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AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.20, NO.3, SUMMER 1989

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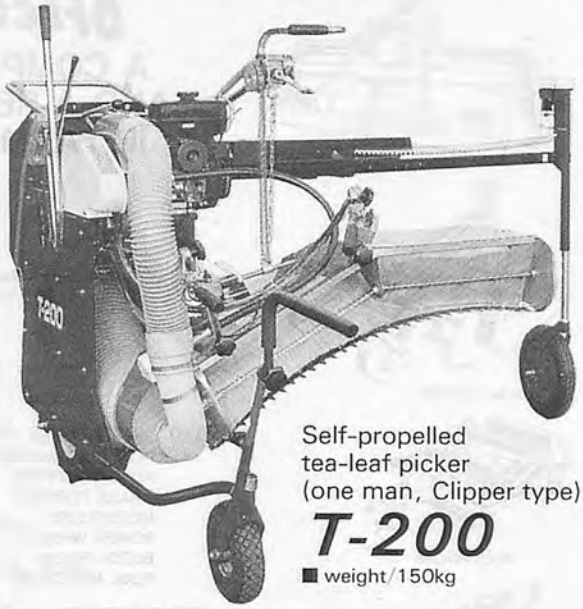

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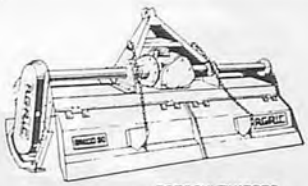
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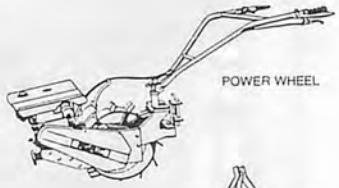
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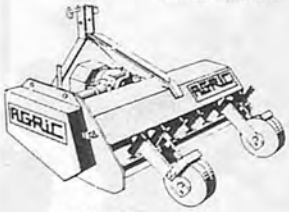
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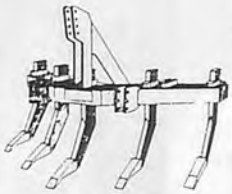
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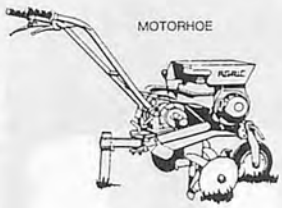
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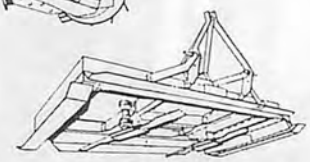
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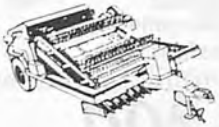
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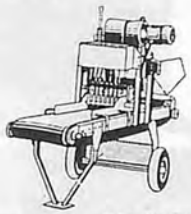
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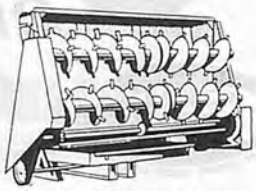
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EDITORIAL

More on the Changing Environment

In the preceding Spring issue of the AMA, the editorial sounded off some alarm and concern about the ecological imbalance that is being widely felt in particular relation to forest denudation and its adverse effect on the future well-being of mankind — food availability that derives basically from agriculture.

The present editorial for the AMA Summer issue continues to be alarmed and concerned — this time, about the warming of the air temperature and destruction of the ozone stratum on a global scale. This condition is seen as a direct offshoot of the destruction taking place on the face of the Earth, i.e., forest denudation and such; air pollution and products of the chemical industry such as aerosols, to name a few. Naturally, the concern goes back to man and the quantity, let alone quality, of the food that will become available to him in the years ahead.

To be sure, the changing environment is scary, at best. It is frightening considering that reliable reports have it that the air temperature has increased at an average rate of 1°C just over the last few years and threatens to continue to increase further to 3 - 5°C for the next 30 years or so. The meteorologists and other scientists are not about ready to conclude that, in the face of these changes in our environment, the extinction of mankind is not far behind. But it does seem it will be unless man himself is willing and able to control the rising temperature, and consequently, the havoc that it can cause on agriculture. And this is an issue that is not to be taken lightly by policy makers in all countries of the world.

The AMA, for instance, sees that the next 100 years will put to the test some already know technologies in taming the environment so that man can live in comfort. It also foresees that new technologies will have to be developed in terms of narrowing the gap between population growth and food availability for the teeming millions. Hence it will be the job of demographers and population control institutions to promote near-zero growth in population. And it will be the responsibility of agriculturists to grow more than "two blades of grass where only one grew before." Agricultural production methods can no longer depend on animal power and man power when large-scale production is called for. Mechanizing farm operations, among other considerations, will be a major key to harnessing the full potential of agricultural resources – land resources, in particular. Agricultural mechanization and other agricultural technologies will have to go hand-in-hand in a common front to fight hunger through large-scale food production.

The poverty in many countries of the Third World continues to be a major problem that needs to be addressed squarely by governments of both those countries and those countries with advanced economies under a common slogan, "Live and Help Live" instead of "Live and Let Live."

And AMA shall continue to play its bit in helping promote agricultural mechanization because it believes, and believes strongly, that this phase of agricultural development will continue to be a major contributor to solving the perennial and frightening food problem. This is why AMA is in close touch with scores of agricultural engineers world-wide.

Yoshisuke Kisida
Chief Editor

Tokyo
July, 1989

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Application of Electro-osmosis to Reclaim Saline Soils

by
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Abstract

The paper describes a case where the application of electro-osmosis resulted in a decrease in the salt content of saline soils. Soil samples with three different salt contents with four replications were selected for the experiment. The observations included measurements of types of salts present in the soil samples, electrical conductivity, quantity of water expelled, and current density as a function of time. The results supported the usage of electro-osmosis in saline soils reclamation.

Introduction

Leaching has been practiced for quite a long time for removing excess salts from soils. Often, before leaching can be effective, internal soil drainage must be improved by tilling, ditching or pumping, or by a combination of methods. However, this is expensive and time consuming. Therefore, the use of electro-osmosis to expedite the salt removal process has been evaluated.

The phenomenon of electro-osmosis, forcing a liquid through a porous medium by imposition of an electric potential, has been known for a long time. Casagrande (1941, 1947, 1948) was first to successfully apply electro-osmosis for dewatering and stabilizing soft soils (in terms of stability) and since then many other investigators such as Adamson, et al (1966) and Wang and Vey (1953) have also successfully used this technique. Bruch and Lewis (1973) have applied this method to ground water pollution control in soils of low hydrawlic permeability. Morley and Parry (1971) have utilized electro-osmosis in mining application to promote cementing and irreversible hardening of clays. Amba, et al (1966) utilized electro-osmosis to increase the flow rate of reservior fluids during petroleum recovery. Greyson and Rogers (1970) used electro-osmosis to dewater sewage sludge. The effectiveness of expelling water from poultry excrement by electro-osmosis has been studied by Cross and Boyd (1966) and Nurnberger, et al (1966).

Very little research has been conducted on the use of electro-osmosis in reclamation of saline soils. The objective of this research was to investigate the possibility of using electro-osmosis in removing soluble salts from saline soils.

Materials and Methods

Three soil samples, viz A, B, and C with different salt contents were selected for the experiment. Some physicochemical properties of these soils are given in **Table 1** and **2**. The test assembly consisted of 12 similar soil bins made up of 4 mm thick plastic plate. The effective dimensions of the soil bins were 52.5 cm x 42.5 cm x 12.5 cm. The schematic diagram of a soil bin is shown in **Fig. 1**. Stainless steel plate (1 mm thick 20 cm x 15 cm) were used for electrodes. The distance between the two electrodes was 50 cm. Twelve similar AC-DC transformers, one for each bin, were used to supply the DC current. They had an output voltage and current rating of 0-400 V and 2 000 mA, respectively. The voltage and current imposed upon each sample were measured by a voltmeter and milliammeters, respectively (**Fig. 1**).

The experiment was divided into two stages. At the beginning of the first stage, the bins were filled up with the soils in question and compacted uniformly by using a weight which applied a pressure of 200g/cm^2 on the soil. The average bulk densities of the 0-10 cm for soils A, B and C were 1.48 g/cc, 1.48 g/cc and 1.36 g/cc, respectively. Distilled water was added to the bins to bring the soil to a fully saturated condition. The bins were allowed to drain to remove all the

Table 1 Grain Size Distribution and Organic Matter Content of the Soil Samples

Soil	Sand (more than 50μ)	Coarse silt (20-50μ)	Fine silt (2-20μ)	Clay (less than 2μ)	Organic matter
A	10.32%	16.81%	5.24%	65.53%	2.10%
B	8.93	18.93	3.12	66.58	3.05
C	7.32	17.44	5.17	64.74	5.33

Table 2 Main Types of Salts Present in Soil Samples Unit: g/100g

Soil	NaCl	Na_2So_4	$MgSo_4$	$CaSo_4$	$CaCo_3$	$MgCo_3$	KCl	Total salt content
A	0.096	0.047	0.054	0.024	0.015	0.012	0.010	0.26
B	0.162	0.065	0.077	0.038	0.027	0.017	0.011	0.40
C	0.257	0.088	0.105	0.078	0.025	0.033	0.017	0.62

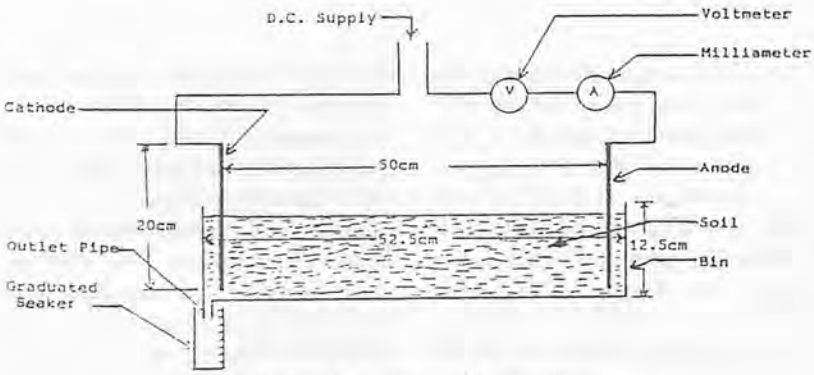

Fig. 1 Schematic system used in experiment.

Table 3 Chemical Analysis of the Soils at Beginning of Stage One

Soil	Na^+ ppm	K^+ ppm	Ca^+ ppm	Mg^+ ppm	pH (0–10 cm)
A	4 088	172	409	1 748	8.5
B	8 800	275	1 035	3 395	8.6
C	11 907	567	1 143	5 715	8.8

excess water. At this stage, the soil moisture contents, the pH and the electric conductivities of the soils were determined. The salt content of each soil was estimated from electric conductivity values (United States Salinity Laboratory Staffs 1954). These soil characteristics determined at the beginning of stage 1 are listed in **Table 3**. Electricity was applied at a constant 30 V through the test period. The reason for selecting this voltage was that preliminary tests indicated voltage less than 30 V DC is not enough effective for this purpose. Six hours after the application of electricity, the expelled liquid was collected at the cathode end of each bin (**Fig. 1**). The current flow and the amount of liquid expelled was measured everyday at 6 pm. The tests were discontinued when the rate of water expelled from a bin became either zero or very negligible. At this stage, the moistue content and the degree of salinity of the soil left in the bin were determined.

The second stage of the test began by saturating the soil once again with distilled water. Then the electro-osmosis test was repeated just as during the first stage. At the end of each stage of the test, chemical analysis was carried out on both expelled liquid and the soil in the bins. The average room temperature and relative humidity during the test period were 21°C and 32%, respectively.

Results and Discussion

The rate and quantity of water expelled and the current density obtained during the test periods for the three soil samples are shown in **Table 4**. In the first stage, it took 11 days to expell the water from soil A while it took only 9 and 8 days for soils B and C, respectively, with the same voltage input. This was probably due to a higher initial moisture and lower salt content of soil A compared to soils B and C (**Table 5**). Similar trends were observed in the second stage of the experimentation. For both stages, the current density gradually decreased with time (**Table 4**). This likely occurred because of the reduction in moisture and salt content of the soil sample in the bin. **Table 5** shows some soil properties at the end of each test stage. At the end of the first stage, the electric conductivity of the saturated extract of soil sample A was 4.0 milli mho/cm at 25°C. According to the United States Salinity Laboratory recommendations (1954) saline soils are those whose electric conductivity of saturated extract is more than 4.0 milli mho/cm at 25°C. Thus, soil A had reached an acceptable level of salinity at the end of first stage whereas soils B and C still contained excessive soluble salts (**Table 5**). That was the reason for carrying on the test to the second stage. At the end of the second stage, the electric conductivities of the saturated extract of soils A, B, C were 1.86, 2.24, and 3.46 millimho/cm at 25°C, respectively (**Table 5**). These values show that the soil had reached acceptable level of salinity.

