment in field operation.

Economics of Operation

1 A tractor-mounted stubble shaver (single row unit)

(i) Cost of operation/day of 8 h working for stubble shaving, off-barring and fertilizer application with a 35 hp tractor at Rs.50/h	Rs400
(ii) Output per day	2 ha
(iii) Cost of operation/ha	200

2 Double row unit

(i) Output per day	4 ha
(ii) Cost per ha	Rs100

3 Mannually with conventional tools labour requirement

(i) Stubble shaving with 'spade'	30 man/day/ha
(ii) Off-barring	18 man/day/ha
(iii) Fertilizer application	2 man/day/ha
Total man/day/ha	50
Labour rates	Rs.12/man/day
Total cost/ha	Rs.600
Total cost of operation/ha for shaving, off-barring and fertilizer application	Rs.600*

*(US$ 1.00=Rs.12.30)

Results and Discussion

The new IISR stubble shaver which combines off-barring and fertilizer placement with stubble shaving simultaneously, has proved to be an important multi-purpose equipment for sugarcane ratoon culture. It has been tried on a fairly large scale and found acceptability among the cane growers. This is a useful time- and labour-saving device for better ratoon management. Stubble shaving is a standard practice and if done with the help of this equipment, the cost of operation is reduced to about 1/3 for the single row and approximately 1/6 for the single two-row unit. Not only this, fertilizer is placed in close proximity of the root system in metered quantity, uniformly in the field and as a result the losses through volatilization from the surface (broadcast system) are also minimized. There is also a feasibility of providing granular insecticide along with fertilizer. Off-barring operation while cutting old roots improves the tilth also.

The new two-row stubble shaver with all the attachments has been tried on the IISR farm and during trials, has given an output of 3.5-4 ha/day. By adopting this piece of equipment and other recommended practices such as timely application of irrigation and other critical inputs, burning of trash and proper plant protection measures, etc., ratoon yield per unit time and input can definitely be increased. This will improve the economics of cane cultivation for the farmers, on one hand, and ensure justifiable high recovery in the early phase of crushing season for the sugar mill, on the other.

Fig. 2 The tractor-mounted stubble shaver in field operation.

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Supplemental Mechanical Weed Control for Maize-Cowpea Rotation in Mucuna Mulch

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Abstract

Weed control is a major problem for farmers in the humid and sub-humid tropics. Mucuna mulch has been found to reduce this problem to a large extent. Some weeds are, however, able to grow through the mulch, especially where the mulch is light. Some mucuna seeds also fall into the mulch and are not harvested. Later on they germinate and pose weed control problems. The use of mucuna mulch has been found to be more effective if it is supplemented with mechanical weed control since herbicides are usually too expensive for farmers and some herbicides are even injurious to crops.

The effectiveness of supplementing mucuna mulch weed control with hand pulling of weeds, hoeing weeds with a special "V" hoe and mowing weeds with an ordinary 2 kW lawn mower has been evaluated. Hand pulling once, twice and thrice resulted in no crop damage, consumed 150 to 155 h/ha, 300 to 310 h/ha and 450 to 465 h/ha, respectively, and yielded 3.0, 5.1 and 5.0 t/ha of maize, respectively, and 1.5, 2.5 and 2.5 t/ha of cowpea, respectively. Hoeing once, twice, and thrice virtually did not damage the crops, consumed 130 to 135 h/ha, 260 to 270 h/ha and 390 to 405 h/ha, respectively, and yielded 2.8, 5.2 and 5.1 t/ha of maize, respectively, and 1.6, 2.7 and 2.6 t/ha of cowpea respectively. Mowing once, twice and thrice resulted in 0.2 to 5% crop damage, consumed 20, 40 and 60 h/ha, respectively, and yielded 2.5, 5.0 and 4.0 t/ha of maize, respectively, and 1.2, 2.5 and 2.2 t/ha of cowpea, respectively.

Introduction

In the humid and sub-humid tropics, farmers effect weed control by hand-weeding with a hoe or cutlass in zero-tilled, conventionally tilled and mounded fields. Where vegetables are grown on small farms, hand-pulling of weeds is practised. These weed control methods are laborious, back straining and time consuming. These and other factors make weeding a major energy bottleneck in tropical farming absorbing some 50 to 70% of the total manpower utilized (IITA 1975).

The above problems may be eliminated by using herbicides to control weeds. The use of herbicides, however, has the following disadvantages:

1. Herbicides are imported and are generally expensive.
2. Herbicides are selective in controlling weeds.
3. Herbicide applicators are generally expensive.
4. Herbicide application requires thousands of litres of water which is not readily available to the farmer, and transportation of such large quantities of water is a problem to the farmer.
5. Selective herbicides are usually only practical in the case of mono-cropping, which is not a common practice in the tropics.
6. Some herbicides may injure crops.
7. Illiterate farmers misuse herbicides to the detriment of their own lives. Also, herbicides have negative effects on health.

Work at the International Institute of Tropical Agriculture (IITA) indicate that Atrazine plus Alachlor, for example, is effective in maize at 1.5 + 3.0 kg/ha but controls grasses poorly at lower rates, while pre-emergence application of Atrazine plus Metolachlor at 2.5 kg/ha is injurious to maize crop. IITA source (1978) shows that Metolachlor at 2 or 3 kg/ha gives good control of annual weed in cowpeas while *Euphorbia heterophylla L* could not be controlled by this and other herbicides. Further work at IITA (1978) reveals the effectiveness of 24-D, Bentazon and Pendimethalin in controlling certain weeds but ineffective in controlling others in maize while

Bentazon, applied post-emergence, injured cowpeas and caused severe yield reduction. Alachlor at 2.0 kg/ha and Metribuzin at 0.4 kg/ha were also injurious to cowpeas (IITA 1978). Glyphosate and Estermine were effective in controlling most weeds in zero tillage except *Talinum triangulare L* (IITA 1979).

Dead mucuna mulch farming provide an almost effective solution to the aforementioned problems. When mucuna mulch is used, however, some mucuna seeds drop in the field. These seeds germinate later on to constitute what is known as volunteer mucuna resulting in a weed control problem. Also, where the mulch is not thick enough, some weeds are able to germinate through the mulch. *Euphorbia heterophylla L* has been found to penetrate even thick mucuna mulch.

The work presented here evaluates some mechanical ways of controlling mucuna volunteers and other weeds in mucuna mulch farming for the first season maize followed by second season cowpea, with the aim of finding the most effective supplemental mechanical weed control method.

Materials and Method

The investigations were conducted in 1983 and 1984. A large field covered with full season dead mucuna mulch was divided into 40 plots, each measuring 10 m by 5 m with 1 m headlands between plots. The establishment of dead mucuna mulch has been well developed by IITA (1976).

The first season of both years were planted to IITA streak resistant maize variety TZESR-W while the second seasons were planted to IITA cowpea variety TVX 3236. The field used was level and zero-tilled. Both the maize and cowpea were planted with the IITA rolling injection planter (IITA 1979). The row spacing for both crops was 75 cm. Ten days after planting the maize, 15:15:15 (NPK) fertilizer was applied at the rate of 150 kg/ha followed four weeks after with 50 kg/ha of calcium-ammonium-nitrate. The fertilizer band applicator (Baryeh, Navasero, Garman and Kang 1984) was used to apply the fertilizer. **Fig. 1** shows the maize at four weeks old receiving fertilizer. The mucuna mulch is also clearly seen in this figure. In the second season, insects in the cowpea were controlled with a weekly spray of Gammalin 20EC insecticide (3 ml product in 1ℓ of water), while soil fertility was improved with 15:15:15 fertilizer at 100 kg/ha. **Fig. 2** shows a thick mucuna cover with a volunteer mucuna appearing out of the mulch.

Ten-week control treatments were used, with each treatment replicated four times resulting in a randomized complete block design. The treatments are listed in **Table 1**.

Traditional hoes used for weeding either have straight cutting edges or shallow, curved cutting edges. A special "V" hoe was fabricated for the investigation. The hoe, shown in **Fig. 3**, was so shaped as to facilitate penetration into the mucuna mulch and cut or uproot weeds. Preliminary weeding trials in mucuna mulch showed that traditional hoes and hoes with lead angles larger than 45° did not penetrate the mulch as easily as the 40° hoe. Hoes with lead angles less than 35° could penetrate the

Fig. 1 Application of fertilizer to maize.

Fig. 2 Dead macuna mulch with volunteer macuna appearing.

Table 1 Weed Control Treatments

Treatment	Description
1	Hand-pulling once
2	Hand-pulling twice
3	Hand-pulling thrice
4	Hoeing with a "V" hoe once
5	Hoeing with a "V" hoe twice
6	Hoeing with a "V" hoe thrice
7	Mowing once
8	Mowing twice
9	Mowing thrice
10	No weeding

Fig. 3 "V" hoe with dimensions (a) and assembled with handle.

mulch but were too narrow and could not cut many weeds per stroke of the hoe. The preliminary trials also indicate that straight cutting edged and shallowly curved cutting edged hoes required twice and 50% as much time as the 40° "V" shaped hoe, respectively. Where weeding was done once, it was done three weeks after planting. First and second weedings for two weeding treatments were done three and six weeks after planting, respectively. Weeding three times were done three, five and seven weeks after planting.

The following mulch properties were measured just before the first weeding and at harvest time: percent cover, thickness, weight and tensile strength. The percent mulch cover was assessed by subjective observation. Mulch thickness was assessed at four different points on each plot along two diagonals by inserting a pointed meter rule vertically through the mulch until the tip lightly touched the soil surface. The thickness was read directly on the meter rule. The mulch tensile strength was measured with an Instron universal testing machine. Mulch weight was determined by weighing the mulch contained in a 50 cm by 50 cm steel quadrat. The quadrat was placed at four different spots on each plot and the weights found were averaged. The mulches were replaced after weighing. Weed count and weed weight were made from fixed quadrat along a transect in each plot and averaged just before the first weeding and at harvest time. Crop damage was assessed by counting chopped crops and crops lodged through weeding. Weeding time was measured using a stop watch. The yields were recorded at 14% moisture content (wb) for maize and 12% moisture content (wb) for cowpea. Fuel consumption of the mower was measured by filling it and running it for 2 h and refilling with a measuring cylinder to find how much fuel had been used. This was verified by filling the mower and running and timing it until the fuel was finished. Samples and measurements were taken at 10 A.M. when the morning dew had vanished.

Results and Comments

The average mulch properties for the first and second seasons are shown in **Tables 2** and **3**. The results of the first seasons of 1983 and 1984 did not differ significantly so they have been averaged to obtain the composite results in **Table 2**. Similarly, the results for the second seasons of 1983 and 1984 have been averaged to obtain **Table 3** since results for the two years were not significantly different. Tensile strength values were obtained from unshattered mulch.

Table 2 shows that the mulch cover for all the hand-pulling and all the hoeing treatments did not change significantly after the weeding operations compared to their values at first weeding. The change in percent cover for the hoeing operations was mainly due to the mulch disturbance by the hoe passing through it to cut or uproot weeds. Hoeing once and twice changed the mulch cover by only 5% each, while hoeing three times changed it by 8%. Hand-pulling once and twice did not affect the mulch cover while hand-pulling thrice reduced the cover by only 2%. Mowing, however, disturbed the mulch cover significantly. Mowing twice and thrice reduced the cover by 45% and 50%, respectively. Mowing once had 80% of the mulch cover at harvest time.

The mulch thickness followed a similar pattern with mowing once, twice and thrice reducing the mulch thickness by 57%, 79% and 85%, respectively. This is so because the mower cut through the mulch to cut the weeds, and shattered the top part of the mulch in so doing. The mulch became less evenly distributed after the mowing treatments. This also explains the deterioration in the mulch cover in the mowing treatments. In contrast, the mulch thickness for the hand pulling and hoeing treatments did not show any significant change in the mulch thickness. The reduction in mulch thickness for these treatments were mostly due to the feet of the people who stepped on the mulch as they weeded.

The mulch weight did not change significantly for the hand-pulling and hoeing treatments mainly due to the fact that these treatments did not seriously disturb the mulch. In these treatments, the mulch weight reduced by an amount lying between 35 and 80 g/ha. These reductions were mainly due to the drying up of the mulch with time and some mulch decay close to the soil. In the mowing treatments, the shattering of the mulch by the mower increased the contact area between the soil and the mulch, resulting in a higher mulch decay, consequently contributing to the reduction in mulch weight with time. Also, some of the shattered mulch were too small to be picked and weighed contributing to the mulch reduction in weight. The uneven mulch distribution due to mowing mentioned earlier could also affect the mulch weight if enough weight readings are not taken. Mowing once, twice and thrice resulted in mulch weight reduction of 19%, 48% and 60%, respectively. Mowing thrice thus resulted in thrice as much mulch weight loss as mowing once. The mulch decay, however, improves soil fertility. This is likely to reduce the use of fertilizers with time.

The tensile strength of the mulch was similar for all treatments

Table 2 Average Mulch Properties for First Seasons of 1983 and 1984

Treatment	Percent cover, %		Mulch thickness cm		Mulch weight, g/ha		Mulch tensile strength, N/cm²	
	At first weeding	At harvest*	At first weeding	At harvest*	At first weeding	At harvest*	At first weeding	At harvest*
Hand-pulling once	100	100a	13	12a	1000	956a	750	200a
Hand-pulling twice	100	100a	14	12a	1050	1000a	750	205a
Hand-pulling thrice	100	98a	13	11a	1100	1025a	750	205a
Hoeing once	100	95a	12	12a	995	960a	750	210a
Hoeing twice	100	95a	13	12a	1020	970a	750	205a
Hoeing thrice	100	92ab	13	12a	1005	958a	750	200a
Mowing once	100	80 b	14	6b	1015	820b	750	215a
Mowing twice	100	55c	14	3c	1050	550c	750	202a
Mowing thrice	100	50c	13	2c	1000	400d	750	206a
No weeding	100	100a	13	11a	1035	1005a	750	100b

* Means followed by the same letters in the same column are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Table 3 Average Mulch Properties for Second Seasons of 1983 and 1984

Treatment	Percent cover, %		Mulch thickness cm		Mulch weight, g/ha		Mulch tensile strength, N/cm²	
	At first weeding	At harvest*	At first weeding	At harvest*	At first weeding	At harvest*	At first weeding	At harvest*
Hand-pulling once	100	95a	10	8a	870	785a	180	–
Hand-pulling twice	100	90a	10	8a	850	780a	175	–
Hand-pulling thrice	100	80bc	9	7a	900	810a	176	–
Hoeing once	100	90a	10	9a	850	805a	182	–
Hoeing twice	100	90a	9	7a	840	800a	172	–
Hoeing thrice	100	80bc	10	8a	800	750a	178	–
Mowing once	100	72c	9	3b	825	605b	173	–
Mowing twice	90	48d	9	2b	775	550b	177	–
Mowing thrice	80	40d	8	2b	700	420c	171	–
No weeding	100	90a	12	10a	885	808a	174	–

* Means followed by the same letters in the same column are not significantly different at the 5% level according to Duncan's Multiple Range Test.

just before the first weeding. At harvest time, the tensile strength was between 200 and 220 N/cm² for all treatments except the no-weeding treatment. The reduction was between 530 and 550 N/cm². The no-weeding treatment had reduced in tensile strength by 650 N/cm² having a value at harvest time equal to half of those of the other treatments. This mulch weakening was due to the increased weed growth in this treatment, which moistened the mulch and promoted some decay which weakened its tensile strength. Other mulch properties for the no-weeding treatment did not change significantly from the first weeding to the harvest time as expected since nothing was done to disturb the mulch. The small mulch disturbance for this treatment came from the growing weeds.

In the second season, the mulch percent cover for hand-pulling improved at the time of the first weeding because the mulch was then made up of mucuna, dried maize stems and leaves and dried weeds. At harvest time the mulch percent cover for hand-pulling once and twice and hoeing once and twice had not changed significantly from the value just before first weeding. This agrees with the first season's results. Hand-pulling thrice and hoeing thrice had 20% less mulch cover at harvest compared to the value before first weeding. The value at harvest time was significantly different from the corresponding values for hand-pulling once and twice and hoeing once and twice disagreeing with the results for the first seasons. The reason for this is not very clear but it could be due to mulch disturbance by the operators. It is clear that the mowing treatments deteriorated the mulch cover in the second seasons, too. Mowing once, twice and thrice reduced the mulch cover by 28%, 42% and 40%, respectively, at harvest time.

During the second season, the mulch thickness did not change significantly from the time of first weeding to the harvest time for all the hand-pulling and hoeing treatments agreeing with results for the first season. Table 3 shows a high

significant difference between the mulch thickness at harvest time for the hand-pulling and mowing treatments and between the hoeing and mowing treatments. Mulch thickness for mowing once, twice and thrice treatments had reduced by 67%, 78% and 75% at harvest time compared to their values at first weeding. Mowing once reduced the second season mulch thickness more than the first season's mulch thickness, while mowing thrice reduced it less in the second season's compared to the first. The reason for this is not clear but it is clear that the reductions for both seasons are significant.

The mulch weight for the hand-pulling and hoeing operations for the second seasons followed the pattern for the first season showing no significant difference between themselves at harvest time. Neither do they show any significant difference between the values at first weeding and those at harvest time. The mulch weight for each of these treatments decreased by an amount lying between 45 and 90 g/ha for the same reason as the first season. Just like the first season, the second season's mulch weight for the mowing treatments are significantly different from the other treatments due to the mower's mulch shattering action and probably more drying of the mulch. The end of the second season is dryer being the beginning of the long dry season. The mulch weights at harvest time for these treatments were also significantly different from those at first weeding. During the second seasons, the mulch weight at harvest for mowing once and twice were not significantly different unlike the first season. The reduction in mulch thickness for mowing once, twice and thrice were 27%, 29% and 40%, respectively.

In the second season, the mulch became very brittle and it was impossible to register any strength reading at harvest time. At the time of first weeding the mulch tensile strength was about 180 N/cm^2. The mulch cover would have been poorer in the second seasons had it not been improved with maize stems and dried leaves and dried weeds. The rains are lower in the

Table 4 Average Weed Properties, Crop Damage and Maize Yield for the First Seasons of 1983 and 1984

Treatment	Weed population, weeds/m^2		% change	Weed weight, g/m^2		% change	Crop damage, %	Weeding time, h/ha	Maize yield*, t/ha
	At first weeding	At harvest		At first weeding	At harvest				
Hand-pulling once	90	66	27$^-$	25	20	25$^-$	0	150	3.0c
Hand-pulling twice	82	38	54$^-$	26	15	42$^-$	0	300	5.1a
Hand-pulling thrice	75	5	93$^-$	22	6	73$^-$	0	450	5.0a
Hoeing once	88	62	30$^-$	24	17	28$^-$	0	135	2.8c
Hoeing twice	65	30	54$^-$	15	8	47$^-$	0.2	270	5.2a
Hoeing thrice	95	8	92$^-$	32	8	75$^-$	0.3	405	5.1a
Mowing once	102	154	51$^+$	36	34	6$^-$	1.5	20	2.5cd
Mowing twice	97	145	50$^+$	28	20	29$^-$	3.0	40	5.0a
Mowing thrice	70	134	52$^+$	18	10	44$^-$	4.0	60	4.0b
No weeding	75	350	367$^+$	20	160	700$^+$	0	0	2.4c

– Percent reduction; + Percent increase; * Means followed by the same letters in the same column are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Table 5 Average Weed Properties, Crop Damage and Cowpea Yield for the Second Seasons of 1983 and 1984

Treatment	Weed population, weeds/m^2		% change	Weed weight, g/m^2		% change	Crop damage, %	Weeding time, h/ha	Cowpea yield*, t/ha
	At first weeding	At harvest		At first weeding	At harvest				
Hand-pulling once	150	90	40$^-$	38	26	32$^-$	0	155	1.5b
Hand-pulling twice	125	48	62$^-$	35	19	46$^-$	0	310	2.5a
Hand-pulling thrice	98	3	97$^-$	28	6	80$^-$	0	465	2.5a
Hoeing once	158	95	40$^-$	32	22	31$^-$	0	130	1.6b
Hoeing twice	135	50	63$^-$	28	15	47$^-$	0	260	2.7a
Hoeing thrice	94	4	96$^-$	21	6	71$^-$	0.2	390	2.6a
Mowing once	232	267	15$^+$	58	52	10$^-$	2.0	20	1.2b
Mowing twice	214	240	12$^+$	48	33	31$^-$	3.0	40	2.5a
Mowing thrice	207	228	10$^+$	45	22	51$^-$	5.0	60	2.2a
No weeding	411	550	34$^+$	200	855	328$^+$	0	0	1.0c

– Percent reduction; + Percent increase; * Means followed by the same letters in the same column are not significantly different at the 5% level according to Duncan's Multiple Range Test.

second season, making weed growth rate lower than in the first season. At harvest time about 50% of the weeds were dried up but stood upright. These were counted as weeds.

The weed properties, maize crop damage and maize yield for the first seasons are shown in **Table 4**, while **Table 5** gives weed properties, cowpea crop damage and cowpea yield. Both tables indicate that weed population and weed weight decreased with increasing number of weeding as would be expected.

In the first season, hand-pulling twice showed twice as much percent reduction in weed population as hand-pulling once, while hand-pulling thrice showed almost twice as much percent reduction in weed population as hand-pulling twice. Similar percent reductions in weed population were shown by the hoeing treatments. Each of the mowing treatments, however, demonstrated about 50% increase in weed population at harvest time compared to the time of first weeding. This was the case because firstly, the mower chopped off the weeds as opposed to uprooting in hand-pulling and hoeing. Hence the chopped stems of the weeds grew again after some days. Secondly, the mower missed the small weeds which were below the mower's cutting height and these continued to grow later. In the second seasons, hand-pulling twice and hoeing twice displayed one and-a-half times as much percent reduction in weed population compared to hand-pulling once and hoeing once. Hand-pulling thrice and hoeing thrice also showed about one and a half times as much percent reduction in weed population compared to hand-pulling twice and hoeing twice. Again, the mowing treatments showed increases in weed population for the same reason as the first seasons. The increases were, however, lower than in the first season. The increases were lower because the second season rains are lower than the first season's so the weeds grow at a slower pace.

In the first season, the percent reduction in weed weight from time of first weeding to harvest time was between 25 and 73% for hand-pulling, between 28 and 75% for hoeing and between 6 and 44% for mowing. Corresponding values in the second season were 32 and 80% for hand-pulling, 31 and 71% for hoeing and 10 and 51% for mowing. It is interesting to note that the mowing treatments showed increases in weed population but decreased in weed weight. This is due to the fact that although the weeds increased, they were shorter due to the mowing, hence the decrease in weight. The no-weeding treatment, of course, increased tremendously both in weed population and weed weight for both seasons as indicated by **Tables 4** and **5**. The percent increase in weed population and weed weight in the first seasons were over 10 times and over twice as much as the respective values in the second seasons. This is due to the higher rains which promotes rapid weed growth in the first season. Also, towards harvest time in the second season, the long dry season begins making the weeds dryer than those of the first season.

Crop damage was not severe for all the treatments. The hand-pulling and hoeing treatments had zero crop damage while the mowing treatments had between 1.5 and 4.0% crop damage in the first season and between 2.0 and 5.0% in the second season. In addition to zero crop damage, the hand-pulling and hoeing could uproot the weeds along rows without damaging the crops. Hand-pulling could even remove weeds at the base of crops. The mowing treatments had the disadvantage of not being able to clear weeds along the rows without damaging the crops.

Hand-pulling once, twice and thrice involved 150 to 155 h/ha, 300 to 310 h/ha and 450 to 465 h/ha of time, respectively, for both seasons. Hoeing once, twice and thrice required 130 to 135 h/ha, 260 to 270 h/ha and 390 to 405 h/ha, respectively, for both seasons. In contrast, mowing once, twice and thrice required 20, 40 and 60 h/ha, respectively. Thus hand-pulling and hoeing, respectively, utilized 7.7 and 6.7 times as much time as mowing. Hence, there is a tremendous saving in time in mowing.

The yield column in **Table 4** shows that hoeing twice had the highest maize yield followed by hand-pulling twice and hoeing thrice. These are followed by hand-pulling thrice and mowing twice. There is, however, no significant difference between these yields. This suggests that yield-wise, weeding twice is the same as weeding thrice. Consequently, the third weeding is unnecessary. Single weeding and no-weeding showed significantly low maize yields showing just about half as much yield as double weeding. The poor yield of the no-weeding treatment has also been found at IITA (IITA 1975). Navasero and Khan (1970) have also stated that weeds reduce rice yields by as much as 36%. A similar pattern is displayed in **Table 5** for cowpea yield. Weeding twice and thrice showed no significant difference in cowpea yields while weeding once and no weeding showed significantly low yields. Again, the cowpea yields suggest two supplementary weedings are sufficient to give good yield.