Table 6 shows the chemical composition of the discharged liquid and soils in the bin at the end of

Table 4 Liquid Expelled from Soil Samples and Relevant Current Densities in Each Day at First and Second Stages of Experiment

	Liquid expelled (cc)						Current density (mA/cm²)					
	First stage			Second stage			First stage			Second stage		
Day	A	B	C	A	B	C	A	B	C	A	B	C
1	40	25	18	63	41	30	0.74	0.74	0.74	0.74	0.74	0.74
2	36	18	15	58	38	28	0.74	0.74	0.70	0.74	0.74	0.74
3	30	17	14	53	35	25	0.74	0.67	0.61	0.74	0.74	0.70
4	25	14	12	49	32	22	0.68	0.59	0.50	0.73	0.70	0.64
5	22	12	9	46	29	20	0.62	0.54	0.42	0.70	0.61	0.58
6	21	11	8	40	25	17	0.55	0.40	0.30	0.63	0.48	0.43
7	16	9	3	32	22	15	0.42	0.29	0.21	0.54	0.41	0.35
8	14	5	1	25	18	12	0.30	0.22	0.13	0.47	0.37	0.28
9	9	2	0	18	14	9	0.26	0.12	0.08	0.41	0.26	0.22
10	5	0	–	15	10	6	0.18	0.06	–	0.30	0.20	0.18
11	2	–	–	9	7	3	0.14	–	–	0.25	0.15	0.11
12	0	–	–	6	3	0	0.09	–	–	0.18	0.11	0.08
13	–	–	–	5	0	–	–	–	–	0.12	0.07	–
14	–	–	–	2	–	–	–	–	–	0.09	–	–
15	–	–	–	0	–	–	–	–	–	0.05	–	–

Table 5 Results of Soil Saturation Extract at Beginning and End of Each Test Stage

Stage	Soil	Moisture content (0–10 cm) (%, d.b.)	Electric conductivity (Millimho/cm)	Salt content g/100g
Beginning	A	29.75	6.93	0.26
	B	27.04	9.14	0.40
	C	29.12	13.94	0.62
First	A	17.05	4.00	0.15
	B	18.22	6.72	0.23
	C	18.11	8.23	0.36
Second	A	18.32	1.86	0.07
	B	19.05	2.24	0.08
	C	18.51	3.46	0.13

Table 6 Chemical Analysis of Discharged Liquid and Saturation Extract of Soil at End of each Test Stage

Stage	Soil	Material	Na^+ (ppm)	K^+ (ppm)	Ca^+ (ppm)	Mg^+ (ppm)	pH (0–10 cm)
First	A	L*	592	25	59	253	12.2
		S	11	–	–	–	7.5
	B	L	940	29	110	361	12.0
		S	44	–	–	–	8.0
	C	L	1 404	67	188	545	11.7
		S	56	–	–	–	8.2
Second	A	L	430	18	43	184	9.4
		S	10	–	–	–	7.1
	B	L	820	26	67	318	10.5
		S	15	–	–	–	7.4
	C	L	1 242	59	166	482	11.1
		S	15	–	–	–	7.8

*L = Liquid ; S = Soil in the bin.

each test stage. The expelled liquid contained higher amount of Na^+ compared to other salts. Relatively little $CaSo_4$ and $CaCo_3$ were discharged due perhaps to their low solubilities. These observations show that it is possible to remove soluble salts from saline soils using electro-osmosis. Due to some evaporation (Joules heating) and water expelling from the bin (electro-osmosis), the soils were dehydrating gradually during the experiment. The electrodes were replaced by new ones after the first stage because they had become corroded.

It is felt that the saline soil can be reclaimed in the field using electro-osmosis technology. The positive electrodes (anodes) in the form of rods could be installed near the toes of the slopes of the drainage excavations. The negative electrodes (cathodes) would be installed in the soil at a distance away from the slopes of the cut and would be made in the form of perforated pipes resembling a well point. The water collected at the negative electrode could then be pumped out and discharged. This would, in the process, remove some excessive salts from the soil.

Although the method of reclaiming saline soils by the use of electro-osmosis seems to be more economical than the conventional methods, the economic aspect of this method should be studied and evaluated in real field situations.

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Testing of Bullock-drawn Ploughs in Lateritic Soils

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Introduction

The state of Orissa is situated in the north eastern section of India. The major source of water for agriculture is rainfall which is very erratic and its distribution is quite uneven. Despite the average annual rainfall of 1 500 mm, Orissa experiences drought periods once in three years. Conservation of moisture through the use of improved agricultural machinery is one of the solutions to such problem. Mould board plough prepares the land well in considerably less time and creates a conducive environment for better moisture absorption and improves the soil tilth. There has been a substantial research work in the development of suitable mould board plough in India. Many iron ploughs have been fabricated and are being used by Indian farmers.

A particular plough developed at a place considering the soil parameters and climatic factors may not be suitable for other regions of the country. Farmers of different regions of Orissa use different mould board ploughs without considering their soil profiles. Thus an experiment was undertaken in this dryland project in order to evaluate the performance of different ploughs generally used by the farmers under upland lateritic soil condition.

Field experiments in the dryland agriculture research project are being conducted at two sites (upland and medium land) of the Central Research Station, 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 textural, 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 textural up to 30 cm depth. The detailed characteristics are given in **Table 1**.

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

	Upland	Medium land
Mechanical composition		
Sand (%)	78.70	64.00
Silt (%)	7.80	7.00
Clay (%)	13.50	29.00
Texture	Sandy loam	Sandy clay loam
Colour	Reddish brown	Pinkish grey
Bulk density (gm/cm^3)	1.80	1.82
Porosity (%)	35.00	32.00
Field capacity (cm^3/cm^3)	0.16	0.24
Infiltration rate (cm/har)	2.00	1.00
pH	5.10	5.80
Organic carbon (%)	0.55	0.39
Total nitrogen	0.05	0.03
Electrical conductivity (mm hos/cm)	0.05	0.09

Details of Treatments

Seven mould board ploughs and one desi plough were used for the test. The field trials were conducted on a 20 m x 10 m lot laid out in a randomized block design with three replications. The land was ploughed three times by the desi plough as generally adopted by the farmers of Orissa and once by the mould board ploughs. During ploughing the moisture content of the soil was about 16%. The details of the treatments are given below.

Treatments:

Acknowledgement: The authors are grateful to the Indian Council of Agricultural Research, New Delhi for providing financial assistance for the experiment and to Shri N.R. Nayak and Shri Ch.R. Subudhi, ex-junior agricultural engineers for their help during field trials. Thanks are also due to Dr. S.N. Das and Dr. R. Lal, Dean of Research and Dean of the College of Agricultural Engineering and Technology, respectively, for their advice and valuable suggestions.

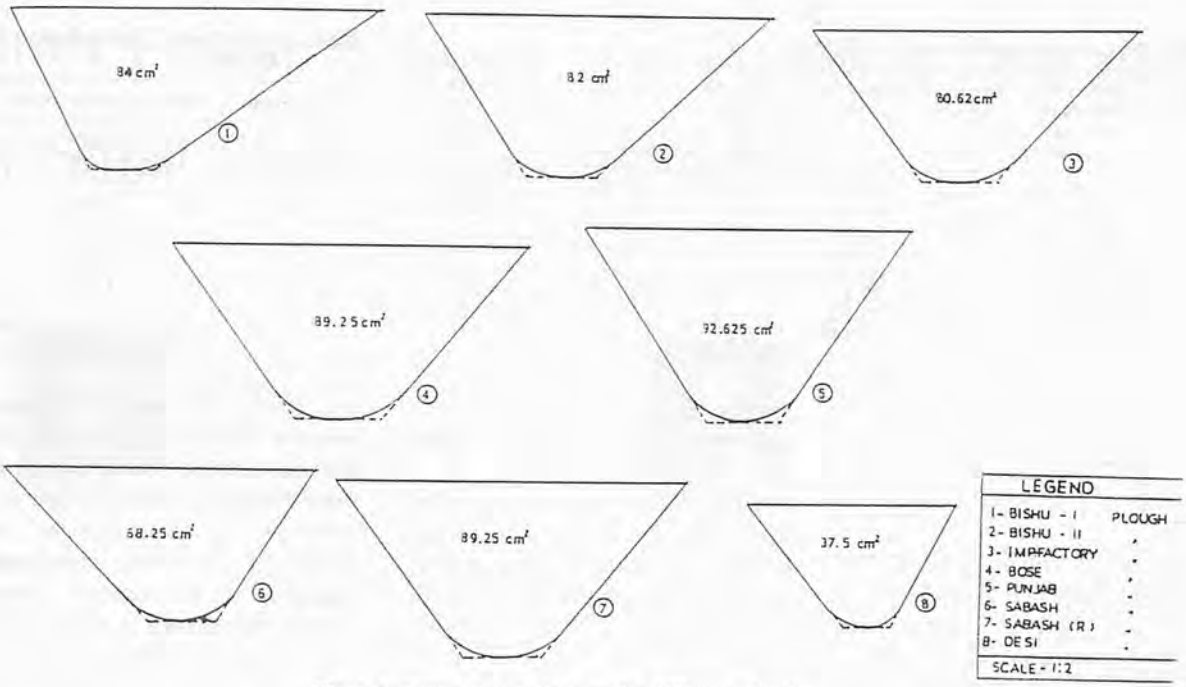

Fig. 1 Furrow cross-sections cut by different ploughs.

T_1 Ploughing by Bishu mould board plough-I once and disking once.

T_2 Ploughing by Bishu mould board plough-II once and disking once.

T_3 Ploughing by Implement Factory mould board plough once and disking once.

T_4 Ploughing by Bose plough once and disking once.

T_5 Ploughing by Fidu-I plough once and disking once.

T_6 Ploughing by Sabash plough once and disking once.

T_7 Ploughing by modified Sabash plough once and disking once.

T_8 Ploughing by Desi plough thrice and disking once (Farmer's practice).

Land preparation by different ploughs was followed by disking with disk harrow and planking by locally-made wooden plank. The paddy crop (Variety-DR 92) was grown on the field with seed rate of 75 kg per ha. Chemical fertilizers were used at the rate of 60 kg N, 30 kg P_2O_5 and 30 kg K_2O per ha.

Results and Discussion

Figure 1 shows the cross sectional views of furrows cut by different ploughs. The shape of the furrows in all the cases is trapezoidal. The top width, bottom width, depth of penetration, cross sectional area of each furrow and draft experienced by a pair of bullocks during ploughing were recorded (**Table 2**).

The draft experienced by a pair of bullocks in Fidu-I plough was maximum at 105.18 kg as it was difficult to drag this plough on the field.

Table 3 shows the effective field capacity, inversion, pulverization, unit draft and performance index of different ploughs under test.

The Bishu mould board plough-II developed by the Orissa College of Agricultural Engineering and Technology at Bhubaneswar inverts and pulverizes the soil better than any other ploughs under test. Pulverization was measured with the hlep of penetrometer and expressed in cm. Considering all the parameters measured during operation, the performance index was calculated for each plough and the results show that the Bishu-II mould board plough obtained the highest value. As the crop encountered dry spell about 5 weeks in 1986, the yield was very low for

Table 2 Depth, Top Width, Bottom Width and Cross-sectional Area of Furrow Cut by Plough with Draft Values

Treatments	Depth of penetration cm	Top width cm	Bottom width cm	Cross-sectional area cm²	Draft kg (f)
T_1	8.0	18.0	3.0	84.0	76.93
T_2	8.0	17.0	3.5	82.0	69.98
T_3	7.5	16.0	5.5	80.62	58.36
T_4	8.5	17.0	4.0	89.25	53.71
T_5	9.5	16.0	3.5	92.62	105.18
T_6	7.5	15.0	3.2	68.25	74.12
T_7	8.5	17.0	4.0	89.25	84.01
T_8	6.0	10.0	2.5	37.50	64.73

Table 3 Performance Index Values of Ploughs

Treatment	Effective field capacity (A) ha/8 h	Depth of furrow cm	Inversion (I) %	Pulverization (P) cm	Unit draft, (D) kg(f)/cm²	Performance index=AdIP/D
T_1	0.1745	8.0	72.32	10.41	0.9158	1147.4503
T_2	0.192	8.0	87.23	10.78	0.8534	1692.4787
T_3	0.192	7.5	70.64	8.91	0.7240	1251.8501
T_4	0.192	8.5	57.84	7.55	0.6018	1184.3495
T_5	0.192	9.5	69.33	10.46	1.1356	1164.8026
T_6	0.1846	7.5	80.12	9.79	1.0860	999.9695
T_7	0.1811	8.5	79.52	9.89	0.9413	1284.1214
T_8	1.3333	6.0	57.149	8.89	1.7262	211.9102

Table 4 Grain Yield in Quintals per Hectare

Treatment	Average yield (q/ha)
T_1	6.20
T_2	12.42
T_3	10.57
T_4	9.00
T_5	6.50
T_6	7.00
T_7	8.33
T_8	4.92
	S.E. (m) = 0.423 q/ha
	C.D. = 1.29 q/ha

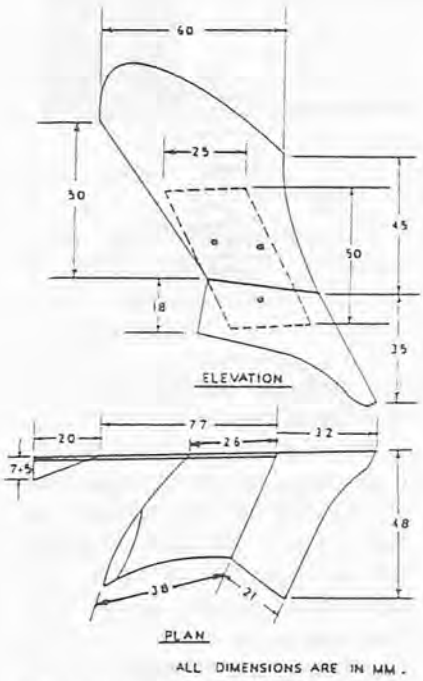

Fig. 2 Bishu-II mouldboard plough.

the kharif season. The yield data for 1985 kharif is shown in **Table 4**.

Grain yield values indicate that the Bishu mould board-II plough brought about the highest yield of 12.42 quintals per ha and is significantly superior to all other ploughs.

Conclusion

Timely operation with considerably less time is essential for dryland farming system for assured production. Agricultural land where weed is a constant menace has to be ploughed throughly just after the first shower and before the depletion of soil moisture. Under such a situation, a suitable mould board plough has to be used by the farmers as primary tillage implement. On testing different ploughs under dryland lateritic soil condition, it was found that the Bishu mould board-II plough had the best performance which brought about the highest yield because it might have developed a conducive soil environment for better crop stand. **Figure 2** shows detailed dimensions of this plough.

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Application of Electro-osmosis to Reclaim Saline Soils

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Draft Power Selection for Puddling Operation in Small Farms in Bangladesh

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Abstract

Bangladesh is facing draft power shortage for land preparation in both dry and wet soil conditions. This power shortage can be mitigated by introducing small tractors, power tillers and also by increasing the number of draft animals. In the present study, investigations were carried out to justify the operational and economic suitability of mechanical power sources for puddling operation. The parameters investigated were: field capacity and total operating cost per ha for its final preparation. Tractor and power tiller of 20 kW and 7.5 kW sizes, respectively, and draft animals with 0.23 kW power output each were selected for the field experiments. Analysis of the experimental data showed that the tractor was more economical in comparison with the power tiller and bullocks.

Introduction

The intensity of land preparation for both dry and wet soil conditions continues to increase in Bangladesh in order to accelerate the production of food for the burgeoning population. In wet soil condition, the land is tilled with the use of different power sources: bullocks, power tillers and tractors. Land preparation under such a condition is referred to as puddling operation which is mainly adopted for seedbed preparation and transplanting of paddy seedlings. Puddling is one of the best methods for increasing land productivity. In this method, soil, weeds and other organic matters are mixed to increase soil fertility. Puddling operation also increases the water retention capability of the soil and produces a favourable condition for plant growth. However, in dry soil condition, weeds and other organic matters are partly dried up by the sun, partly fall under furrow slices and otherwise, the mixing and fermentation of organic matter do not occur properly in the absence of water. This means that, wet soil condition is a better means of land preparation in comparison with dry soil condition because it helps green manuring of the soil and reduces chemical fertilizer requirement.

Prospect of Puddling Operation

Bangladesh comprises a total area of 14.4 million ha of which 9.13 million is cultivable land and 6.32 million ha falls under rice cultivation (1). Since the separation from Pakistan in 1971, about 0.4 million ha, i.e., 6.33% of the total riceland was brought under irrigation (2). Due to the integrated efforts of the farmers and the government the irrigated area under different crops continued to increase (**Table 1**) (3). In the country's Third Five Year Plan it was estimated that 4.45 million ha will be brought under irrigation and 88% of the target will be covered by the end of 1990 (4).

The yearly average rainfall is 2 030 mm but it is not uniformly distributed throughout the cropping seasons, i.e., in Rabi (mid-October to mid-March) and Kharif (mid-March to mid-October) seasons. In the Kharif season the main crops grown are rice, jute, sugarcane and sunhemp. The land for these crops is prepared in dry soil condition depending upon the natural rains. But in recent years,

Table 1 Irrigated Area for Various Crops in Bangladesh — Unit: 1000 ha

Crop	1979-80	1980-81	1981-82	1982-83	1983-84
Rice	1229.15	1259.11	1339.11	1460.32	1502.02
Wheat	172.47	194.74	189.88	193.62	214.47
Oil seeds	3.24	4.80	4.05	4.98	7.29
Potato	64.78	71.26	77.92	73.28	73.68
Cotton	1.21	1.62	2.43	3.24	6.48

Source: BBS

the changing pattern of rainfall has caused the farmers to resort to small-scale irrigation with the use of low lift pumps, shallow tube wells and deep tube wells. Besides the draft animals, the farmers are also utilizing some small tractors and power tillers for land preparation in wet soil condition. Hence, puddling operation has come to utilize mechanical power sources, specially for rice production.

Problems of Productivity and Mechanization

Some 3 225.4 Megawatts of draft power is estimated to be engaged in agriculture in the country. Yet, there is a shortage of about 174.31 MW for crop production based upon a 150 percent cropping intensity (5). Rice yield is very low in comparison with other South and East Asian Countries like Japan, China, Indonesia, Burma, and Thailand (1).

This low yield situation is generally attributed to the following: i) fragmentation of lands; ii) lack of irrigation and drainage facilities; iii) costly imputs such as seeds, herbicides, pesticides and chemical fertilizers; and iv) inadequate tillage operation due to insufficient draft power.

In order to address the twin problems and prospect of introducing mechanical power for land preparation in wet soil condition, the present study was undertaken in order to compare bullock power and mechanical power (power tiller and tractor) in terms of improving the productivity in rice cultivation.

Objectives of the Study

The main objectives of the study were:

i) To identify the parameters necessary for an economic selection of draft power for small rice farms, and

ii) To analyse and recommend the most economical means of puddling operation to supplement the draft power shortage.

Materials and Methods

The experiments were carried out at the Bangladesh Agricultural University Farm in the month of May through August. The soil was sandy loam clay. The availability of water supply was the main advantage for the study area and the plots were submerged under 15 cm of water during the puddling operation.

Experiments for each individual power source were conducted in three separate plots. The preparation time before going to the field and time lost due to small technical repairs or due to operators needs were not counted during puddling operation. Only the effective field time and fuel consumption for tilling each experimental plot were recorded.

Puddling Operation by Bullocks

A pair of healthy local bullocks with an estimated total power of 0.46 kW was engaged to till the selected land. The tillage implements used for bullocks were: one wooden plough, ladder and yoke. At the begining of the transplanting season (May to August) two ploughing operations were done followed by laddering. After 7 days, two operations were done again and the land was kept undisturbed for 3 days after laddering. Final operation was conducted on the fourth day. Proper levelling was done by laddering and thus the land was prepared for transplanting. Actual tilling width and depth were 10.9 cm and 6.1 cm, respectively.

Puddling Operation by Power Tiller

Bangladesh imports walking-type power tillers mainly from Japan, China and South Korea. The power ratings of these tillers fall within the range of 5 to 10 kW. A diesel power tiller of 7.5 kW nominal rating (Yanmar, Model: YZC-X-ES 105C, made in Japan) was selected for the study. Three successive operations were done with this machine which was fitted with a rotary tiller for final preparation of land. First operation was conducted at the begining of May; second operation after 7 days, and the third or final operation was done within 4 days before transplanting. The power tiller was equipped with cage wheels to reduce slippage. The working width of the rotary tilling implement was 70.7 cm and an average tilling depth of 10.15 cm was maintained during field operations.

Puddling Operation by Tractor

The sizes of farm tractors in use in Bangladesh vary in the range of 15 to 50 kW. For the present study, a farm tractor of 20 kW nominal rating (Yanmar, Model: YM-2700) was selected. The working width of the rotary cultivator was 150 cm and an average tilling depth of 12.5 cm. The preparation of land was completed by two successive operations with 10-day intervals between them.

All the experimental data for puddling operation accomplished by the three power sources are shown in **Table 2**.

Cost Components of Power Sources

The cost involved in puddling operation was divided into two categories: fixed cost and variable

Table 2 Performance Parameters of Different Power Sources

Power source	Tilling depth (cm)	Tilling width (cm)	Actual field capacity (ha/h)	Fuel consumption (gal/ha)
2-Bullocks (0.46 kW)	6.1	10.9	0.02	–
Power tiller (7.5 kW)	10.15	70.7	0.12	2.03
Tractor (20 kW)	12.5	150	0.21	5.06

cost. The fixed cost items included depreciation, interest on investment, shelter, repair and maintenance, and medical treatment for the animals. Taxes and insurance were not compulsory for farm machinery and equipment, hence these two items were excluded in cost calculation. Depreciation was calculated using the straight line method. The rate of interest, including surcharge, was 16%. A very nominal charge was involved for housing and shelter of the farm appliances (Table 3).

The useful life of farm machinery and equipment at the farmers level (being 3-10 years) was low in comparison with the government farms due to improper repair and maintenance. The yearly total use was assumed to be 800-1 000 h depending upon the natural, climatic and production situations of the country. The annual repair and maintenance cost of tractor, power tiller, rotary cultivator and bullock-drawn implements used were estimated at 19-12% of the purchase price. The annual cost for care and medical treatment of bullocks was assumed to be 2% of their purchase price. Items of fixed cost and their details under Bangladesh conditions are shown in Table 3.

Since it is the common practice that the farmers and their family members operate their tractor, power tiller and bullocks during land preparation, the cost for driver, helper and farm worker were excluded in calculating the recurring costs. Also, no separate cost item was included for small repairs and daily maintenance since such jobs are also accomplished by farmers themselves. The recurring costs, therefore, pertain only to fuel, lubricating oil, transmission oil, hydraulic oil, grease and the feeding cost for bullocks (Table 4).

Table 3 Details of Fixed Cost Items

Machinery/ Implement	Purchase price (Taka)	Expected life (yr) and annual use (h)	Depreciation per yr and scrap value (%PP)	Cost for shelter per yr (%PP)	Cost of R&M medical treatment per yr (%PP)
2-Bullocks (0.46 kW)	16000	6 (800)	13 (22)	5	2
Bullock-drawn implements	200	3 (800)	33 (0)	–	10
Power tiller with rotavator	75000	5 (800)	18 (10)	1.5	12
Tractor with rotavator	225000	10 (10000)	10 (10)	1.5	12

Table 4 Variable Cost Items

Power source	Feeding cost for bullocks (Taka/h)	Fuel consumption (l/h)	Lubricating oil (l/h)	Transmission oil (l/h)	Hydraulic oil (l/h)	Grease (lb/h)
2-Bullocks (0.46 kW)	2.5	––	––	––	––	––
Power tiller (7.5 kW)	––	1.12	0.04	0.03	––	0.01
Tractor (20 kW)	––	4.82	0.05	0.04	0.02	0.01

Sources: Department of Animal Nutrition and the Bureau of Research, Testing and Consultation, at Bangladesh Agricultural University, Mymensingh

Cost Calculation

The following formula (7) was used with some modification:

$$AC = \frac{FC\%PP}{100T} + (C_1 + C_2 + C_3 + C_4 + C_5) \quad (a)$$

where

AC – total hourly operating cost, Taka/h

FC – annual fixed cost in percent of purchase price, Taka

T – annual hours of use

$C_1, C_2, C_3, C_4, \& C_5$ – cost for fuel, lubricating oil, transmission oil, hydraulic oil and grease respectively, Taka/h.