The mulch cover, mulch thickness, mulch weight and weed population pattern at first sight may suggest that mowing is not good. The weeds on the mowing plots grew again because they were cut instead of uprooting, but the weeds did not have enough time

to grow to the detriment of good crop growth and yield before they were mowed again. Although the mower disturbed the mulch, the disturbance as mentioned earlier will improve the soil fertility with time. The weeds along rows which the mower could not easily cut did not seem to have affected the yield. The tensile strength of the mulch did not affect the yield, the crop damage and the weeding time.

The mower consumed 0.5 ℓ/h or 20 ℓ/ha for two mowings which small and medium-sized farmers can afford.

According to the results, there is no significant difference between hand-pulling and hoeing with the "V" shaped hoe. Both of them are time consuming and back-straining. Where weeds cause itchiness, hand-pulling can be a nuisance. If for some reason, a farmer chooses to hoe the weeds, the "V" hoe is recommended in place of the traditional hoe.

The high yield and the saving in time for the mower indicates that it is a good and effective supplemental non-chemical weed control device for the tropical farmer. The use of the mower will enable the farmer to farm larger areas and save time for other social and family activities.

Conclusion

Mucuna mulch partially solves the weeding problems of the tropical farmer who cannot afford to pay for herbicides. Investigations presented here reveal that mowing can be used in addition to mucuna mulch to achieve good and effective weed control, high maize and cowpea yields and a saving in weeding time and physical strain of the farmer.

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(Continued from page 44)

of wet land rice transplanted at 28 days interval to study the actual evapo-transpiration (ET) from the field. The maximum ET was very close to open pan evaporation. The microlysimeters were found not suitable for use in the rainy season and also for continuous long duration studies.

Natural Ventilation for Agricultural Buildings in Brazil: Irenilza de Alencer Nääs, Campinas State Univ., Agric. Engg. College, Campinas, Brazil.

Animals are provided with buildings to shelter from the weather. In order to have effective protection and efficiency for high production, the interaction of climate, animal and building must be quantified.

The purpose of an adequate ventilation system is to provide good condition in controlling internal temperature by removing heat from the building. Using natural ventilation this can be reached by optimizing the building openings and matching construction material on the design inputs.

Although no single design of a ventilation system is to be applied as a total solution, this work shows a simplified design for a natural ventilated swine building.

The model was validated for a building with a lot of 100 swine from piglets to finishing stage.

Measuring Seepage from Fish Ponds by Seepage Meter: Raj Vir Singh, Assoc. Prof., Dept. of Irrigation and Drainage Engineering, College of Technology, G.B. Pant Univ. of Agriculture and Technology, Pantnagar, U.P., India; Surendra Kumar, B. Tech. (Agric. Engg.) Student, Ditto; R.S. Teotia, Ditto.

Seepage of water from fish ponds constitute a serious problem because it involves loss of much water. Seepage tests were conducted in different fish ponds located at the Fisheries Research and Training Centre, Pantnagar. The rates of seepage as measured by seepage meters ranged from 20.1 mm/day to 25.4 mm/day. The average seepage rate was 22.09 mm/day. Seepage rates also changed from hour to hour.

A Study on Sugarcane Detrashing: A.C. Srivastava, Scientist, Indian Institute of Sugarcane Research, Lucknow 226002, India.

Various parameters involved in sugarcane detrashing were analysed through dimensional analysis. A general equation for evaluating the force requirement for detrashing/defoliating has been developed. The constants associated with the general equation were determined with the help of a force measuring device which was developed at the Indian Institute of Sugarcane Research, Lucknow, India. ■■

Effects of Electrostatic Charging and Vertical Air Current on Deposition of Pesticide on Cotton Plant Canopy

by
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Abstract

The objectives of this study were to investigate the influence of electrostatic force and vertical air current to carry pesticide deposits, obtained by cone, fan and disc type nozzles, on the cotton plant canopy. The pesticide deposit quantities and the relative deposition rates were determined and compared between different application treatments using three different nozzle types. As tracer substance BSF was used, the deposit was detected by fluorometric method. The results obtained by BSF was controlled by using real pesticide. Because of the high relative humidity during the application period, electrostatic charging effectiveness was not as high as expected.

Introduction

Pesticide cost in cotton productions can reach up to 50 % of total production costs in the Çukuova Region, Turkey. Especially, chemical applications against the white fly *(Bemisia tabaci)* increased the production costs since 1974. Since white flies put their eggs generally under side of the leaves, the traditional spraying method used in Turkey cannot transport enough active ingredient to the underside of the leaves. Despite the high application dosage, the biological efficiency of the chemical is not high enough because of the spraying with coarse droplets (17).

Actual application rate for ground equipment is about 300 *l* per ha and VMD is bigger than 250 μm. All the tractor-mounted and trailed sprayers, used for cotton pest control, were equipped with classical cone type nozzles. A large portion of the spray is often lost as airborne drifts, and some droplets settle down on the soil.

The total deposition on the plant canopy is not higher than 25 % of the applied amount even if it is used as a good conventional sprayer (11).

Most of the modern pesticides used in cotton production in Turkey are imported. But the equipments for spraying are locally made and need technological improvements. For example, significant cost reductions in cotton pest control are possible by decreasing the application rate and droplets diameters. The introduction of electrostatic-charged spray could be another effective solution in reducing the production costs (9).

The investigations were carried out on the electrostatic-charging methods since 1950, and proved that electrostatic-charging of the droplets could reduce drift and increase the effectiveness of the spray deposition (1, 2, 3, 4, 8 and 12).

Other researchers, working on the effectiveness of the droplet size, proved that spraying with droplets less than 100 μm increased pesticide deposition on the plant canopy and biological efficiency of the chemicals (5). This shows that the electrostatic-charging method is compatible with new application techniques such as ULV and air blast spraying.

Since the electrostatic force effectiveness on small droplets (less than 100 μm VMD) is higher than the gravitational force, in the suitable meteorological conditions, the drift could be reduced by electrostatic-charging drastically (6, 9).

The relative humidity of the air in the environment has a great influence on the electrostatic-charged droplets deposition (14, 16). It was reported that when the

Note: This research work was done and financed by the cooperation-program between The University of Hohenheim (FRG) and The University of Cukurova (Turkey)

Table 1 Properties of Cotton Plant Studied

Item	Property
Variety	Çukurova 1518
Seeding date	April, 1986
Duration of the field works	July 1 - 30
Row spacing	75 cm
Plant spacing on the rows	21 cm
Plant heigth on 1st of July	65 cm
Plant heigth on 30th of July	75 cm
Leaf area index on 1st of July	1.2
Leaf area index on 30th of July	1.4

Table 2 Nozzle Specifications

Nozzle type	Discharge rate l/min	Operation pressure (bar)	Speed of sprayer km/h	Applica-rate l/ha	VMD(1) (μm)	NMD(2) (μm)	CH(3)
Cone type nozzle Tecnoma H1-15/10	0.344	2.4	4.32	63.7	142.5	65	2.2
Flat fan type nozzle SS 11001	0.324	2.0	4.32	60.0	198.0	84	2.4
Rotational disc type nozzle	0.400	2.5	4.32	49.4	82.5	65	1.3
Micron Micromax, gleu injector, 5000 rpm							

Remarks: (1) Volume median diameter, (2) Number median diameter, (3) Coefficient of homogeneity.

relative humidity of the air increased from 10 to 96 %, relative deposition may be reduced two-fold (14).

Physical and electrical properties of the spray solutions have also great influence on the electrostatic-charging effectiveness (6, 13, 15).

Practical methods of charging agricultural sprays fall into three classes: corona, induction and contact charging (10, 14). But some British workers are discussing that induction and contact charging methods are the same in principle (12).

The objectives of this study were to investigate the influence of electrostatic force and vertical air current to carry pesticide deposits, obtained by cone, fan and disc type nozzles, to the cotton plant canopy. The pesticide deposit quantities and the relative deposition rates were determined and compared between different application treatments using three different nozzle types.

Methods and Materials

Materials

Cotton plant – Field studies were carried out at the Çukurova University agricultural faculty's experimental farms. Some properties of cotton plants which were used as research material, are shown in **Table 1**.

Spray nozzles – Three types of nozzles were used in the investigation. They were cone type nozzle from Tecnoma; flat fan type nozzle 11001 from Spraying System and rotational disc type nozzle from Micron-Micromax. Their specifications and operational characteristics are given in the **Table 2**.

Electrostatic charging unit and air distribution set – Power for the electrostatic charge generator was supplied from the tractor's 12 V DC battery, and connected to a high voltage genarator, which gave 12 kV to the system.

The compressed air was obtained from a 100-liter air tank. The air in the tank was supplied by Universal 650 M tractor's own compressor. The air was transported by plastic tubes to the air distribution caps which covered the hyraulic nozzles. Air velocity was 4 m/s and discharge rate was 1085 m^3/h at the spraying point.

Schematic diagrams of the installation sets are shown in **Figs. 1** and 2, and their mountings on the sprayer boom are shown in **Figs. 3** and 4.

Fig. 1 Electrostatic charging unit and air distribution set for cone and flat gan type nozzles.

Fig. 2 Electrostatic charging unit for disc type nozzle.

Fig. 3 Spraying system for the cone and fan type nozzles with electrostatic charging unit and air distribution set.

Fig. 4 Spraying system for the disc type nozzle with electrostatic charging unit.

Tracer substance and insecticide – The spray solution consisted of BSF (Brillant Sulpho-Flavin), diluted in tap water. Its density was 1 g/cm^3, dynamic viscosity was 65 mN/m. and electrical conductivity 1260 μs/cm for 0.1 % BSF solution.

Ofunack 40 EC was used as insecticide with 3 l/ha application dosage against white fly. Its active ingredient is pyrdaphention.

Methods

Working procedures – A randomized complete block design with three replications was used. The experiments were carried out in three steps.

On the first step, in order to collect the tracer deposit on both sides of leaves, 20 plants were chosen on 4 rows in each plot randomly. From each plant, 5 leaves were marked before spraying tracer substance, and filter papers were fixed on both sides of the leaves. After spraying the filter papers were collected separately and put in two jars 100 ml of distilled water. The jars were shaken for 15 min. Solution samples were taken from each jar and analysed quantitatively using a fluorometer.

In order to avoid errors which could take place by choosing different plants and leaf positions, the same plant and leaves on the chosen plant in each plot were used for every treatment.

On the second step, in order to control the results obtained by papers, spray deposits were collected directly from the leaves, utilizing 40 mm diameter circular leaf portions cut by special scissors. The other procedures conducted for quantitative analysis were similar, using filter paper samples.

On the third step, the insecticide was sprayed on the cotton canopy, and the biological effectiveness of the treatments and nozzles were determined by counting white fly larvae under leaves.

Quantitaitve determination – The spray deposit was detected by the Turner Fluorometer, Model 111. Filters used in the fluorometer were 405 (first) and 2A-12 (second). First, the calibration diagram of the fluorometer was prepared by working with standard BSF solutions at the different sensivity levels of the fluorometer. The concentrations of the standard BSF solutions and their corresponding fluorometric readings at three sensivity levels are given in **Fig. 5**.

The amount of deposits on the filter papers and leaves were computed by using the following equation:

$$Dm_{10} = m_{10} \cdot V_{wd} \cdot F_{rn} \cdot \frac{1}{A}$$

where,

Dm_{10} = The amount of BSF deposit (μg / cm^2),

m_{10} = Fluorometric coefficient at the sensitivity 10 (4.10^{-3} μg/ml),

V_{wd} = Quality of distilled water for washing out the spray deposit (100 ml for 5 filters or leaves in a same jar),

A = Area of filter papers or leaf portions with 40 mm diameter,

F_{rn} = Fluorometer dial readings.

Therefore, this equation becomes,

$$Dm_{10} = 4.10^{-3} \cdot 100 \cdot \frac{F_{rn}}{62.83}$$

$$= 6.37 \cdot 10^{-3} \; F_{rn} \; \mu g/cm^2$$

Caluculation of relative deposition – The application rates for the different nozzles were: cone type

Fig. 5 Fluorometer calibration diagram.

nozzle, 63.7 l/ha flat fan type nozzle, 60.0 and disc type nozzle, 49.4.

If these volumes of solutions were distributed uniformly on one ha horizontal unit area, the depositions on the unit field surface will be: 0.637 $\mu g/cm^2$ for cone type nozzle; 0.600 $\mu g/cm^2$ for flat type nozzle; and 0.494 $\mu g/cm^2$ for disc type nozzle.

The average leaf area index, in the duration of the experiments (from July 1-30), was 1.3 and depositions were 0.490, 0.461 and 0.380 $\mu g/cm^2$, respectively.

The relative depositions of the sprayed solution on the experiment plots, as the percentage of actually used amounts, are as follows:

$$RD_{cone\ nozzle} = \frac{Dm_{10}}{0.490} \cdot 100$$

$$RD_{fan\ nozzle} = \frac{Dm_{10}}{0.461} \cdot 100$$

$$RD_{disc\ nozzle} = \frac{Dm_{10}}{0.380} \cdot 100$$

Biological efficiency control – The biological efficiency was determined by the Henderson Tilton Equation (7).

$$T = (1 - \frac{T_s \cdot C_e}{T_e \cdot C_s}) \cdot 100$$

where,

T = Biological efficiency (%)

T_s = Counting on the experiment plots after pesticide spraying (5 days after)

T_e = Counting on the experiment plots before spraying

C_s = Counting on the control plots at the same time which T_e counts were obtained

C_e = Counting on the control plots at the same time which T_e counts were obtained

Since the white flies lay their eggs on the nether side of the leaves, the larvae were counted only under the leaves.

Results and Discussion

The summary of the results obtained by using filter papers which are given in the **Tables 3, 4 and 5**, and in **Fig. 6** are as follows:

In favorable atmospheric conditions, in the treatment of traditional application, the relative depositions obtained by the cone and fan type nozzles were 51 %. This value was 44 % for disc type

Table 3 BSF Deposits and Relative Deposition on Filter Papers with Cone Type Nozzle

Treatment	BSF deposition ($\mu g/cm^2$)				Relative deposition (%)		
	On the leaf(a)	Under the leaf(b)	Total a + b	Ratio a/b	On the leaf	Under the leaf	Total
Traditional application	0.230	0.0230	0.253	10.00	46.93	4.69	51.62
Electrostatic charged app.	0.246	0.029	0.275	8.48	50.20	5.91	56.11
Air carried application	0.202	0.028	0.230	7.21	41.22	5.71	46.93
Electrostatic charged and air carried app.	0.228	0.031	0.259	7.35	46.53	6.32	52.85

Table 4 BSF Deposits and Relative Deposition on Filter Papers with Flat Fan Type Nozzle

Treatment	BSF deposition ($\mu g/cm^2$)				Relative deposition (%)		
	On the leaf(a)	Under the leaf(b)	Total a + b	Ratio a/b	On the leaf	Under the leaf	Total
Traditional application	0.205	0.032	0.237	6.40	44.46	6.94	51.40
Electrostatic charged app.	0.237	0.039	0.276	6.07	51.40	8.46	59.86
Air carried application	0.223	0.032	0.255	6.96	48.37	6.94	55.31
Electrostatic charged and air carried app.	0.252	0.037	0.289	6.81	54.66	8.02	62.68

Table 5 BSF Deposits and Relative Deposition on Filter Papers with Disc Type Nozzle

Treatment	BSF deposition ($\mu g/cm^2$)				Relative deposition (%)		
	On the leaf(a)	Under the leaf(b)	Total a + b	Ratio a/b	On the leaf	Under the leaf	Total
Traditional application	0.134	0.035	0.169	3.82	35.26	9.21	44.47
Electrostatic charged app.	0.172	0.045	0.218	3.74	45.26	11.84	57.10

Fig. 6 BSF deposit on the filter papers according to different nozzles and treatments.

Table 6 BSF Deposits and Relative Deposition on Leaves with Cone Type Nozzle

Treatment	BSF deposit ($\mu g/cm^2$)	Relative deposition (%)
Traditional application	0.218	44.48
Electrostatic-charged application	0.221	45.10
Air-carried application	0.215	43.87
Electrostatic-charged and air-carried application	0.236	48.16

Table 7 BSF Deposits and Relative Deposition on the Leaves with Flat Fan Type Nozzle

Treatment	BSF deposit ($\mu g/cm^2$)	Relative deposition (%)
Traditional application	0.163	35.35
Electrostatic-charged application	0.190	41.21
Air-carried application	0.190	41.21
Electrostatic-charged and air-carried application	0.213	46.20

Table 8 BSF Deposits and Relative Deposition on Leaves with Disc Type Nozzle

Treatment	BSF deposit ($\mu g/cm^2$)	Relative deposition (%)
Traditional application	0.178	46.84
Electrostatic-charged application	0.253	65.57

Fig. 7 BSF deposit on the leaves according to the different nozzles and treatments.

nozzle.

The ratio of collected deposits on and under filters were 10.00, 6.40 and 3.82, respectively, for the cone, fan and disc type nozzles in the treatment of traditional application. This means, that the disc type nozzle is more efficient in carrying deposit to the nether sides of the leaves. The results of the biological efficiency determinations confirmed this conclusion.

The total relative deposition was increased more or less by electrostatic charing for all of three types of nozzles when compared with traditional application results. These increases are; 4.49 % for cone type nozzle, 8.46 % for fan type nozzle, and 12.89 % for disc type nozzle with increases in relative depositions obtained from the nether sides of the leaves of 1.22 %, 1.52 % and 2.63 %, respectively.

As these values indicate, the relative deposition increases are not high enough as one expects from the treatment of electrostatic charging. Most probably, the high relative humidity during the field experiments could have affected these results in a negative sense.

Carrying the droplets pulverized by cone type nozzle to the plant canopy in a vertical air current decreased the total relative deposition by 4.7 % compared to traditional application, and increased 3.91 % when the fan type nozzle was used. Since air carrying method requires bulky and expensive construction, and high velocity airstream needs a big blower or a compressor, this little amount of increase in relative deposition could not be justified economically.

The treatment of the electrostatic charging and vertical air current together, had a positive effect on the efficiency for the fan type nozzle on the total relative deposition. But it is not high enough, considering the complexity and cost of the system.

The quantity of deposits and relative depositions on the circular leaf portions are given in the **Tables 6, 7 and 8**, and in **Fig. 7**. When these results are compared with those obtained from the filter papers, the deposit quantities and relative depositions are found to be generally less. It could be reasoned that the contact angle between cotton leaves and droplet is higher than to filter paper; i.e., the deposits of droplets on filter papers is greater.

According to these results all the treatments using the cone type nozzle are not the appropriate application methods to increase the deposit and the relative deposition on the cotton plant.

Electrostatic charging increased the total relative deposition to 5.86 % for the fan type nozzle and 18.73% for the disc type nozzle compared to the traditional application.

The biological control results, given in the **Table 9**, confirmed the results obtained with the filter papers and with the circular leaf portions. According to the active ingredient transportation capacity of the different nozzles to the nether side of the leaves, biological efficiencies were changed.

The nozzle, carrying more ingredient to the nether side is much more efficient as shown in the **Tables 9 and 10**.

The total relative depositions on the filter papers and on the circular leaf portions are given in the form of a bar diagram in **Figs. 8 and 9**.

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Table 9 Biological Efficiency, by Type of Nozzles and Treatments

Treatment	Biological efficiency (%)		
	Cone type nozzle	Flat fan type nozzle	Disc type nozzle
Traditional application	68.94	80.29	85.04
Electrostatic-charged application	77.42	86.47	90.58

Table 10 Relative Deposition Under the Leaves According to Different Nozzle Types and Treatments

Treatment	Relative deposition under the leaves (%)		
	Cone type nozzle	Flat fan type nozzle	Disc type nozzle
Traditional application	4.69	6.94	9.61
Electrostatic-charged application	5.91	8.46	11.84

Fig. 8 Total relative deposition on the filter papers.

Fig. 9 Total relative deposition on the leaves.

Design and Construction of a Simple Rice Parboiling Hardware for Use in Nigeria

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Abstract

Parboiling of rice – a hydrothermal process – is a treatment given to raw paddy in Africa. It enhances the quality of rice during milling.

An appropriate technology equipment was designed and constructed for rice parboiling in Nigeria. Results show that the machine reduced the time of parboiling from 48 h to 4.5 h and was found to improve the quality of milled rice significantly.

Introduction

The treatment of rough rice referred to as rice parboiling has now assumed increased importance in many developing countries in Asia and Africa (Velupillai and Vernna, 1982).

Properly done, parboiling enhances the quality of rice during milling in three significant ways:

(i) Head rice recovery is significantly high;

(ii) Nutritional value of the resulting polished rice is high because vital micro-nutrients (vitamins and minerals) lodged in the bran become translocated into rice during parboiling thus making them available to the consumer; and

(iii) Parboiled rice is less prone to enzyme-driven oxidative deterioration.

Mattews et al, 1982 stated that parboiling can reduce breakage in milling to essentially zero %. Today, about one-fifth of the world's total rice is parboiled (Adewusi 1982).

In Nigeria, there is a remarkable preference for imported rice because the quality is better than locally produced ones (Ayotade, 1982).

Traditional methods of parboiling rice in Nigeria involve soaking the paddy in cold water for a period of 12 to 72 h before boiling the rice. Modern methods of parboiling involve steeping (soaking) the rice at higher temperatures and then steaming.

Objectives

The general objective of this study was to develop a relatively inexpensive system of parboiling rice that would drastically reduce the number of man-hours involved in the traditional process.

The specific objectives are:

i. To design a suitable system for parboiling up to 50 kg of rice.

ii. To construct the unit using locally available material.

iii. To test and obtain the optimum working conditions of the equipment.

Design Criteria

The process of parboiling designed for the system was steeping in temperatures ranging between 60°C and 90°C after which the rice would be steamed for a certain period.

The design was to be such that the unit would be used for both steeping and steaming. Heat losses were to be minimized and the temperature of steeping was to be automatically controlled. There was to be only one chamber for both steeping and steaming so as to reduce space and financial commitment.

Design and Construction

The requirements of the design include:

i. Galvanized sheets for the par-

Fig. 1 Parboiling chamber, cross section.

Fig. 2 Parboiling chamber, outside view.

boiling chamber;

ii. Galvanized iron pipes and other necessary fitting such as gate valves, socket and union connections;

iii. Electric heaters (mounted close to the floor of water compartment; and

iv. Control panel which includes thermostat, switch, signal light, fuse, cables and connectors.

Schematics of the parboiling chamber is shown in **Fig. 1** and the outside features in **Fig. 2**.

The inner chamber's dimension are 60 x 50 x 50 cm and is made from galvanized iron sheets. To minimize heat loss, insulation was provided between the inner and outer walls. The parboiling compartment has a false bottom made of 25 mm angle iron arranged horizontally around the chamber. On this false floor are set two baskets made from 2 mm gauge wire. Each of these baskets have a paddy-holding capacity of 25 kg.

Water is fed directly from the top of the unit to a level that covers the paddy and the lid, which is also insulated and screwed down to allow for pressure steaming. A steam outlet is provided at the top of the lid to prevent excessive pressure buildup.

Four electric heaters of 2.75 kW each are attached below the false floor in the water holding compartment which is of 150 mm depth. The heaters and thermostat are connected to the mains through control box.

Drain pipes with valves are provided for draining excess water before steaming and for draining all the water at the end of operation. These pipes are made of 19 mm galvanized pipes and have extension pipes that can take the water to an outside drain.

Operation

To operate the equipment, the parboiling compartment with paddy in the baskets (**Fig. 3**) is filled with water and heated at a temperature of between 70 and 90°C. This temperature is achieved in about 1 h.

This temperature is kept constant for about 3 h at the end of which water is drained to a level below the false floor in the chamber. The remaining water is heated to generate steam for a period not exceeding 30 min. The control is activated by means of a switch on the control board.

Preliminary Tests

Tests were carried out on two varieties of rice (Faro 11 and BG 90-2) produced at the National Cereals Research Institute in Ibadan, Nigeria – an institute that carries out research on cereal grains. There were 7 treatments as shown in **Table 1**.

The control was soaked in water at room temperature for 24 h and then boiled for 20 min. Parameters tested included protein, fat and amylose. The paddy had a combination of shade and sun drying and was milled in two passes. Recovery (%), head rice (%), percentage broken and percentage of white speck were also determined. There were two replications for each treatment.