Equation (a) was valid for calculating total hourly operating cost of tractor and power tiller, excluding the cost of hydraulic oil for power tiller. For bullocks, the cost for fuel, lubricating oil, transmission oil, hydraulic oil and grease was replaced by feeding cost which can be shown by the equation:

$$AC = \frac{FC\%PP}{100T} + C' \quad (b)$$

where C′ – feeding cost for a pair of bullocks, Taka/h

Results and Discussion

Performance

The performance rate of the three power sources shows that field capacity was highest for tractor, and lowest for the bullocks; the power tillers falling between the two. This was expected since the tilling width of the wooden plough and working speed of the bullocks were low during puddling operation in comparison with power tiller and tractor. The time required per ha of land was in the reverse order, i.e., highest for bullocks, intermediate for the power tiller and lowest for the tractor. These factors, in turn, affected the fuel requirement and operating cost for these three types of power sources.

Operating Cost

The laddering cost (estimated at 22% of the total tilling cost) was involved only for bullocks and not for power tiller and tractor in land levelling. To till 1 ha of land the cost for bullocks, power tiller and tractor were Taka 447.68, Taka 447.55 and Taka 588.02 per operation, respectively, (Table 5). Though it

Table 5 Cost Comparison for Find Preparation of Land in Wet Soil Condition

Power source	Total hourly cost (Taka/h)	Required time (h/ha)	Cost per operation (Taka/ha)	Total operating cost (Taka/ha)
2-Bullocks (0.46 kW)	9.85	45.45	447.68	2533.84
Power tiller (7.5 kW)	55.05	8.13	447.55	1342.65
Tractor (20 kW)	124.58	4.72	588.02	1176.04

seems not very logical to compare the operating cost for bullocks with that of power tiller and tractor as their rate of power generation was different, it was, nevertheless, required for the sake of comparison. Accordingly, the cost of power tiller and tractor over bullocks, and tractor over power tiller for final preparation of land were Taka 1 191.19, Taka 1 375.80 and Taka 166.61 per ha, respectively.

Conclusion

The study shows that the field capacity of power tiller and tractor was higher than that of bullocks. But the total operating cost per ha for bullocks was the highest in comparison with power tiller and tractor. Hence, the time requirement and cost involvement for power tiller and tractor are more economical and cheaper. Therefore, the introduction of mechanical power source in puddling operation will improve the socio-economic condition of the farmers and the draft power situation of the country.

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Effects of Different Direct Sowing Techniques and Date of Sowing on Rice Production

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Abstract

Rice cultivation by traditional method (manual transplanting) is a laborious and time-consuming job that results usually in low plant population. Low plant population is one of the reasons for low rice yield in Pakistan.

The present study was conducted in clay loam soil in order to determine the suitable direct seeding technique and optimum rice plant establishment parameters. The seeding techniques used were; puddle broadcasting (PB); dry line sowing (DLS) and dry broadcasting (DB). The sowing dates were: May 16 (STI); May 31 (ST2); June 16 (ST3) and June 30 (ST4). Among the common weeds of rice, *Marsilea minuta L.* was found in all plots. High grain weights of 22.2 and 25.8 g were associated with DLS and ST1 treatments, respectively. Maximum grain yields (4365.3 and 6373.2 kg/ha were obtained from the dry line seeding on May 16 while ST4 had a decrease of 71.8% in grain yield over ST1 due to cold stress during grain formation.

Introduction

Rice (*Oryza sativa L.*) is the principal food grain for the majority of mankind. The well-being of the world population depends upon the selection of better rice varieties and improved rice cultivation methods. After Thailand and USA, Pakistan is the leading rice exporter in the world. The disturbing fact is that rice production in the country has been at a standstill for the last several years. This is due to low plant population, delayed transplanting and poor pest management practices (Iqbal et al 1985), in addition to scarcity of farm labour.

Direct sowing of rice offers a convenient substitute to the traditional transplanting (Mabbayad and Obordo, 1970). The total time requirement per hectare for rice production is about 1 300 man-hours by manual transplanting, 500-600 man-hours by mechanical means and 200-300 man-hours by direct sowing (Brown and Quantril, 1973). The direct sowing of the submerged paddy (DSSP) requires 30% less farm labour than mechanized transplanting (Washio 1984). Direct sowing of rice has equivalent yield potential to transplanted paddy if water management and weed control are effective. The studies by Prasad and Singh, 1975 and Lokaphadhan, 1976 had also favoured the direct sowing of rice. Qinghua (1985) gained success by growing rice with limited quantity of water. Majid and Saeed (1973) achieved good harvest through direct seeding of those varieties which also did well when transplanted. Direct seeded crop is also helpful in developing a multi-cropping system as they mature early. Chatterjee and Khan (1978) recorded 6% more wheat yield on an area which was previously under direct seeded rice compared with transplanted one. The present study was launched to seek the response of different direct seeding techniques with respect to the sowing time or dates.

Material and Methods

The study was conducted at the National Agricultural Research Centre (NARC), Islamabad during 1985. The soil was characterized as clay loam with pH 7.5, organic matter (OM) 0.47%, Nitrogen 0.07%, P205 11.2 ppm and K20 503 ppm.

Two main production factors (sowing methods and dates of sowing) were compared in the study. Sowing was done on May 16 (ST1), May 31 (ST2), June 16 (ST3) and June 30 (ST4) in the main plots. The sowing methods were puddle broadcasting (PB): dry-line sowing (DLS); and dry broadcasting (DB). The IR-6 rice variety was used as a test crop. Sowing of DLS and DB

was done at the field capacity moisture while PB treatment was done in the saturated field conditions. The single-row seed drill (Fig. 1) was used for DLS treatment. Fertilizer was applied to each plot on equal basis in the form of DAP (diammonium phosphate) and ammonium sulphate. Zinc sulphate was distributed uniformly in the whole experimental area. Weeding was carried out twice at 30 days and 60 days after sowing (DAS).

The experiment was done as randomized complete block design with four replications. The plot sizes was 9m x 9m and 9m x 3m. In addition to 1056 mm rainfall, eight irrigations of 3-acre inches each were applied to the experimental crop. The study was laid in the low land area. The crop was severely flooded as a result of heavy rainfall during the monsoon. Various agronomical parameters were studied. Grain yield was calculated on a hecrate basis at 14% moisture contents. Weed population data were taken before the first weeding. The data were analysed using the analysis of variance method and the differences between the treatment means were tested by LSD test at 5% level of significance.

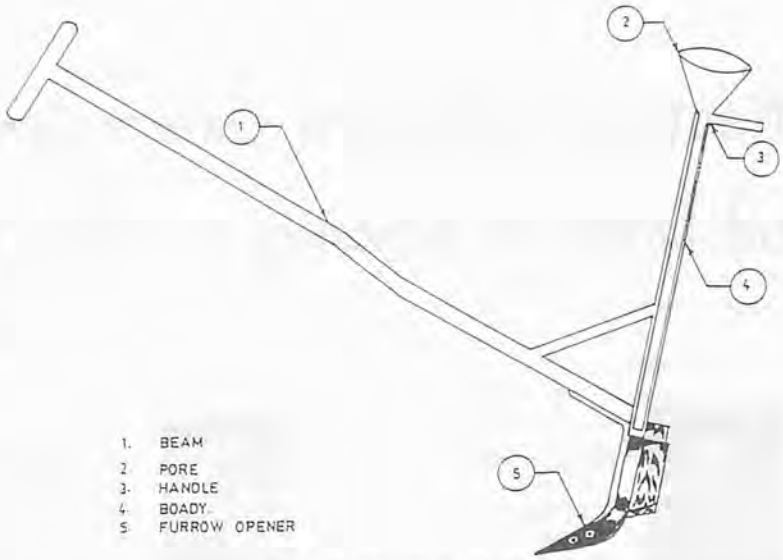

Fig. 1 Single-row seed drill.

Results and Discussion

Information regarding weed density was gathered from randomly selected spots in each plot. The weed species *Marsilea minuta L.*; *Phyllanthus niruri L.*; *Paspalum districhum Linn.* and *Cyperus iria Linn.* were commonly observed. The maximum weed population (156.4 plants/m^2) was observed in the DLS seeding technique (Table 1). The ST3 encouraged the seed germination and growth of the weed plants (Table 2) but statistically ($P<0.05$) there was no difference with ST1, ST2 and ST4. The species of *M. minuta* were in excess in all seeding techniques (Fig. 2) and (Fig. 3) followed by *P. niruri. C. iria* gained the least position in both seeding techniques and sowing period. Weeds were considered the major pest of paddy because they cause heavy yield losses (20–60%) as they compete with rice plants for nutrients, moisture and light (Shad, 1986).

Significant difference ($P<0.05$) in total panicle number was measured among the direct seeding techniques. The DBC method produced maximum number of panicle (321.8/m^2) followed by DLS (Table 1). Table 2 shows an advantage of panicle formation with ST1 over ST2, ST3 and ST4. The increase in panicle establishment with ST1

Table 1 Effect of Different Sowing Methods on the Yield and Yield Components of Direct Seeded Rice (1985)

Sowing methods	Wood population (m^{-2})	T. panicles (m^{-2})	Spikelets per panicle	Grains per panicle	100 grain weight (g)	Grain yield (kg/ha)
Puddle broadcasting (PB)	101.1*a	306.1	10.2	90.5	21.2	4 343.0*a
Dry line sowing (DLS)	156.4a	307.1	10.9	100.5	22.2	4 565.3a
Dry broadcasting (DBC)	123.9ab	321.8	10.8	89.6	20.8	3 849.3b
P< 0.05	38.6	NS	NS	NS	NS	485.8

NS: non significant; * Unlike letters in each column show significant difference at P>0.05.

Table 2 Effect of Sowing Time on the Yield and Yield Components of the Direct Seeded Rice (1985)

Sowing date	Weed population (m^{-2})	T. panicles (m^{-2})	Spikelets per panicle	Grains per panicle	1 000 grain weight (g)	Grain yield (kg/ha)
16 May (ST1)	115.4	384.8a*	11.3a*	115.8a*	25.8a*	6 373.2a*
31 May (ST2)	120.2	286.8c	10.9a	120.7a	25.5ab	5 221.9b
16 June (ST3)	144.8	304.6bcd	10.9a	97.8b	23.8b	3 619.0d
30 June (ST4)	128.2	270.6d	9.3b	43.3c	10.3c	1 796.0d
P 0.05	NS	55.3	0.99	18.1	1.8	559.8

NS: non significant, *; Figures having the same letter in each column show in-significant difference at P 0.05.

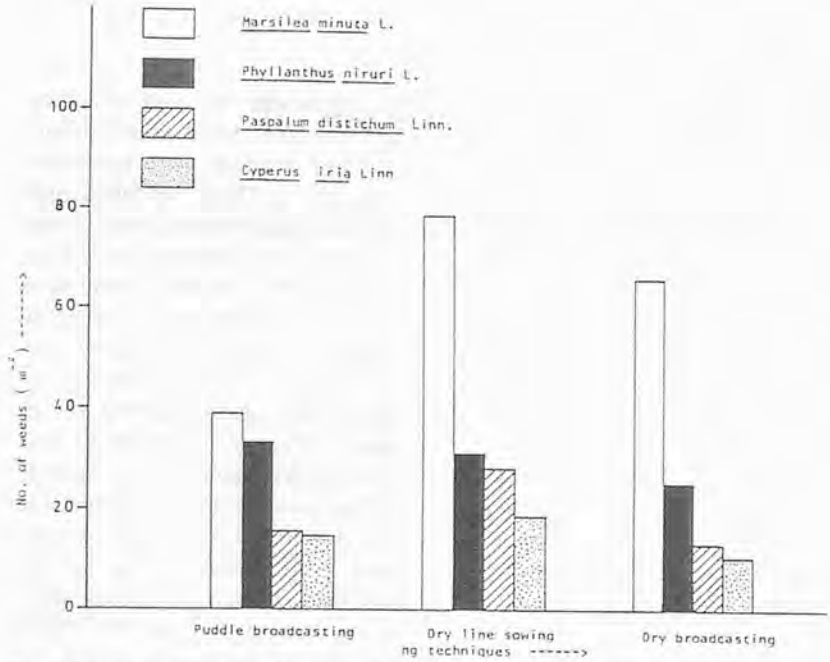

Fig. 2 Weeds' response to different direct-sowing techniques of rice.