Fig. 3 The parboiler in operation.

Table 1 Tests Carried Out on Rice Parboiler

Treatment	Soaking temperature (°C)	Soaking time (h)	Steaming time (min)
1	70	4	20
2	80	4	20
3	90	4	–
4	80	4	10
5	80	3	20
6	Unparboiled Rice	–	–
7	Control (Local method)	–	–

Table 2 Chemical Analysis of Parboiled Rice

Treat-ment	Protein (%)	Fat (%)	Amylose (%)
1	8	0.8	17
2	9.65	0.8	14
3	9.55	0.75	14.1
4	8.45	0.70	16.6
5	8.40	0.80	17.0
6	9.0	0.9	20.0
7	9.35	0.75	19.6

Table 3 Analysis of Physical Characteristic of Parboiled Rice

Treatment	Recovery (%)	Head rice (%)	Broken (%)	White speck (%)	Other losses (%)
1	73.2	83.75	13	60	3.25
2	67.5	85	10.5	–	4.5
3	49.12	41	55	–	4
4	62.2	91.5	2	3.5	6.5
5	57.8	84.0	6.0	5	–
6	72.8	36	49.5	100	14.5
7	70.5	84.5	5.5	11	–

Results

A summary of the result is shown in Tables 2 and 3.

The results show that treatment 2 is the best method for recovery, head rice and white speck. The protein content of this treatment is significantly higher than others and is in fact the highest of all the treatments. Although the local method had a high recovery, the percentage of white specks was unacceptably high and the odour generated by the long hours of soaking was repulsive.

The parboiler functioned effectively and little problem of minor leakage at the points of heater connections were detected and corrected.

Conclusion

This method of parboiling was found to be easier and faster and also gave better results as far as recovery of rice is concerned. Further research work needs to be done on using other heat sources, especially sources that do not utilize electricity.

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Agricultural Mechanization in Developing Countries

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Operational Safety Requirements for Farm Machinery: A Case Study in Pakistan

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Introduction

Development is driven by the process of technological innovations and its sucessful transfer. Advanced technology has greatly reduced man's physical burdens through the use of machines. The operator has to make many decisions to use the machines properly and safely. Improper decision or mistakes result in accidents. These mistakes can be due to a variety of stresses. The stresses are caused by fatigue, noise, vibration, seating position, controls, temperature, humidity and visibility. The operator must adjust to all these factors for safe operation.

The task of developing and manufacturing of a product is becoming more and more sophisticated due to demand for high performance, automatic adjustments, conveniences and safety regulations. Due to increased awareness for the human health, the developed world is adopting and enforcing safety regulations. The products cannot be sold unless they meet these safety regulations. Product safety is closely related to man-machine relationship. The product must perform without inducing stresses. Product safety also means safeguarding the operators and the by-standers in case of mishap.

In agriculture automatic controlled tractors, field machinery and other inputs have significantly increased the efficiency of crop production. Developed countries have developed machines for specific jobs, with due considerations to human safety. Developing countries are also using machines either imported or locally manufactured. The imported machines require proper knowledge and training to operate. Lack of training results in accidents. The locally-manufactured machines generally lack safety features, proper materials and quality construction. The example to illustrate can be agricultural chemicals which are used throughout the world. In developing countries these are used without safety devices. The farmers are not trained. The extension agencies and the sellers do not educate the farmer either.

In Pakistan the farm machinery manufacturing industry is developing. Approximately 500 manufacturers are producing farm machinery and parts. Most of them are using general purpose machine and improper techniques in manufacturing. The locally manufactured machines thus do not conform to standards. The manufacturers do not incorporate safety devices nor print safety signs.

Ways to Accomplish Safety

To achieve safety training is most essential for manufacturers, dealers, farmers, and operators.

Training of Manufacturers

A well-made product saves a lot of hassles. The realization of safety in machine building needs to be emphasized to the manufacturers. It is an established fact that majority of Pakistani farm machinery manufacturers have little knowledge of their products and its production in the proper way. Quality control is not observed. The machinery design selected has

no safety devices. The trend is to produce cheap products in the hope that it sells better. The expensive products which perform better and have safety features require efforts in marketing. The Pakistani manufacturers are neither ready nor organised to put up strong marketing efforts. A properly manufactured farm machine is possible by careful selection and use of raw materials, quality checks of components and products and incorporation of safety devices and decals.

An understanding of the farmers' problem requires practical knowledge and experience. This is lacking in majority of the farm machinery manufacturers in the country.

The tractor population in Pakistan is growing. The emphasis is shifting in favour of mechanized farming. The use of tractor and allied implements require skill to operate. The skill factor is coupled with socio-economic aspects of rural life, machine complexity and operating environment. Several studies have been carried out from time to time on various aspects of mechanization. However, no work on farm machinery safety in the country has been reported yet. This study is the first attempt.

There is enough justification that concrete measures should be taken to make the makers and the users of farm machinery realize the importance of safety. The research institutes extension agencies, press and the authorities have a very vital role to play in creating the awareness about safety.

Training of Dealers

The dealers are the representative of the manufacturers for farmers and vice-versa. They have to carry out the following functions to enable the farmer to use the machine with complete safety and effectiveness for maximum return on investments: pre-delivery checks, briefing and debriefing of the farmer, training and service.

To enable the farmer to use the machine safely and properly the dealer's staff has to be trained, motivated and equipped with knowledge of the products being marketed.

The training of dealer on safety aspects is very essential as well as the use of safety devices and decals on the machine. They must bring it to the notice of the farmers. Many instances have been reported about dealers being unaware of the safety aspects of machines they sell.

Training of Farmers

A large proportion of the farmers in the country are illiterate. This is a strong reason for not being aware of the proper use of machine and not even striving for it. The practical training on functional and safety aspects of farm machinery means a full understanding and acquiring of skills to utilize the machine fully. It is a common observation that most machines at the farms in Pakistan are under-utilized.

Objectives of the Study

This study was formulated with the aim of knowing the mode of safety required by the user of farm machineries in order to minimize accidents.

Review of Literature

The National Safety Council (1) stated that tractor accidents claim the lives of an estimated 1000 persons annually in U.S.A. A rate of about 2.2 deaths per 10000 tractor is reported. Schnieder (2) reported that the leading causes of accidents in the U.S. seem to be improper operation of tractor and equipment, which include excessive speed, carelessness and loss of control of the tractor. Knapp (3) reports that in 61% of the accidents investigated the shields of the tractor P.T.O. were missing. McGlade and Law, (1962) in their traffic safety research review found that there is an intrinsic and measureable cause of all accidents. It is possible to get insight into this cause by studying the situation and activities in which accidents occur. The causes of accidents can be generalized as inadequacy of safety training.

Discussing the stress theory, Kerr (1964) held that unusual, negative, distracting stress upon people increases their susceptibility to accidents due to poor reflexes. The stress is caused by internal and external factors. The internal factors are disease, alcohol, etc. The external factors are temperature, visibility, noise, fatigue, etc.

McFarland (1958) stated that "in general, any control lever that is difficult to reach and operate, any instrument that is difficult to read, any seat that causes poor posture or discomforts or any unnecessary obstruction to vision contributes directly to an accident". He further said that many accidents occured when the efficiency of the operator was impaired by some temporary conditions and that the efficiency and safety of driving might be adversely infulenced by fatigue. This is in support of the adjustment stress theory.

Knapp (1966) worked on man-machine relationship in tractor accidents and reported that the man-machine relationship is obvious in tractor accidents. That the manufacturer of the tractor must accept a large responsibility for reducing unseen physical damage and trauma producing accidents. He concluded that over 75% of

all tractor fatalities studied could have been prevented if appropriate protection had been installed in the tractors and operators observed safety. Hanse (1966) said that accidental injury and fatality rates can be reduced by providing more protective devices for individual machines and educating the user.

There is an increasing concern today in both industry and community for the value of human life in the developed world. Industrialized countries are experimenting and implementing safety devices. Governments of the developed countries are involved in both equipment- safety regulations and employee standards. Professional bodies are adopting safety standards and universities are carrying out research and educational programs in an effort to reduce accidents.

Begining in 1920 and becoming more obvious in 1960 onwards, there have been improvements in tractor and implements with respect to safety devices and warnings (Zink 1968). Agricultural engineers have a continuing responsibility to recognize new situations and sources of accidents. The more comfortable, trouble-free, and efficient, a manufacturer can make the equipment, the safer will be the environment for the operator.

Pakistan Situation

The Multan area was selected for farm safety study due to the presence of a large number (2969) of tractors and allied manchinery (8122). A random sample of 4 % was taken from the total population of tractor owners. Opinions were collected from farmers at farmer's field in the local dialect.

Types of Safety

The safety factor was studied with respect to the manufacturers and operator safety, manufacturer safety included incorporation of safety devices and warning label/ signs displayed. The operator safety covered operator training programmes, safety awareness and enforcement of safety regulations.

Demand and mode of safety was observed in relation to different factors, i.e., size of land holding, age, literacy and experience of farmers. Thirty-four percent demanded only manufacturers' safety. They thought that manufacturers' safety is the solution to all the mishaps. The accidents could be minimized if the manufacturers incorporate safety devices in the machines. Operater safety believers were 40 %. They thought that safer use of farm machinery could reduce accidents. Nearly 20 % of the respondents said both types of safety are necessary to reduce accidents. Only 6 % did not believe in safety. They said that hazards are unavoidable. It comes from God and nobody can stop it. Hence, to them there is no need to adopt safety measures. The overall breakdown of these results is shown in **Table 1**.

Table 1 Overall Requirement of Safety

Manufacturers Safety		
i.	Incorporation of safety devices	30%
ii.	Warning label and controls	4%
Operator Safety		
i.	Safety awareness	25%
ii.	Safety training programme	8%
iii.	Enforcement of safety regulations	2%
iv.	(i) + (ii) + (iii)	2%
v.	(i) + (iii)	4%
Operator + Manufacturers Safety		
i.	Safety awareness + incorporation of safety devices.	7%
ii.	Safety awareness + safety training programme.	4%
iii.	Incorporation of safety devices + enforcement of safety regulations.	4%
iv.	(ii) + (iii) + warning labels.	3%
v.	Warning labels + safety awareness	3%

Safety in Relation to Landholding

The total land area of Pakistan is 80 million ha of which 20 million was cultivated in 1983. There were 4.07 million farms of which 75 % were smaller than 5 ha accounting for only 33 % of the cultivated area. Medium and large farmers were using agricultural machinery on hiring basis. Landholders were studied in four groups, i.e., less than 5 ha, 5 to 10, 10 to 20 and above 20 ha. It is shown in **Table 2** that 60 % of the total farmers interviewed had landholdings of 20 ha and above. They were using tractors and allied machinery for the last three years. They hired skilled operator to operate their machines. Twenty-seven percent of

Table 2 Safety in Relation to Landholding (Unit: %)

Size of holding (ha)	All safety	Manufacturers' safety	Operators' safety	Operator & manufacturers' safety	Safety not required
All size	100	34	40	20	6
less than 5	6	2	3	0	1
5 to 10	15	8	4	3	0
10 to 20	19	9	6	3	1
20 and above	60	15	27	14	4

this cadre demanded operator safety. They said that there should be a tractor operator training school. To them operator training was necessary to reduce accidents and to increase operator performance. On the other hand, skilled operator claimed that owners of the machinery did not pay well. About 15 % of this group demanded manufacturers' safety. In their opinion machines being manufactured were not so reliable and to them manufacturers' safety was the only solution to reduce the mishaps.

Safety by Age Level

The population of Pakistan was about 95 million in 1985 and is increasing at the rate of 3.1 % per annum. Of this estimate about 70 % lives in villages and the rest in cities. Sex ratio was 114 males to 111 females. About 53 % of the total population was under 18 years. As many as 30 % of the population was 19 to 44 years age group. Four age groups were studied, i.e., less than 18, 19 to 29, 29 to 47 and 48 years and above. The percentages of these groups in sample were 10, 46, 33 and 11 %, respectively. As depicted in **Table 3**, age group of 19-28 years was dominant in farm machinery operation. Fifteen percent believed on manufacturers safety, 15 % had faith on operator safety. There were 12 % respondent who believed on both manufacturer and tractor safety. About 4 % of this group did not believe on any safety measures. The age group 19 to 28 years required manufacturers safety 15 %, operator safety 15 %, operator plus manufacturers safety 12 %, and 3 % did not ask for any safety.

Safety vs Literacy

The literacy rate in Pakistan was about 27 % in 1985. Approximately 45 % had primary education, 30 % passed middle standard, 25 % were matriculate and the rest had higher education. In the sample 61.5 % respondent were illiterate. There were 12.5 % primary, 16.0 % middle and 10 % matriculates and above. Nearly 24.5 % farmers from illiterate farming community demanded operator safety (**Table 4**). According to them it is difficult to find experienced and skilled operators. Twenty percent asked for manufacturers' safety. About 3 % of this group did not believe in safety. They said there is no need to adopt safety, hazard came from God and nobody could stop it.

Table 3 Safety by Age (Unit: %)

Age range (year)	All safety	Manufacturers' safety	Operators' safety	M + O safety*	Safety not required
All ages	100	34	40	20	6
18	10	5	3	1	1
19–28	46	15	15	12	4
29–47	33	12	15	5	1
48 and above	11	2	7	2	0

* Manufacturer plus Operators' Safety.

Table 4 Safety by Literacy (Unit: %)

Literacy	All safety	Manufacturers' safety	Operators safety	Operators and manufacturers' safety	Safety not required
All level	100	34	40	20	6
Illiterate	61.5	20	24.5	14	3
Primary	12.5	4	5	2	1.5
Middle	16	5	8.5	2.5	0
Matric and above	10	5	2	2	1

Table 5 Safety Requirements by Experience (Unit: %)

Experience in years	All safety	Manufacturers' safety	Operators' safety	Operators and manufacturers' safety	Safety not required
All exp.	100	34	40	20	6
one	6	4	0	2	0
2–5	32.5	10.5	15	5	2
5 and above	56.5	18.5	24	10	4
untrained	5	1	1	3	0

Safety by Experience

Experience means practice. Observance of safety measures is necessary for all. The sample was divided into four groups based on experience. **Table 5** shows that persons having experience of about 5 years in operation of agricultural machinery required operator safety (24%). They believed that safety must be observed during operation by everyone in order to minimize accidents. Four percent of this group did not believe in safety. They attributed all the mishaps to God, rather than blaming the operators or machines.

Conclusions and Recommendations

Built-in machine safety and operator safety are equally important. In order to achieve the objective of incorporating safety features and development and implemention

of safety codes and standards in farm machinery an agency at national level should be established.

This agency should be governed by the following terms of reference: 1. Development of safety codes and standards for farm machinery. 2. Implemention and testing of safety devices, decals and other features. 3. Training on safety – This requires the help of the media and other sources to educate the users and sellers of farm machines in safe operation of machines.

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Agricultural Mechanization in Orissa, India

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Abstract

The study was undertaken to identify the constraints in the use of agricultural implements and machinery in the State of Orissa. It was observed that mechanization in agriculture is not up to mark because of the problems which are mostly social, economical and technical in nature. In this paper attempts have been made to suggest various recommendations to overcome those problems.

Introduction

Orissa is located in the east coast of India between 17.41° and 22.34° North Latitude and 31.24° and 17.29° East Longitude. Of the total geographical area of 15.57 million ha 6.56 million ha are under cultivation. The average rainfall is 148.22 mm of which 85% is received between June and October. The month of July receives the highest rainfall of 325 mm. Paddy is the major crop which is grown on 4.13 million ha amounting to about 65% of the total cultivated land. Next to paddy is pulse which accounts for about 22%. The other important crop is oilseed which is about 8% of the cultivated area.

In spite of the fact that the State has abundant natural resources, better condition such as climate, soil for adaptability of agricultural machinery, the progress of mechanization in agriculture is very slow. As a result the economic condition of the farmer has not improved. The annual production of food grain is 5.51 million t which adds only 2.5% to the national production, whereas the State of Punjab and Uttar Pradesh add 20.4 and 20.9%, respectively. Per capita (rural) income is Rs. 548 the highest being Rs. 1627 in Punjab.

Attempts are made in this paper to identify the constraints of mechanization in the State and to suggest few recommendations to overcome them.

Constraints

The capital investment in a mechanized farm is much higher than that in the traditional farming. But the net result of this high capital investment is better farm management and, therefore, higher yields. That is why various States of the country show much higher level of production between mechanized and traditional farms. Many constraints come in the way of mechanization of agriculutre in the State. They are natural calamities, lack of consolidation of holding, inadequate irrigation facility, under-utilization of draft power unit, and inadequate energy sources and industrial infrastructure.

Natural Calamities

Almost every year the State is hit either by flood, cylcone or drought. In the 1950s and early 1960s, the State suffered from natural calamities once every fourth year. Now this happens every two years. As the rainfall is not well distributed through the year, either there is excess water for few months or scarcity of water. This reduces the production of food grain by 50 to 60% and strains the economy of the farmers.

Lack of Consolidation of Holding

Land consolidation in the State is in progress. A major portion of the cultivated area is yet to be consolidated. Due to small and scattered holdings, farmers are unable to perform intensive cultivation, a major constraint for mechanized farming.

Inadequate Irrigation Facility

The net irrigated area, including surface flow and ground water resources is about 20% of the total cultivated area. Only 12.5% of the

area is put under multi-cropping system due to lack of assured irrigation water. That is why the average fertilizer consumption in the State is only 13.1 kg/ha in comparison with the national average of 44.9 kg/ha.

Under-Utilization of Draft Power Unit

The study in the local area shows that the bullocks maintained by the farmers are engaged about 70–80 days during the year. The output-input ratio of energy for such animal is 0.535. This implies that the maintenance of animal demands more energy than what is obtained from them and as such animal power for agricultural operations strains the economy of the farmers.

Inadequate Energy Sources and Industrial Infrastructure

The people of Orissa are more dependent on agriculture due to lack of an industrial base. Nearly 77% of the work force is engaed in agriculture and less than 6% in industry. Unless there is diversification from agriculture to industry and other non-farm occupations, improvement cannot be expected.

Energy is the basic requirement for agriculture which is scarce in the State. It is essential to increase the production which seems difficult without mecahnization and mechanization is impossible without energy sources. Therefore, energy is proved to be a major constraint for agriculture in the State.

Achievement

In certain areas of the State some improvements on the introduction of farm machinery are made but by and large, farmers still follow the traditional method of cultivation. As a result the other scarce resources such as land, irrigation water, fertilizer, time and proper performance of farm operations are under-utilized.

In order to analyze the mechanization status of the State it is essential to record the cropping pattern (**Table 1**) and, hence, the labour utilization for agricultural operation. As paddy is grown in major portions of the area, a large amount of labour is required each year. However, the present trend is changing significantly due to the popularization of improved agricultural implements. Most of the farms are bullock-human power operated and a negligible percent only use the tractor-bullock power. The multi-cropping system has increased the demand of labour manifold. The labourers are not available at the crucial moment of different agricultural operations.

The use of improved agricultural implements is becoming popular among the farmers because of the following identified reasons: i) labour saving, ii) easy and quick work, iii) timeliness of operation, iv) reduction of drudgery, and v) increase economic return to farmers.

Deep tillage practice is useful in alluvial soils for increased infiltration rate. The tool for deep tillage is mould board plough (**Fig. 1**). The size of the mould board plough depends on the size of the bullock, soil type and field conditions. The implement has an advantage of adequate strength, deep penetration ability and overcomes the problem of wear and tear of regular wooden plough. There is an increase in the number of mould board plough of 91% during the 1977 census year over that of the 1972 census year whereas there was only 37.8% increase in respect of wooden plough. During the year 1983-84 about 26 000 traditional wooden ploughs were substituted by mould board ploughs.

Tractors used (**Table 3**) on the selected farms range from 25 to 30 hp and are limited to primary tillage operation and transport. Other

Table 1 Important Cropping Pattern in Orissa

	Kharif	Rabi	Summer
Highland			
Irrigated	Paddy Paddy	Mustard Weat	Groundnut Til
Unirrigated	Jute Groundnut	Horsegram Niger	Fallow Fallow
Medium land			
Irrigated	Paddy Paddy	Wheat Vegetables	Paddy Pulses
Unirrigated	Paddy Paddy	Groundnut Pulses	Fallow Fallow
Low land			
Irrigated	Paddy Jute	Paddy	Paddy Vegetables
Unirrigated	Paddy Jute	Paddy Paddy	Pulses Pulses

Table 2 Areas Planted to Various Crop

Kharif			Rabi		
Crop	Area (000' ha)	Percent	Crop	Area (000' ha)	Percent
Rice	4,022	61.3	Rice	137.17	2.0
Other cereals (Bajra, Jawar, etc.)	446	6.8	Wheat	66.05	1.0
Pulses	381	5.8	Pulses	1,493	22.8
Oilseeds	295	4.5	Oilseeds	537	8.1
Vegetables	280	4.3	Vegetables	329	5.0
Other Crop	77	1.2	Sugarcane	50	0.8
			Other Crop	17	0.3
Total	5,502	83.8	Total	2,629	40.0
Fallow	1,058	16.2	Fallow	3,931	60.0

Table 3 Tractor Population in Orissa

Year	No. of tractors
1966	700
1972	1400
1979	2000
1980	2400
1981	2800
1982	2900
1983	3200
1984	3400

Table 4 Farm Implement Manufactured in Government Implement Factory, Bhubaneswar

Implement	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85
Mouldboard plough	5355	8270	9000	11890	7870	4800	10780	12400	8308	5300
Disc harrow	–	100	450	150	1050	505	320	–	–	–
Seed drill	–	–	460	849	938	110	–	2100	1950	1340
Rake weeder	835	1300	3844	3070	2408	1190	1500	11560	4084	3200
Garden rake	987	1940	1093	1220	–	2043	10	1444	949	500
Trench hoe	612	1959	2950	2829	1400	4100	1060	2190	2998	1500

Fig. 1 Mouldboard plough.

field operations are carried out by bullock-human power.

After the first ploughing by mould board plough the secondary implement, namely, bullock-drawn disc harrow (Fig. 2) is used to reduce the clod size and pulverize the soil. Combination of mould board plough and disc harrow does the work very efficiently and saves time and labour up to 50%. The use of mould board plough in combination with disc harrow laso reduces weed infestation.

In traditional practice the seeds are broadcast in the field without maintaining proper depth and spacing. In this method excess seeds are thrown. The manually-operated three-row seed drill (Fig. 3) is popular for dry seeding of paddy and other crops maintaining proper depth and spacing.

This implement is very popular among farmers. The salient feature of the machine is a seed box allowing precision metering of fine and broad seeds. The machine has three furrow openers and fitted with a central shaft with seed cups. The seed covering and light compaction is done by the furrow opener due to the weight of the drill. The seed drill is easy to operate and accurate in metering.

Fig. 2 Disk harrow.

Interculture to eliminate weeds before they compete with the crop is an important practice and, therefore, a combination of tillage and weeding is necessary. The use of rake weeder (Fig. 4) and trench hoe (Fig. 5) reduces labour requirement cost and makes timely weeding efficient. This rake weeder and other hand tools are accepted by the farmers for interculture and allied operation.

Hand compression low volume knapsack sprayers (Fig. 6) are used as plant protection equipment. These sprayers are in operation throughout the State and are efficient.

The common method of threshing paddy is by bullock treading (Fig. 7). This method is time consuming, labourious and not suitable for bad weather. Gradually the pedal operated paddy threshers

Fig. 3 Manually-operated seed drill.

Fig. 4 Rake weeder.

Fig. 5 Trench hoe.

Fig. 6 Hand-compression sprayer.

Fig. 7 Threshing of paddy by bullock treading.

Fig. 8 Operation of pedal thresher.

(Fig. 8) are gaining popularity among the farmers. The research for power operated paddy thresher and multicrop threshers is being carried out to reduce the net unit threshing cost by increasing efficiency and capacity.

Conclusion

The farmers of Orissa are inclined to use improved agricultural implements, but the use is not up to the mark. These problems are mostly social, economical and technical in nature. The lack of spare parts, repair and service facilities are major problems. Moreover, the cost of the farm machines is prohibitive for small and marginal farmers.

By now the implements are manufactured in a factory at Government level. The private sector industries have yet to manufacture agricultural implements. Policy decision should be made in the Government level to encourage them.

Farm size influences the efficiency of mechanization as it is relatively easy to achieve economy of scale on large farms. Therefore, consolidation and cooperative farming is an immediate need in the State.