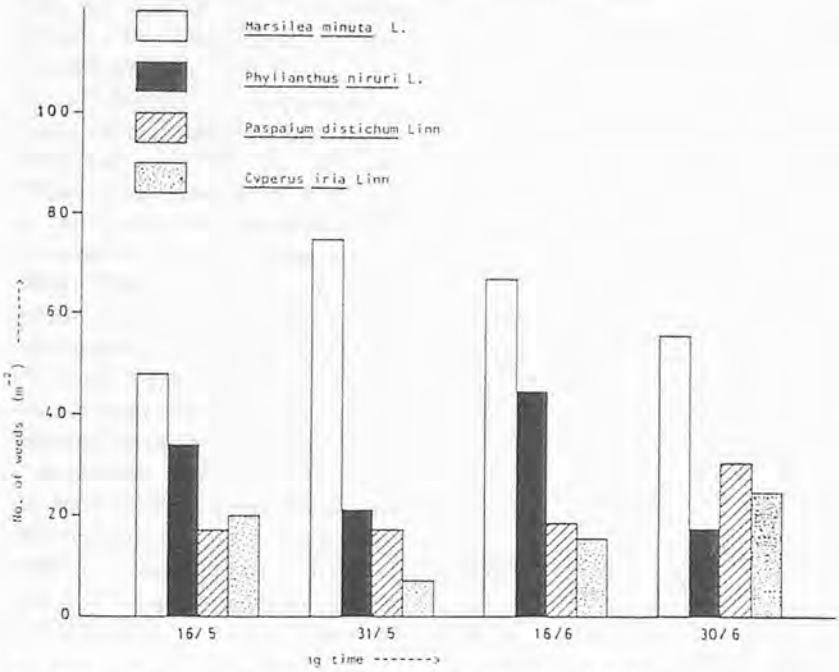

Fig. 3 Weeds' response to different sowing time of direct seeded rice.

was 34.17% and 26.32% over ST2 and ST3, respectively.

Results on spikelets per panicle showed equal response to all direct seeding techniques of rice at $P<0.05$ level of significance (**Table 2**). In general, the DLS technique generated higher spikelets per panicle than the PB and DBC techniques. As far as the date of sowing is concerned, May 16 was found appropriate for direct seeding of rice as the rice crop produced the maximum number of spikelets (11.3). The lowest numbers of spikelet (9.3) were observed in ST4 (**Table 2**). The increase in spikelet development with ST1 was 21.5% over ST4.

It is evident from **Table 2** that the seeding period of 30th May (ST2) appeared slightly favourable in generating maximum grain production per panicle (120.7). This was insignificant with ST1 and produced a high number of grain (115.1). ST4 failed to develop the required number of panicle grain and, consequently, achieved the least position among the different sowing dates. A sharp decrease in panicle grain formation was noted by delaying the sowing date after 16th June (**Fig. 5**). Generally, grain formation was linearly correlated (r=0.53) with panicle development. Panicle grain development rate was also slightly favourable to the dry line seeding (DLS) while it was insignificant with PB and DBC techniques. Ultimately, the DLS attained the highest position by producing the maximum number of grains (100.5) per panicle (**Fig. 4**).

Significant differences in the 1000-grain weight were recorded at four different sowing periods (**Table 2**). The highest grain weights of 25.8 g and 25.5 g were induced from ST1 and ST2, respectively. The late sowing (30th June) was found to be too late for direct seeding of rice as the air temperature became too low at the time of fertilization, hence caused stress to grain development, i.e., the grains did not attain the required size. **Fig. 5** indicates a linear decrease in the grain weight with respect to the sowing period. Moreover, significant increase in grain development was obtained with ST1 over ST4. The 1000-grain weight was directly affected (r=0.88) by the highest number of grains per panicle. But no significant effect on the grain weight was recorded with any of the seeding techniques (**Table 1**). In general views, the DLS produced the maximum weight of 22.2 g which had a negligible difference with the other seeding methods (PB and DBC) (**Fig. 4**).

Maximum paddy yields (4565.3 kg/ha and 6373.2 kg/ha) were, however, claimed in favour of dry

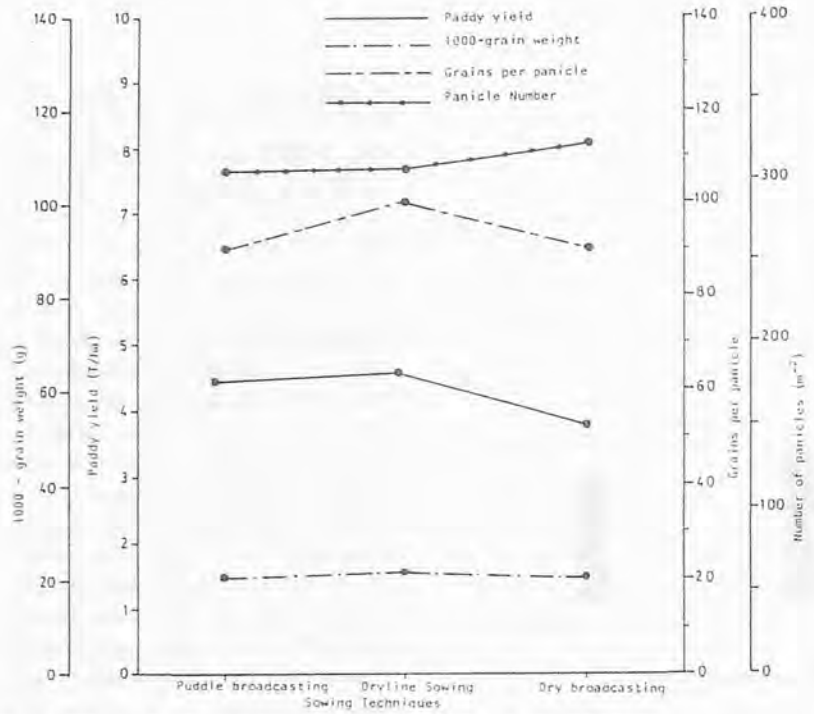

Fig. 4 Effects of different direct seeding techniques on rice cultivation.

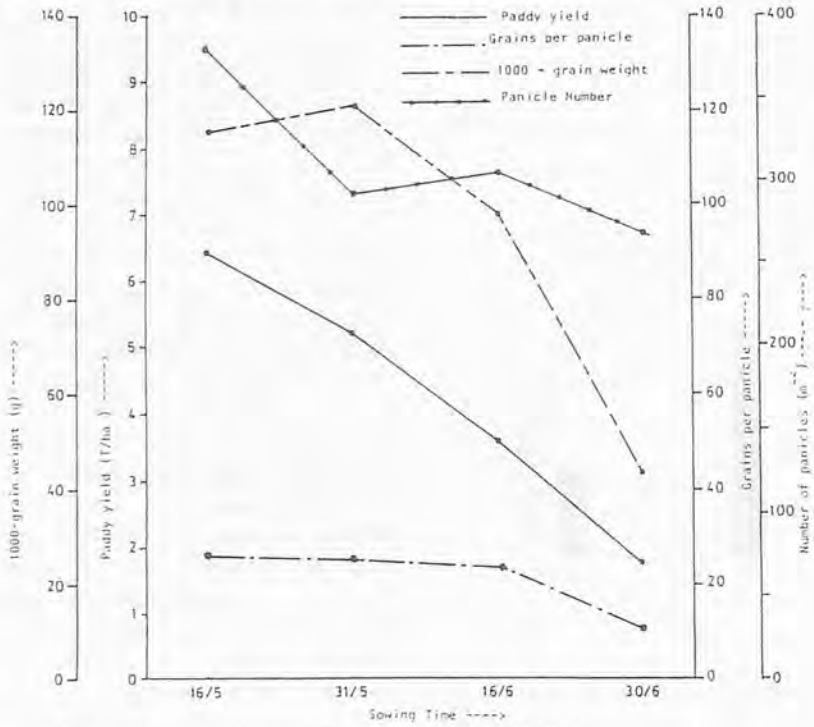

Fig. 5 Effects of sowing time on direct seeded rice cultivation.

line seeding (Table 1). May 16, (Table 2) was the best period for direct placement of rice seeds into "wattar" soil layers. A significant difference in paddy yield was induced through direct dry seeding (DLS) with 5.1% and 18.6% lead over the remaining seeding techniques (PB & DBC), respectively. These results are in conformity with the findings of other investigators (Prasad and Singh, 1975) and Lokaphadhan, 1976). Uneven position of the seed placement in DBC plots resulted in low soil moisture conduction from soil matrix and its availability at seed interface. On the other hand, more subsurface rice seedings were present in DLS plots. These seedlings indicated the potential of plant establishment with adequate soil moisture present in the subsurface. A contrast study was reported by Qinghua (1985) who grew dry rice with limited quantity of water. The seeding period of 16 May (ST1) appeared to be the best time for dry seeding of rice because at that time optimum temperature for flowering and grain development was available. The lowest rice yield (1796.0 kg/ha) was blamed to late seeding of rice (ST4) through the ultimate decrease in temperature at the time of grain formation. The increase in rice yield was anticipated to be due to high plant stand, large number of grains per panicle, maximum grain weight and optimum temperature, especially at the time of grain formation. Moreover, paddy yield was positively correlated in a linear manner with the number of grains per panicle (r=0.82) 1000-grain weight (r=0.78). The paddy yield was adversely affected by the presence of weeds (r=–0.01).

The aforecited discussion concludes that the dry, direct seeding of rice with a suitable time in mid-May brings better yield even as there is no clear explanation for it. Further comprehensive studies on dry, direct seeding of rice are necessary.

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Injecting Fertilizer Solution in Wetland Paddies

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Abstract

Fertilizer deep placement has been proven effective in increasing fertilizer use efficiency in wetland rice production. Because of problems associated with fertilizer granules, machines developed to place them gave inconsistent resutls. A new liquid injector equipped with a simple peristaltic pump was designed and tested. Test results show that it gave significantly higher yields and higher N efficiency than did any of the other methods tested. Split N application by injecting 1/3 and 2/3 of N at the proper time ensured balanced crop growth and maximum yield in both transplanted and direct-seeded rice.

Introduction

In any rice establishment method, N fertilization is one of the important factors that affect rice production (Mikkelsen, 1987) as N accounts for about 67% of the fertilizer applied to rice (Vlek and Byrnes, 1986). Efficient N use in flooded rice is a major concern. In many studies, only 20-40% of the applied N is recovered by the crop (De Datta, 1986; Vlek and Byrnes, 1986) because of extensive losses due to inadequate fertilizer management. Ammonia volatilization has been identified as a major avenue of N loss from urea applied in tropical flooded rice (Mikkelsen et al., 1978; Fillery et al., 1984).

Since N use efficiency and yield response are closely related (Craswell) et al, 1981), N fertilizer management practices designed to maximize plant recovery of fertilizer N should improve rice grain yield.

Research on deep placement of fertilizer started in the 1940s (Mitsui, 1955). Many studies at the International Rice Research Institute (IRRI) and other institutions have demonstrated that fertilizer use efficiency in flooded rice cultivation could be significantly increased by placing fertilizer N in the reduced soil layer at depths ranging from 5 to 15 cm (De Datta, 1987; Obcemea et al., 1984). In spite of more than 40 years of efforts, however, it has not been possible to use these research findings at the farm level because of the unavailability of fertilizer materials like urea briquettes or urea supergranules (USG). Moreover, these are costly and there are problems attendant on deep placement. Also, most farmers are reluctant to use the recommended basal dose of N fertilizer prior to transplanting or seeding. The usual practice of the farmers is to apply N fertilizer into the floodwater when the crop is established at 14-20 days after transplanting (DAT) or seeding (DAS). Therefore, a fertilizer management practice that combines farmers' timing of N application, water management, and deep placement is needed.

For mechanical deep placement, applicators have been developed for prilled urea (PU), the most common fertilizer material for rice production in Asia (Khan et al, 1984). However, the performance of these machines in the field has often been inconsistent. Whether this was related to conceptual or technical problems has not been well understood.

This paper presents the results of field studies that evaluated the effectiveness of band placement of liquid urea solution using a newly designed mechanical applicator.