Mechanized cultivation, though expensive in terms of initial cost, is more efficient than traditional farming. Therefore, steps should be taken to develop implements suitable for various climatic conditions, soil types and size of holdings.

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Field Reliability of Farm Machinery

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Abstract

The reliability engineering concept and its application to farm machinery are reviewed. Methods of achieving satisfactory reliability in farm machines are discussed. It is observed that a major effort for quality and reliability of a product is required from the manufacturer to reduce overall cost and achieve maximum consumer satisfaction.

An attempt has been made to apply reliability theory to farm machinery with special reference to mechanical reapers. The method developed in this study in determining machine reliability is basic and is applicable under most conditions. The method uses field data, without any modification, for estimation of parameter values for the reliability function.

Introduction

Timeliness in farm operation is a very important factor for successful agriculture. Farm equipment failures, especially during the busiest part of the season, cause delays which result in losses and inefficient labour utilization. The optimum period for tillage, seeding, pest control and harvesting are influenced by weather, soil moisture and cultivars. The economic penalties for missing the optimum operational opportunity can be disastrous. To make allowance for the time losses due to breakdown in planning, one needs to know the probability of machine failure. The failure can be taken care of in the short time provided service is available. Unfortunately, the service structure is not satisfactory in Pakistan. To create satisfactory service facilities requires significant time, money and effort. Therefore, reliable farm machines can be more useful and dear to the farmer in Pakistan. The subject of reliability has become of increasing interest to the engineering profession. Reliability engineering techniques and terminology are well developed. This is mostly in the electronics, aerospace and nuclear engineering industries.

The task of designing and supervising the manufacture of a product is becoming more and more difficult due to: (1) rapid strides in sophistication of products: (2) the understanding of severity of the environmental conditions under which they must perform; and (3) competition. Today time is insufficient and economically not feasible to go through the complex cycle of design, field test, redesign, resets and so forth. Rapid development can be best attained by systematically combining and statistically analyzing the entire data and parameter spectrum. What is new about the reliability effort is the planned experimental strategy and systematic collection and statistical analysis of all data.

Literature Review

The volume of literature available dealing with the use of reliability in design and manufacture of farm machinery is limited. Archer (1983) describes the problems of reliability prediction in terms of varying farm conditions under which a particular machine is designed to work.

Richardson et al (1967) carried out a survey of farm machinery durability. Hunt (1971) reported the results of a survey for the incidence of breakdowns, lost time and repair costs experienced by farmers growing maize and soy bean. His study included the probabilities of breakdowns for various machines depending on age-use and concluded that an average farmer has less than a 50-50 chance of getting through the season without a breakdown that has timeliness cost associated with it.

Hollenback (1977) applied reliability methods to a combine in both pre-and post-production operations. The methodology is applied through the implementation of reliability procedures which covers the reliability elements of requirements, analyses reviews, tests, warranty and reports. Management support and an effective customer use programme are keys to the reliability effort. Kumar et al (1977) published papers on reliability engineering concepts applied to combine harvesters.

Objective of Study

Reliability of any equipment is of increasing concern and importance to all segments of society. Chaudhary (1984) reported the results of survey concerned with the mechanical reapers' breakdown, lost time and repaired cost experienced by the farmers in Pakistan. The farmers were more interested in improving their equipment reliability. They insisted that manufacturers should increase reliability through better design and construction. This study had been undertaken with the following main objectives: i) To highlight the importance of reliability engineering and its application to farm machinery; ii) To formulate an algorithm to estimate reliability of farm machinery; and iii) To assist the designer and manufacturer in producing more reliable machines.

Limitation of the Study

The study mainly deals with reliability procedure on specific data needs, their collection and analysis. In Pakistan, the use of mechanical reapers by farmers has just started, hence limited failure frequency data was available. The collection of farm machinery failure data (for tractor, combine harvester, etc) is, however, currently in progress. A comprehensive study of the machine field reliability will be reported in a later report.

Theoretical Considerations

Reliability is usually defined as the probability that the device/equipment will complete a specific task under specified conditions for stated period of time (or distance, or number of revolutions, etc). Reliability is thus a mathematical expression of the likelihood of satisfactory operation.

Thus, in reliability, the definition of failures, the time period and the operating conditions must be clearly stated. A failure may be defined as any condition which prevents operation of a machine or which causes or results in a level of performance below a specified limit. For example, in a combine, failure could be a broken elevator, chain link (a down-time failure) or it could be a broken screen in the shoe resulting in a degradation of performance. The failure rate of a population of items for a period of time from t_1 to t_2 is the number of items which fail per unit time in that period expressed as a fraction of the number of non-failed items at time t_1. In reliability, the reciprocal of failure rate is the mean time between failures (MTBF). The time period can vary with the machine type. For combines it could be the harvest season for a particular crop. Environmental and operating conditions are the field conditions under which a particular machine is designed to operate.

Machine failures can be categorized into three basic types (Amstarder 1971): early life failures, random failures, and wear-out. Out-of-tolerance failures are usually classified as wear out failures. Early failures occur because of some defect in a part or assembly resulting from a deficiency in design and or manufacturer inspection. During the random failure period the failures occur because of random occurance of environmental stress levels sufficiently severe to cause component failures. This period in the life of the components is also known as "useful life period". The wear-out period is characterized by an increase in failure rate due to parts' degeneration with age. **Fig. 1** shows the relationship of three classes of failure which is also known as the "bathtub curve".

Fig. 1 Failure rate or "Bathtub" curve during machine's life (Kumar, 1977).

Methods of Achieving Satisfactory Reliability

The institution and operation of a product reliability programme is mentioned briefly here. **Fig. 2** (taken from Anon, 1977) applies to electronic equipment but the principles are similar to mechanical equipment. The figure shows that the achievement of reliability as a team effort starts with the designer and involves all phases of production, marketing and feed-back from the end-user.

Simplicity of design generally increases reliability and reduces costs. Pugh (1978) quantified the complexity as:

$$\text{Complexity} = (Pp \times Pt \times Pi)/f \quad (1)$$

where,

- Pp = No. of parts
- Pt = No. of different types of parts
- Pi = No. of interconnections and interfaces
- f = No. of functions the product is expected to perform

Simplicity is associated with a low complexity factor: the lower the number, the greater the product reliability, the lower its cost, the higher its quality.

The reliability of a machine is the product of individual component's reliabilities. The reliability of individual components which are essential for the functioning of complex machines must, therefore, be very high if satisfactory operational reliability is to be achieved. Taking a hypothetical tractor as

Fig. 2 A reliability program (Anon, 1977).

example, we find that: If the engine, transmission, tyres and steering system have reliabilities of 0.85, 0.95, 0.98 and 0.95, respectively, for operation in specified conditions, then the reliability of the tractor as a whole is only 0.75. In other words, there is a one-in-four chance that the tractor will breakdown within a specified period of time.

The Exponential Model in Reliability

Miller (1977) describes the application of exponential model in reliability problems where it is hypothesized that failure rate is constant over the entire life of a mechanism. In this case the chance of no failure in time t is called reliability R(t) and can be written as:

$$R(t) = e^{o\int^{t}\lambda\, dt} \quad \text{or} \qquad (2)$$

$$R(t) = e^{-\lambda t}$$

where,

λ = failure rate (inverse of MTBF)

However, R(t) is the complement of cumulative probability of a failure in time t.

$$R(t) = 1-F(t) = e^{-\lambda t}$$

The probability densitiy function (pdf)

$$f(t) = \frac{df(t)}{dt} = \lambda e^{-\lambda t}$$

The complete exponential pdf is

$$f(t) = \lambda e^{-\lambda t}\ (t > 0, \lambda > 0) \qquad (3)$$

0 otherwise

There are many kinds of failure distribution in use. The choice of a distribution to use depends on the characteristic failure rates.

In this study the Weibull failure distribution was used because it is a three-parameter distribution, and increasing constant and decreasing failure rate pattern can be described by varying the parameter value.

The Weibull Failure Model

The Weibull failure probability function (pdf) is given as:

$$f(t) = \frac{\beta\,(t-\gamma)^{\beta-1}}{\alpha}\ e^{-(t-\gamma)^{\beta/\alpha}}$$

$$t > \gamma \qquad (4)$$

0 = otherwise
α = scale parameter
β = shape parameter or Weibull slope
γ = location parameter or lower bound of life

Integrating the above function gives the Weibull cumulative density function (cdf).

$$F(t) = 1-e^{-(t-\gamma)^{\beta}/\alpha} \qquad (5)$$

The three parameters (α, β, γ) provide considerable flexibility in describing failure distributions. Upon setting $\beta = 1$, the above equation becomes the exponential distribution with delay (i.e., can be thought of as a guarantee period within which no failure can occur or as a minimum life). Thus, the assumption of a constant failure rate (exponential) is also included as a special case in this Weibull failure distribution.

In the case of farm machinery, the first failure can be expected as soon as the machine is placed in service, hence the lower bound is zero. Thus $\gamma = 0$ and the Weibull density function becomes:

$$f(t) = \frac{\beta t^{\beta-1}}{\alpha}\ e^{-(t^{\beta})/\alpha} \qquad (6)$$

and cdf becomes

$$F(t) = 1-e^{-(t^{\beta})/\alpha} \qquad (7)$$

The reliability function,
$R(t) = 1-F(t)$
For Weibull failure distribution

$$R(t) = e^{-(t^{\beta})/\alpha} \qquad (8)$$

Estimation of Weibull Parameters

A least square method can be used to estimate the Weibull parameters. This method is based on the fact that the reliability function of the Weibull distribution can be transformed into a linear function of ℓnt by means of a double logarithmic transformation. Taking the natural logarithm twice of both sides of equation (7) gives:

$$\ell n\, \ell n \frac{1}{1-F(t)} = \beta\, \ell nt - \ell n\, \alpha \quad (9)$$

This is of the form Y = Mx+c

Therefore, a plot of $\ell n\ \ell n \frac{1}{1-F(t)}$ as the ordinate and ℓnt as the abcissa will yield a straight line provided the data fits the Weibull distribution and $\gamma = 0$. From this, values for α and β can then be estimated using simple regression analysis.

Collection of Reliability Data

The farm machinery reliability data can be gathered from the field by conducting surveys among the users. The time of failures of different components can be recorded as the machine works under actual conditions and hence the time between failures can be calculated. This method is known as replacement method as only the failed part is replaced and not the whole unit. A histogram of the time between failure data then yields the relative failure frequencies. Using these times and the cumulative frequency, the Weibull parameter can be estimated.

Prediction of Future Reliability

Kumar (1977) used the Monte Carlo method for predicting the machine future reliability. Details of this method has been given by Meyers (1963).

The Monte Carlo method selects the value of desired variable by choosing a random number from its distribution. In other words, the time between failures can be generated by solving for t in the expression.

$$Y = \int_0^t f(n)\, dn \quad (10)$$

Where:

Y = random number between 0 and 1 selected from a uniform distribution.

f(n) = probability density function

For Weibull distribution

$$Y = \int_0^t \frac{\beta x^{\beta-1}}{\alpha} e^{-(x^{\beta})/\alpha}\, dx \quad (11)$$

$$= 1 - e^{-(t^{\beta})/\alpha}$$

Solving for t we get

$$t = \alpha(-\ell n(1-y)^{1/\beta} \quad (12)$$

Where t gives the time between failures.

Application of Reliability Theory to Mechanical Reapers

The theory presented earlier has been used to estimate the reliability of mechanical reapers.

Data Collection of Mechanical Reapers

Failure random data of mechanical reapers were collected from the 40 different machines by conducting a survey aftter the 1984 wheat harvesting season from Gujranwala and Sheikhupura Districts. The machines were made of both FMI collaborating and non-collaborating firms. The machine ages varied from one to three years. Of the 40 machines studied, 27, 12 and 1 were in the first, second and third year of operation, respectively, with the farmer. The area covered varied from 7-63 ha / machine. Only one of them covered 148 ha. The time of failures of different components was recorded as the machines worked under actual conditions and hence the time between failures was calculated.

Computer Programme and Results

Considering the whole machine as a unit, the time between failures was the time between any two failures, irrespective of component type. A computer programme was developed for estimation of the Weibull parameters. **Fig. 3** shows the histogram of the input data as a function of time between failures. **Fig. 4** shows the flow chart of the computer programme. The programme calculated the Weibull parameters using the least square method. The value of α and β were: $\alpha = 30.558$, $\beta = 0.973$.

Thus the Weibull distribution which predict the time between failure and reliability for the mechanical reaper is:

$$F(t) = 1 - e^{-\frac{t^{0.973}}{30.558}}$$

$$R(t) = e^{-\frac{t^{0.973}}{30.558}}$$

Fig. 5 shows the cumulative actual distribution function and the theoretical and Weibull parameters. Based on the Kolmogoroff and the Smirnov test for goodness of fit, there is insufficient evidence at 95% confidence level to reject the foregoing failure distribution prediction.

A computer programme was developed for the Monte Carlo method in order to predict future time between failure (future reliability). **Fig. 6** shows the flow

Fig. 3 Number of failure observations in each cell.

chart of computer programme to predict the time between failure. **Table 1** shows the output of this programme. The first column of the table gives the failure ranks and second column gives mean time between failure, i.e., 22.66 means that the first failure should be expected after about 23 h. Next 13.34 means that the second failure should be expected about 13.0 h after the first failure had occurred. These figures are for the machine having Weibull distribution. The same programme gives a mean time between failure of 20.5 h. Thus for a harvest season of 150 h between 7 and 8 mechanical reaper failures should be expected.

Fig. 4 Flow chart of main computer programme for estimation of Weibull parameters.

Discussion and Conclusions

1. Knowing machine reliability helps in better planning of farming operation. The method allows the use of actual data without any modification in estimating the parameter values for the reliability function.
2. The reliability prediction was based on the short life data of available farmers' mechanical reapers. The machines included in this study were manufactured by different firms. Thus, it can be concluded that all early failures of the machines were not fully taken care of during the testing and running of the machines before actual harvest. The high number of failures was probably due to the following reasons: i) poor manufacturing technology; ii) untrained machine operator; and iii) unfavourable field conditions.
3. The method developed in this study is very basic and is applicable to all farm machines such as tractor, combine harvester, etc.
4. Knowing the machine reliability, the opportunity time and cost of repair work can be reduced. Furthermore, sufficient parts can be stocked to minimize time lost.
   i) For the farmers, more reliable machinery leads to decreased costs and less risk of income losses as well as generally making his management function easier.
   ii) For the manufacturer, careful attention to quality and reliability (Q & R) during task definition, design prototype testing, production and despatch can bring good name and higher roles.
5. Greater reliability can only be achieved (without substantial increase in machinery prices) if all related sections of the farming industry can assist the designer and the manufacturer by providing feedback information.

Fig. 5 Actual and theoretical cumulative distribution function of mechanical reaper.

Fig. 6 Flow chart of main computer programme to predict the time between failures.

Recommendations

1. In the future, greater emphasis should be placed on farm machinery reliability for better functioning of farm mechanization programme in the country.
2. Detailed reliability study of tractor, combine harvester, reaper, etc as a unit and sub-component should be carried out under present socio-agroclimatic condition.
3. The research institutes should carry out field reliability study programme of machines manufactured by a particular firm. In this way guidance can be provided to i) the farmer, in purchasing more reliable machines; and ii) manufacturer, in producing more reliable machines.

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Indian Society of Agricultural Engineers: 24th Annual Convention
January 21-23, 1988.
At the Punjabrao Krishi Vidyapeeth, Akola 444104
Maharashtra, India

The Indian Society of Agricultural Engineers has accepted the invitation to hold the 24th annual convention at the Punjabrao Krishi Vidyapeeth, Akola from January 21-23, 1988. This is the second occasion that the convention of the society is being held in Maharashtra. Previously, the 15th Convention was jointly hosted by the four agricultural universities in the state in February 1977 at Pune.

The convention would provide opportunity for the professional agricultural engineers to discuss matters related to the various aspects of the development of the agricultural engineering discipline in the country. The programme of the convention would mainly include presentation and discussion of technical papers related to the theme, review of achievements of the society and planning of strategies for the future to serve the farming community. About 400 delegates are expected to participate in this convention.

The main programme at the convention includes (i) Meeting of the ISAE executive council (ii) ISAE general body meeting (iii) Presentation of awards (iv) 3 to 4 concurrent technical sessions in four major areas *viz.* (a) Farm power and machinery (b) Soil and water engineering, (c) Process, food and dairy engineering, and (d) Energy in agriculture. Theme session will be a common session where eminent engineers will present the papers related to the theme of the convention. Plenary session will be held on 23rd January, 1988 to finalize the recommendations of the convention.

For information contact:
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Maharashtra, India

Third International Livestock Environment Symposium
April 25-27, 1988
Constellation Hotel, Toronto, Canada

This livestock environment symposium is planned for the essential purpose of bringing together expert scientists, engineers and practitioners from various disciplines to exchange information on how environment and environmental interactions affect the health, production and reproduction of beef and dairy cattle, swine, sheep and poultry. Research findings, state-of-the-art practices, as well as future research and development needs will be topics for discussion.

Topics will include:

- Natural and mechanical ventilation systems for environmental control
- Environmental effects on swine performance
- Design modifications through physical analyses
- Simulated and microprocessor control of livestock environment systems
- Environmental containment measurement and control in livestock confinement systems
- Livestock responses to stressors
- Simulated and microprocessor control of livestock environment systems
- Environmental and dietary effects on livestock physiology and production
- Nonconventional livestock housing systems
- Extension of research applications to producers

Special Session:
Panel Discussion on the "Guide for the care and use of agricultural animals for research and teaching."
Sponsored by:
The American Society of Agricultural Engineers
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Agritech-Turkey 88
The Istanbul International Agriculture and Irrigation Show
October 5-9, 1988

Agritech-Turkey 88 takes place at the Istanbul Hilton Convention and Exhibition Centre, the only modern, purpose-built, international exhibition complex in the country.

Agriculture is Turkey's most important economic activity, providing 20% of Gross Domestic Product (GDP) and employing 60% of the workforce. However the country's vast agricultural potential is not being utilised and productivity is hindered by obsolete farming methods and equipment. Increased revenue from exports of agricultural produce is vital to sustain the government's programme of rapid social and industrial development.

During the current 5 Year Plan investments totalling US$ 2.6 Billion are being targeted to increase productivity and output, through mechanisation and the widespread introduction of modern farming

techniques. Long term market potential is guaranteed. The South East Anatolia Irrigation Project, now under construction, will provide new agricultural land equivalent in size to Belgium and Holland.

Major Sectors:

- Seeds and seed technology
- Irrigation
- Fertilisers
- Horticulture
- Environmental control
- Specialised planting and harvesting
- Pesticides
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- Consultancy
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- Dairy farming
- Intensive poultry farming
- Animal health.

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PARASITIS 88
2nd Industrial Forum of Industries and Technologies for Pest Control
October 25-28, 1988
Palacio de Congresos
Barcelona, Spain

The Tools for the Future:

Biotechnology

- Genetic engineering - an overview
- Modern plant improvement techniques
- Behaviour modifying chemicals
- Biological control by microorganisms

Informatic

- Overview of future development of software and hardware
- Expert systems - an overview
- Decentralized computing and information retrieval
- Systems analysis in general

Information & training

- Data reduction and analysis
- Simulation techniques applied to crops and pest models
- Utilization of expert systems
- Use of remote sensing

Concurrent sessions

- Public health and hygiene/household pest control
- The safety of pesticides use
- Storage of food
- Actual technologies
  - Importance of diagnostic
  - Mass rearing and quality control

Poster session:

A poster session will be organized at "Parasitis 88": The posters must be 80 cm wide and 120 cm high and readable at a distance of 1m. Subjects presented in the posters' session should preferably deal with R & D in the fields covered by the main symposia (i.e. biotechnologies, informatic, information and training) and possibly have clear business implications for the industry.

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Megh R. Goyal Named 1987 Outstanding Young Extension Worker By ASAE

Megh R. Goyal, associate agricultural engineer, University of Puerto Rico-Mayaguez campus, is the 1987 recipient of the Nolan Mitchell Young Extension Worker Award, presented at the International Winter Meeting of the Americal Society of Agricultural Engineers (ASAE).

The award is presented annually "to honor members of ASAE under 40 years of age for outstanding contributions to the advancement of the profession, and to stimulate professional achievement in extension work".

Goyal has distinguished himself through his many accomplishments in agricultural research and extension and through his intense promotion of the agricultural engineering profession in Puerto Rico. He has gained further distinction through his extensive list of publications. Along with his colleagues, Goyal has significantly advanced the technology of drip irrigation in Puerto Rico.

The honoree has received several ASAE Blue Ribbon Awards in addition to an ASAE Paper Award. He earned his B.S. in agricultural engineering from Punjab Agricultural University and a M.S. and Ph. D. in agricultural engineering from Ohio State University. ■■

BOOK REVIEW

Application of Remote Sensing to Agricultural Field Trials (Agricultural University Wageningen Papers 86-4, 1986)

(The Netherlands)

by J.G.P.W. Clevers

Agricultural field trials are conducted in order to evaluate the influence of different treatments on crop characteristics, e.g., leaf area index (LAI), at different stages of growth. In the quantitative analysis large inaccuracies can occur because samples have to be small when sampling needs to be frequent and destructive.

The main aim of this study is to disclose how remote sensing can support and/or replace conventional field measurements in field trials by enabling quantitative information about an entire field trial to be obtained instantaneously, repeatedly and, above all, non-destructively.

Black and white multispectral aerial photography (with recording being obtained in the visible and near infrared region of the electromagnetic spectrum) is shown to be the most appropriate technique for this application. The validity of canopy spectral reflectance factors, derived by a method of calibration and data correction, is demonstrated.

A simplified reflectance model for vegetation is derived for estimating LAI during the whole growing season by means of a corrected infrared reflectance factor. The latter factor is derived from the infrared reflectance by correcting for the reflectance of the background (soil and yellow leaves). Statistical analysis of several field trials reveals that the presence of treatment effects can be shown with larger power and that coefficients of variation are smaller for the LAI estimated by means of the simplified reflectance model than for the LAI measured in the field.

Free descriptors: field trials, remote sensing, multispectral aerial photography, reflectance factors, simplified reflectance model, estimating crop characteristics, statistical analysis.

Size: 24.5 x 17 cm, 230 p, soft cover

Published by Agricultural University, Wageningen, The Netherlands

Sweet Sorghum Culture and Sirup Production

(U.S.A.)

by K.C. Freeman and others

Sweet sorghum as a source of sweetening or "long sugar" offered a welcome change to the monotonous diets of some of the early pioneers. A pound of sweet sorghum seed provided not only sweetening for the family but forage for the livestock. Some sweet sorghum sirup has at one time or another been produced in every one of the contiguous 48 States of the United States. Sweet sorghum sirup, a wholesome food with an attractive color and a mild, pleasant flavor, is especially well liked by people who are accustomed to its characteristic flavor.

Sweet sorghum is grown most extensively for sirup production in the Southeastern States. Eight States (Alabama, Arkansas, Georgia, Iowa, Kentucky, Mississippi, North Carolina, and Tennessee) in the sweet sorghum sirup area produce about 90 percent of the total sweet sorghum sirup in the United States.

Some sweet sorghum sirup producers grow sweet sorghum in large fields but the average producer grows 1 to 2 acres for sirup. The manufacturing of sirup also is usually on a small scale. Community projects, however, are becoming more common. In these projects, the sirup for an entire community is manufactured at one plant, which is owned by an individual or a corporation. Even though the average acreage is low, sweet sorghum sirup constitutes a meaningful cash crop for most of its producers.

The name "sweet sorghum" is used to identify varieties of sorghum, Sorghum bicolor (L.) Moench, that are sweet and juicy. These sweetstalk varieties are also called "sugar sorghums." Sweet sorghum is grown for sirup or forage, whereas some other sorghums, such as kafirs and milos, are grown for grain. Other types of sorghum include broomcorn, Sorghum dochna var. Technicum (Koern.) Snowden, the head of which is used in making brooms and brushes; and johnsongrass, Sorghum halepense (L.) Pers., and sudangrass, Sorghum sudanense (piper) Stapf, which are cultivated for forage.

Cultural practices for sweet sorghum used for sirup or for forage are similar, but the harvesting and processing methods used are different.

In growing sweet sorghum for sirup, the primary objective is to obtain the largest possible yield of good-quality sirup at the lowest cost. Yield and quality of sirup are influenced by varieties, diseases, insects, weeds, soil type, climatic conditions, cultural and harvesting practices, and manufacturing methods.

Size: 21.5 x 14 cm 56 pp, paper cover

Published by U.S.D.A., Washington, D.C. 20250, U.S.A.

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