Problems on Machine Deep Placement

Several factors contributed to the inconsistent performance of the IRRI-developed fertilizer applicators in farmers' fields. Khan (1982) identified these major areas:

Fertilizer metering – Despite the wide range of metering mechanisms used and studied by Khan et al (1984), metering variation is still

inherent in the machines developed because of the wide variation in size and shape of individual granules. This is true of both the commercial prilled fertilizer and USG. In addition, the hygroscopicity of N fertilizers, particularly urea, encourages caking which prevents a smooth flow of the material despite the use of an agitator.

Fertilizer placement – The presence of water and the changing nature of the soil within fields makes gravity deep placement of fertilizer in a furrow impracticable. Even the use of force feeding mechanisms is limited because of their tendency to clog as water penetrates into the delivery tube. Clogging on the submerged discharge end causes a back pressure which prevents smooth and continuous delivery of the material out of the discharge tube. This results in non-uniform application which is later manifested in uneven color, height and maturity of plants.

Furrow opening and closing – Khan et al (1983) reported that about 40-70% of fertilizer is transferred to the floodwater during furrow closing as the granular fertilizer solution is pushed into the floodwater. It was also reported that with deeper placement, up to 47% of fertilizer can be transferred to the floodwater due to dissolution during transit to the furrow bottom. In addition, poor sealing of furrows causes diffusion of N in the water. Since a considerable volume of granule fertilizers has to pass through an equivalent area, wide furrows are needed to deliver the required amount. Compared with narrow furrows, wide furrows could not be adequately sealed, have more exposure to water while being closed, and require more force to open and close.

Liquid-Injecting Mechanisms in the Past

It has been repeatedly shown that the above-cited problems can be avoided if a gaseous or liquid form of N is used with appropriate mechanisms. Navasero (1974) attempted to apply aqueous ammonia and insecticide in the plant root zone by using thin flexible tubes and a peristaltic pump to force the solution into the soil (**Fig. 1**). The machine was a pull-type but it was bulky and heavy (it weighed 30 kg).

Similar efforts were given to developing a simple gravity-fed injector (**Fig. 2**) weighing only 4.5 kg and utilizing a backpack container for the solution. Studies have shown that it is effective in deep placement of solution (Heinrichs et al, 1977). However, the design had problems inherent to gravity-fed metering. When granules are not totally dissolved, these would clog the small tubes and block the flow of solution into the soil. The discharge end of the tube behind the furrow openers would also be clogged with mud when the operator pulls the machine backward. Because the solution has gravity-flow, the discharge is greatly dependent on the walking speed of the operator.

Studies have proven that the peristaltic pump is exceptionally good in metering liquid solutions. The device could generate sufficient pressure to inject the solution without clogging. The thin tubes used could minimize furrow opening force and width for easier covering. A similar device using the peristaltic pump will be developed and incorporated in the transplanting row marker (**Fig. 3**) and in the IRRI rice transplanter (**Fig. 4**) (Salazar, 1982). The concept plans to combine injection with another operation to reduce labor requirement. In a follow up study on these injectors, the results indicate that the devices are comparable to other deep placement methods (Mazid 1982). Furrow closers, however, have not been installed on these machines as placement was in spots and not in continuous bands. The devices, attached in either the row marker or the rice transplanter, also require taxing hand-cranking for every injection stroke.

Fig. 1 First prototype of liquid injector.

Fig. 2 Gravity-fed liquid injector.

Fig. 3 Liquid injector in an IRRI rice transplanter.

Fig. 4 Liquid injector in a transplanting row marker.

Development of the Liquid Chemical Injector

In 1986, the need to further study fertilizer application methods in the field using ^{15}N prompted the design of a setup where a plastic syringe force-feeds a thin tube which ends beneath a small narrow skid (**Fig. 5**). As in past IRRI designs, the conventional furrow opener and closer were retained. A similar setup was designed to apply water-dissolved urea to the border plants in the field experiment. The syringe is actuated for every plant at a predetermined stroke length representing the rate of application.

The concept of a mechanical pump driven by a groundwheel was firmed up by the encouraging results of the experiment. Since past attempts on similar machines have been successful, a small and light injector equipped with a peristaltic pump and designed for band application was developed (**Fig. 6**). It is a two-row unit covering four plant rows in a single pass (since the banded solution covers two adjacent rows). The operator pushes the machine with a backpack containing water-dissolved urea. A central wheel powers the peristaltic pump assembly composed of a rotor with three evenly spaced rollers alternately compressing two flexible tubings containing the solution against the pump head cavity. As the rollers move, the solution is forced out of the pump head creating a vacuum at the inlet and a pressure at the outlet. The solution is forced out of the thin metal tubings behind the furrowers of each row, at 6 cm below the soil surface. The solution is injected in band at the bottom of the furrow earlier created and is simultaneously covered by a series of closers behind the discharge tubes.

Fig. 5 ^{15}N syringe injector for microplot experiments.

Fig. 6 Liquid injector with simple peristaltic pump.

Laboratory calibration of the peristaltic pump with different tubing sizes reveals a minimum of 30 l/ha and a maximum of 412 liters/ha with 3 and 13-mm diam tubing, respectively, at 20-cm plant spacing (**Table 1**). With a urea/water concentration of 0.8 (by weight), a 13-mm tubing can apply a maximum of 90 kg N/ha. A 50-kg N/ha rate will require a smaller volume of about 200 l/ha. With 6-mm tubing, a rate of about 22 kg N/ha is possible. A nomogram was developed to determine the volume of solution to be applied given the concentration, plant row spacing, and fertilizer rate of application.

Table 1 Laboratory Discharge of Liquid Chemical Injector at Different Orifice Sizes*

Orifice diameter, (mm)	Discharge** ml/10 rev	Discharge** liters/ha	Metering variation, %
3	38.5	30	3.3
5	91.2	71	7.7
6	135.3	106	2.2
9	284.7	222	3.6
13	527.7	412	< 1

* Average of 10 trials. Discharge is effective for four plant rows spaced at 20 cm per row. Pump head cavity was adjusted at the maximum allowable clearance preventing free flow of solution. Lesser discharge is possible with further reduction of these clearance.

** The injector was carefully bled prior to calibration to remove air in the tubing.

During field trials, the machine had a capacity ranging from 9-16 h/ha depending on the operator's skill, field condition and shape, and plant row spacing. The machine row was designed to be adjustable to fit different plant row spacings. It was made from steel sheet, pipe and plastic and weighed only 8 kg. It cost not more than US$50.

Results of Field Studies

To test and evaluate the liquid urea band placement, three field experiments were conducted during 1986, 1987, and 1988 dry seasons at two locations in the Philippines – Pila, Laguna, and Munoz, Nueva Ecija. While rice was transplanted in the 1986 experiment, the 1987 and 1988 experiments included transplanted as well as direct seeded rice. Various fertilizer application methods were compared with band placement of liquid urea solution. In addition, the 1986 and 1987 experiments included ^{15}N balance studies to verify fertilizer N uptake by plant. Results of the 1986 experiment are described in detail by Schnier et al (1988). This paper summarizes the results of the 1987 and 1988 studies.

Band placement of urea as 1/3-2/3 split gave significantly higher grain yields and agronomic efficiencies than the researcher's split (2/3 – 1/3 broadcast) in both transplanted and direct seeded rice (**Tables 2** and **3**). Point placement of USG yielded intermediate values between band placement and researcher's split (**Table 2**). Data from ^{15}N studies show a significant increase in fertilizer N uptake by the plant with band placement as compared with broadcast and incorporated (B&I) method. Plant ^{15}N recoveries (grain + straw) were 70 and 75% with band placement and 34 and 43% with B&I in transplanted and direct seeded rice,

Table 2 Effect of Planting/Seeding Method and Time and Method of Fertilizer N Application on IR64 Grain Yield and Agronomic Efficiency, Munoz, Nueva Ecija, Philippines, 1987 Dry Season

Treatment*	Grain yield (t/ha)	Agronomic efficiency (kg grain/kg N applied)
Transplanted rice		
No fertilizer N	3.3	–
2/3 B&I at TP + 1/3 broadcast at 5–7 DBPI	7.6	49
2/3 band placed at 14 DT + 1/3 band placed at 5–7 DBPI	8.0	54
1/3 band placed at 14 DT + 2/3 band placed at 5–7 DBPI	8.2	56
USG point placed at 1 DT	7.8	52
Hill-wise dibbled		
No fertilizer N	3.3	–
2/3 B&I at seeding + 1/3 at 5–7 DPBI broadcast	7.7	51
1/3 B&I at seeding + 2/3 at 5–7 DBPI broadcast	7.2	45
1/3 band placed at 20 DS + 2/3 at 5–7 DBPI band placed	8.5	60
USG point placed at 20 DS	8.3	57
Row seeded		
No fertilizer N	3.3	–
1/3 B&I at seeding + 2/3 at 5–7 DBPI broadcast	7.3	46
1/3 band placed at 20 DS + 2/3 at 5–7 DBPI band placed	8.1	55
LSD (0.05)	0.4	

Table 3 Effect of Seeding/Planting Method and Method of Fertilizer N Application of IR64 Grain Yield and Agronomic Efficiency, Munoz, Nueva Ecija, Philippines, 1988 Dry Season.

Treatment*	Grain yield (t/ha)	Agronomic efficiency (kg grain/kg N applied)
Transplanted		
No fertilizer	5.5	–
2/3 B&I at TP + 1/3 broadcast at 5–7 DBPI	8.8	38
1/3 band placed at 14 DT + 2/3 band placed at 5–7 DBPI	9.2	43
Broadcast seeded		
No fertilizer	4.3	–
2/3 B&I at seeding + 1/3 broadcast at 5–7 DBPI	8.0	43
Row seeded		
No fertilizer	4.2	–
1/3 band placed at 20 DS + 2/3 band placed at 5–7 DBPI	9.1	56
LSD (0.05)	0.4	

*B&I = Broadcast and incorporation, TP = Transplanting, DBPI = Days before panicle initiation, DT = Days after transplanting, DS = Days after seeding.

respectively, (Schnier et al, 1988). The increase in fertilizer N uptake with band placement was mostly due to increased N uptake from the first N application, indicating that band placement was as effective as USG point placement in minimizing N loss through ammonia volatilization and thus, in increasing the availability of fertilizer N for the rice crop.

The injection of liquid fertilizer using the device offers several advantages over the USG application (which produced the second highest yield): commercial availability of prilled fertilizer lower labor input than USG placement, easy control of split application rates (even during panicle initiation), and accessibility (easy to manufacture) at the village level.

The results further emphasize the suitability of the machine in wetland row seeding to increase the yield potential of direct-seeded rice (Tables 2 and 3). Row seeding also allows mechanical rotary weeding and other cultural practices without plant damage; the seeding rate requirement is also reduced compared with broadcast seeding.

The equipment has potential for deep placement of systemic chemicals, with the same effect of increased effectiveness at lower rates (Heinrichs et al, 1977). Several limitations for its use, however, merit consideration. These are:

A considerable amount of clean water and time is needed to dissolve the fertilizer. The need for extra containers and transfer of the solution within fields may pose constraints to farmers' acceptance of the technology. However, irrigation water, if strained beforehand, may be mixed with fertilizer.

The injector can only be used in row transplanted or row seeded fields and may, therefore, require farmers (who randomly transplant or broadcast) to modify their methods of crop establishment. Machines have already been developed at IRRI to facilitate such crop establishment practices.

Conclusions and Recommendations

The results of the field studies have shown that band placement of urea solution constitutes an alternative fertilizer management practice in which deep placement and farmers' schedule of N application can be combined irrespective of field water management. Band placement, while being less labor-intensive, provides N use efficiency equal to that achieved by USG point placement.

More field tests should be conducted to explore the possibilities of mechanically applying systemic insecticides alone or in combination with fertilizers. Similarly, farmers feedback or reactions to the new technology should be solicited and used to guide future efforts in designing similar machines.

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Evaluation of Urea Supergranule Applicator in Rice Fields

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Abstract

Placement of urea supergranule (USG) at the root zone of the rice crop by hand resulted in significant increase of grain yield compared to USG and prilled urea applied through broadcast method. Hand placement of USG in the field received maximum grain yield of 7 360 kg per ha which was higher than the yield obtained from USG applicator treatment (6 620 kg per ha). Hand placement treatment was significantly superior to broadcast methods of USG (5 890 kg per ha) and urea (6 040 kg per ha).

Even though the total area covered with USG application was wider than the applicator treatment method, the hand placement method meant a savings of $10/ha. As labour cost increases due to its scarcity during peak season, the use of USG applicator is warranted.

Introduction

Nitrogen fertilizer in rice culture is a major component of an overall production system. However, they are no substitute to management practices. As such, indiscriminate use of fertilizers should not be a corrective of the management deficiencies in the system. The choice of rice variety, timely planting, adequate plant population, timely weed control, timely and proper application of adequate fertilizers, proper water management, need-based plant protection and adoption of suitable pre-and post harvest technology are all equally important management needs in rice production.

In irrigated rice production fertiliser nitrogen use efficiency can be increased to 40-60% with placement of fertiliser at root zone (reduced zone). The superiority of USG and sulphur coated urea over best split application of prilled urea is well proven by the Directorate of Rice Research through INSFFER programme, coordinated programme and lead research trials (AICRIP, 1979; IRRI, 1979).

At present, sulphur coated urea has its own limitations as compared to USG. The application of USG at root zones reduces the cost of cultivation by reducing the fertilizer requirement over conventional broadcasting of urea. Also, grain yields of rice can be substantially increased on account of higher fertilizer use efficiency at existing application rates. The placement of USG requires only one application as compared to split application of prilled urea in conventional method. When USG is applied with applicator, it also reduces nearly 1/4th labour cost of labour force used for transplanting. In lowland submerged rice areas there is hardly any scope for top-dressing of nitrogen. These are the potential areas where application of USG at transplanting could be highly beneficial. Data from cost of the experiments has shown that USG was superior to prilled urea resulting in higher grain yields, nitrogen uptake and efficiency of applied nitrogen (Anon., 1982). Thus the use of USG will have a bright scope in rice culture in India. The Indian Farmers Fertilizer Co-operative Limited has taken up the production of USG with approximately 15% higher cost than the prilled urea. USG applicators are being fabricated locally.

The present study was carried out at the Agricultural Research Institute's Farm, Rajendranagar during the rainy season of 1984 in order to determine the efficiency of USG when applied in different methods and also to evaluate the field performance of the USG applicator.

Materials and Methods

An experiment was conducted with variety Tella Hamsa during the rainy season on sandy loam soils at the Agricultural Research

Institute's Farm, Rajandranagar, Hyderabad. Twenty-five day old mat type rice seedlings were transplanted in puddled plot with a spacing of 20 x 15 cm with the use of a 5-row manually operated paddy transplanter (IRRI model) in the first week of August, 1984.

The following treatments were taken up in a randomized block design with mixed replications:

1. Application of USG with applicator.
2. Manual placement of USG.
3. Broadcasting of USG.
4. Broadcasting of prilled urea in split applications.

A dose of 20 kg N/ha was applied as basal dressing in the entire experimental plot of 0.2 ha in the form of diammonium phosphate. The remaining dose of 40 kg N/ha was applied through USG in the first three treatments while the fourth treatment received in the form of prilled urea in two split doses at maximum tilling and panicle initiation stages.

The urea supergranule applicator was fabricated at the Farm Implement Machinery Centre (Indian Council of Agricultural Research Coordinated Scheme). Agricultural Research Institute (Andhra Pradesh Agricultural University), Rajendranagar. It consists of a drive wheel, two hoppers, metering device, two floats made of wood and a handle. The manually-operated two-row supergranule applicator consists of a drive wheel, two hoppers, metering mechanism, two floats and a handle. The drive wheel with overall diameter 575 mm is made of 6 mm MS rod with 28 legs on the periphery of the wheel in order to provide sufficient grip in the field. There are two hoppers made of G.I. sheet with 3 kg capacity each. Two wooden rollers with 8 holes of 15 mm diameter each were provided below the hoppers. The ground wheel and the rollers were mounted on the same shaft. The entire mechanism rested on two wooden floats. A handle is provided to push the applicator in the field. Below the floats were furrow openers. When the implement was pushed in the field the ground wheel rotated and in turn the wooden rollers situated below the hoppers rotated. Each hole on the roller took a granule and dropped it in the pipe which was carried and dropped into the furrows made by furrow openers. The granules were covered with soil by the float when the implement moved forward. The effective periphery of the ground wheel was 120 cm. For every revolution of the wheel, 8 USG were dropped resulting in the spacing between two granules at 15 cm. The rwo-to-row spacing of USG dropping device was 40 cm. The granules dropped in alternate rows. Within the row, plant-to-plant spacing was 15 cm. Each granule dropped between rows around 15 cm distance, the nutrients would be available for 2 hills (**Fig. 1**).

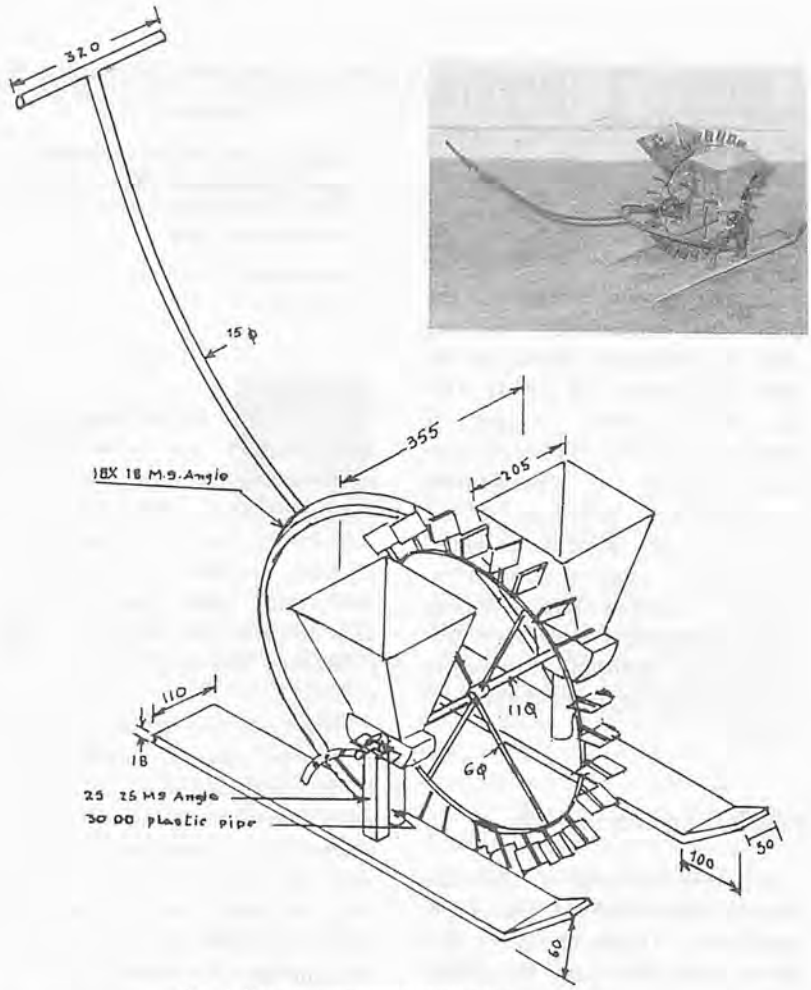

Fig. 1 Urea supergranule applicator.

Specifications of USG applicator:

Length	125 cm
Width	56 cm
Height	80 cm
Weight (empty)	12.5 kg
Hopper	2 Numbers.
Capacity of hopper	3 kg
No. of furrow openers	2
Distance between furrow openers	40 cm
Drive wheel	1 (57.5 mm diameter)
Float	2 Nos. (11 x 43.5 x 1.8 cm)
Wooden rollers	2 Nos.
Diameter of	

each roller	10 cm
Width of each roller	2.5 cm
No. of cells on each roller	8
Size of each cell	1.5 cm
Depth of each cell	1.2 cm

In the second treatment, the USG was applied in alternate rows by employing labour on the same day (August 18, 1984). This was almost similar to that of applying with USG applicator. The same quantity of supergranules (1 g size) were broadcast in the third treatment in order to maintain a uniform dose of 60 kg N/ha. Cultural practices like weeding, water management and plant protection were uniformly extended in all treatments throughout the crop period.

Results and Discussions

Different methods of USG application influenced the grain yield significantly (**Table 1**). It is apparent from the data that hand placement of USG with the help of manual labour (@ 1 USG/2 hills) resulted in maximum grain yield (7 360 kg/ha), which was higher than the yield from USG applicator treatment (6 620 kg/ha). The 11% increase in grain yield (740 kg/ha) in hand placement method might be due to greater number of panicle per sq m (501) and uniform distribution of USG with manual labour. Also, it could be due to the high concentration of ammonia around the root zone of placement site which could be toxic to the nitrifying bacteria and hence reduced the rate of denitrification losses from root zone. Deeply placed nitrogen was apparently less subject to rapid mineralization and volatilization losses as compared to surface applied nitrogen (Vlek and Crasswell 1979). Root zone placement of USG increased the grain yield over split application of urea. This confirms the findings of Rao (1982) and Pillai and Krishnamurthy (1983).

Table 1 Grain Yield as Influenced by Methods of USG Application

Treatment	Panicles/sq m (No.)	Grain yield (kg/ha)
Application of USG with applicator	425	6 620
Manual placement of USG	501	7 380
Broadcasting of USG	416	5 890
Broadcasting of urea	405	6 040
Experimental mean	437	6 480
C.D. (0.05)	63	830
C.V. (%)	11.7	10.4

This study also indicates that the applicator is good enough to use in the field condition, but it needs some improvement to achieve the perfection in metering the placement of USG uniformly at root zone. Although hand placement appears to be better in terms of yield, The applicator is better as it covers 1 ha in 7 man-hours while in the manually placed method it took 64 h (8 women labouers per 8 h), respectively, resulting in savings of $10/ha (Rs 130/ha).

Conclusions

Root zone placement of USG increased the grain yield significantly over broadcasting method. USG applicator can be introduced to replace the hand placement practice with some modifications in metering device.

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Harnessing the Under-utilized Animal Power for Pumping Irrigation Water in Bangladesh

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Abstract

In order to reduce dependence on fossil-fuel operated and capital-intensive imported pumps, an animal-driven pump for drawing surface or groundwater was designed, fabricated and tested at the Bangladesh Rice Research Institute (BRRI). The positive displacement pumping unit draws and delivers water through the reciprocating movement of the pistons. The pump consists of four cylinders of 15-cm diameter each fitted with leather-lined bucket-pistons. A crankshaft setup operates the pistons. The principle of transmitting power to the pump is similar to that used in the animal driven sugarcane crusher with a 1:5.5 speed ratio between the driving and the driven wheels.

The pump, fitted to a 5-cm diameter and 30-m deep tubewell, discharged 170.0 l/min at a bullock speed of 3.8 km/h. However, when a buffalo was employed the pump delivered 225 l/min at an operating speed of 5 kg/h. The pump delivered 213, 231 and 249 l/min when a bullock, a buffalo, and a horse were employed at a speed of 3.43, 3.90 and 4.28 km/h, respectively. The range of total draft, recorded between 16-20 kg, is very low compared to the potential draft capability of an average bullock (60 kg). Rabi (dry season) farmers can cultivate 0.92 ha of boro rice land or 1.8 ha of wheat or a very sizeable area of irrigated winter vegetables.

The pump with a PVC tubewell costs Tk. 6 000 (US$182) and is economically a better alternative for an individual farmer using an expensive shallow tubewell. The cost of irrigation is about 2.5 times less than that of the normal charges from a shallow tubewell. The use of the pump can save 209 litres of imported diesel fuel per hectare per season which is required in operating a shallow tubewell. Moreover, the pump can be manufactured from locally available materials. It is cheap, dependable, and can be fabricated even in remote areas.

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Introduction

The power used in Bangladesh agriculture predominantly comes from the 10.3 million draft animals (Jabbar, 1985). This source provides about 98% of the total agricultural power. Draft animals produce nearly 3 074 megawatt of energy (Baqui, 1986) at the peak demand period during the wet season. This is three times higher than the potential power-generating capacity of the Bangladesh Power Development Board (BPDB), the only national power generating agency in the country. However, most of the draft animals are idle during the dry season when the farmlands are dry.

The national herd size is nearly 23 million of which only 43-50% is used for draft purposes (Mettric and James, 1981; Islam, 1982). Furthermore, the use of animals for draft purposes has probably gone down due to increasing usage of motorized transport vehicles. Non-uniform use of animal power within the year could be the main reason for the inadequate utilization of draft animals. Achieving a more uniform distribution of animal draft power utilization throughout the year may be a difficult task, especially in rainfed agriculture, because the crop cultural practices are dictated by the frequency, timing and quantity of rainfall. Generally, rainfall may occur twice or thrice during the dry season in Bangladesh, thus the soil moisture

remain at favourable range for land preparation only for a limited period (less than a week). Assuming that 43% of the herd is used entirely in land preparation, with six tillings, during the dry season then the total number of days required to complete the entire direct seeded 'Aus,' jute and deep water rice lands comes up to only about 36 days (Islam, 1982). Hence, the draft animals remain idle for a considerable number of days after the period of March 15 to April 15 each year.

There are several issues behind the low usage of animal power in Bangladesh agriculture. In a study at the BRRI there was no evidence of draft power constraint at the aggregate level. The situation at the individual farm level, however, is different (BRRI, 1985).

On the other hand, the increasing price of fossil fuel limits the introduction and adoption of capital-intensive power (engines and motors) operated pumps unless they are sold at a heavily subsidized price. By 1987 it was expected that nearly 60 000 low-lift power-operated pumps (LLPs), 209 625 shallow tubewells and 30 347 deep tubewells (MPO, 1984) would be in operation. Even if this target was achieved, only about 25% of the total cultivable land can be placed under controlled irrigation system. Therefore, in order to utilize the draft animal power more efficiently and uniformly, to reduce dependence on fossil fuel operated pumps, and to cover more area under controlled irrigation system, harnessing the work animals to drive simple, inexpensive pumps has become an important issue.

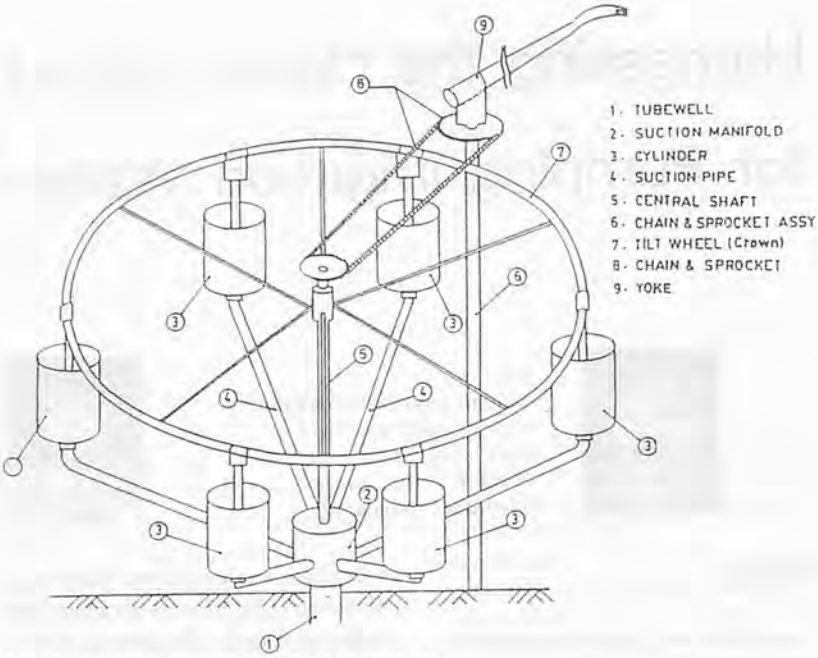

Fig. 1 The animal-driven pump (1st prototype).

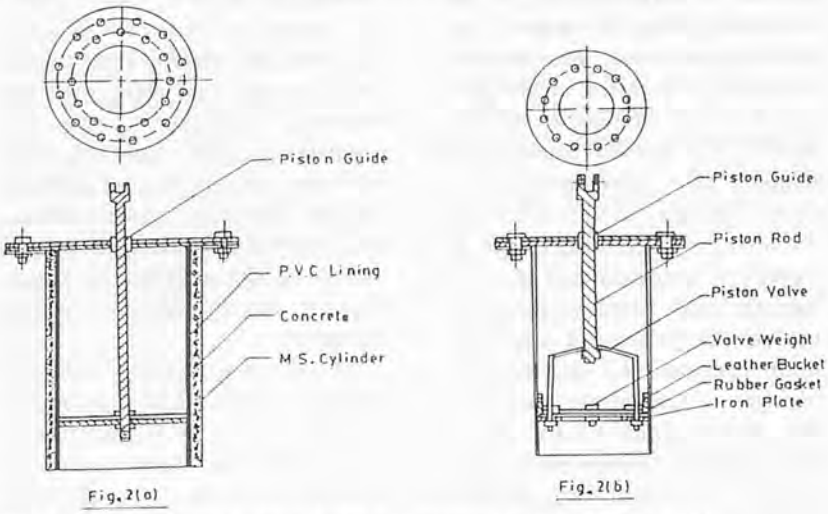

Fig. 2 Different stages of piston design improvement (animal-driven pump).

Lessons from Early Attempts

Two different prototypes (similar to the one shown in **Fig. 1**) were designed, fabricated and tested in 1983. This pump set-up was operated by an animal moving around a circular path. The positive displacement pumping unit draws and delivers water through the reciprocating movement of the pistons. Six cylinders, 20 cm in diameter, were arranged radially with a common suction. The pistons inside the cylinders were actuated by a 1.5 m diameter tilt wheel. One rotation of the wheel completes a working stroke (at a displacement of 15 cm) of each cylinder. Preliminary results showed that PVC-lined steel cylinders with leather-lined buckets (**Fig. 2a**) developed a tremendous friction and in several occasions the pistons froze inside the cylinders. The cylinders were, therefore, modified for better performance without PVC-lining and the tests were repeated. This time it was observed that the power transmission system, using chain and sprocket wheel (**Fig. 1**) was not appropriate because the driven wheel was bigger than the driving wheel, hence the power could not be effectively transmit-

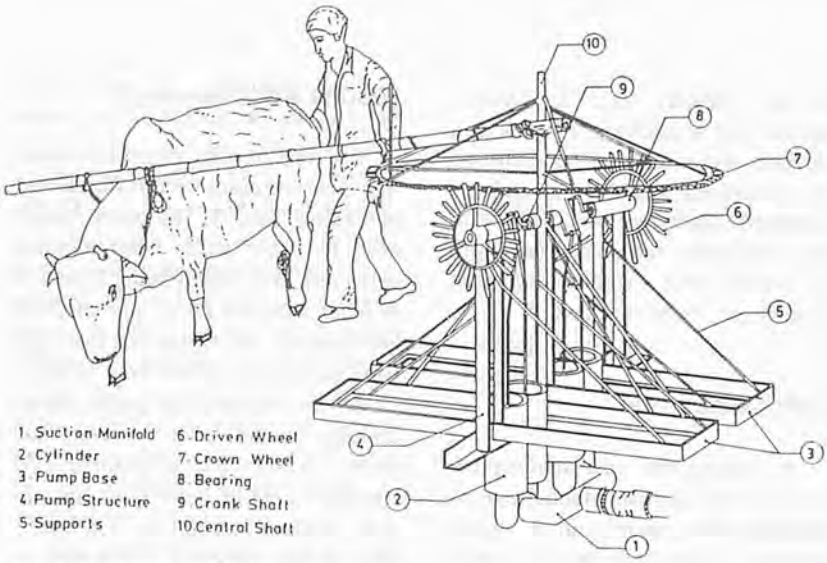

Fig. 3 The BRRI animal-driven pump (conceptual).

Fig. 4 The BRRI animal-driven pump in operation.

ted. A gear system was, therefore, adapted instead of the chain and sprocket. Again it was found that the roller bearing of the piston lift arms would come out of their guide rails within a few minutes of operation. Also, the power requirement became very high due to the bridging of the rollers against the driving wheel. Therefore, no further test was conducted.

From the above experience it was decided to completely redesign the power transmission system by adopting the arrangement commonly used in the local sugarcane crusher. In this new system a large (star-like) driving wheel with teeth around the circumference was developed to drive the smaller diameter driven wheel (which was also provided with teeth around its circumference). These two wheels were arranged in such a way that while the larger diameter driving wheel was operated by the animal, the rotation of the smaller diameter wheel became a function of the rotation of the bigger driving wheel as shown conceptually in Fig. 3. This drive system did eliminate the problem of rail slippage.

The Final Design

Fig. 4 shows the detailed components of the final design of the animal-driven pump consisting of four cylinders, 15 cm in diameter and 30 cm in height. The cylinders were made from 14 gauge mild steel sheet and were fitted with leather-lined buckets (similar to the buckets used in the conventional hand pumps) as illustrated in Fig. 2b. An appropriate piston was selected after several modifications. For each modification a test was conducted to observe its performance under actual operating conditions. Results of the tests conducted with several combinations of pistons and cylinders are presented in Table 1. Test no. 4, with 4 cylinders and leather lined bucket pistons, delivered the highest discharge and, hence the final design was fabricated based on this combination. The pistons are operated by a crank shaft made from 3 cm diameter mild steel shaft attached to the 30 cm diameter driven wheel which, in turn, was operated by the larger 1.5 m diameter crown wheel made from a 3 cm diameter mild steel rod. The diameter of the driven wheel was selected such that the speed ratio of the driving and driven wheel was 1:5.5. A common suction manifold made from 16 gauge steel sheet was used to connect the pumping unit to a tubewell.

Table 1 Test Results of Animal-driven Pump on Surface Water for Piston Selection (Modifications Shown under Remarks)

Test no.	Lift	Speed ratio of driving and driven wheel	Animal speed (km/h)	Discharge of the pump (l/min.)	Remarks
1	1.52	1:4.0	5.31	95.37	2-cylinders with leather bucket pistons
2	1.52	1:4.0	4.72	72.21	2-cylinders with flap valve pistons
3	1.52	1:4.0	5.19	154.71	4-cylinders with leather bucket pistons
4	1.52	1:5.5	4.86	210.00	4-cylinders with leather bucket pistons

N.B. Test results are the arithmetic mean of three observations.

Pump Test Methodology

Several preliminary tests were conducted to observe the performance of the different components of the pump. Three detailed tests were conducted on the finally chosen design. Test on surface water pumping was conducted at the BRRI compound. The ground water pumping test was done near the Kurni village of Mirzapur Upazilla about 50 km away from BRRI headquarter. The pump was coupled to a 5 cm diameter tube-

well, 30-m deep with 13 m long strainer (with 7% open area). The method of installation was similar to that followed for conventional hand pump or shallow tubewell. PVC pipes and strainers were used to construct the tubewell as shown in Fig. 5.

The tests were conducted for a period of 4 hours starting at 10:30 am and continued up to 3:00 pm. At every one hour interval the discharge, for a 3-minute test run, was collected in a large metal pan and was thereafter measured by a container of known volume. The animal speed was obtained by counting the revolution/min of the rotating wheels and was converted into km/h. The draft was measured by using a spring balance.

Additional tests were conducted in the farmers field in Kushtia district by employing a bullock, a buffalo and a horse. The depth of the tubewell was 24.4 m and its designed discharge was 300 l/min. The discharge, animal speeds, depth of water table from the ground surface etc. were recorded.

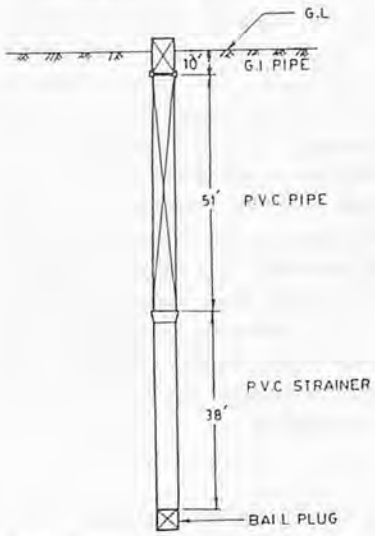

Fig. 5 Schematic diagram of tubewell at Mirjapur for animal-driven pump test.

Table 2 Performance Test Results of the Animal-driven Pump at Kushtia District

Animal	Animal speed (km/h)	Depth of water table (m)	Discharge measured (l/min)
Bullock	3.43	3	213.33
Buffalo	3.90	3	213.09
Horse	4.28	3	248.93

Note: The test results are the arithmatic mean of three tests.

Cost Comparison

A comparative cost analysis between three popular manual pumps (underground pump) and an engine operated (diesel) shallow tubewell (STW) and the animal driven pump was made. The cost parameters are presented in **Table 3**. The interest was calculated based on the following formula:

$$\text{Average interest} = \tfrac{1}{2}(P + S) \times I$$

where,

P = purchase price of machine
S = salvage value
I = interest rate

Results and Discussions

The test results from the three test sites are presented in **Fig. 6** and in **Tables 1** and **2**. The pump, when used to draw water from a pond delivered 210 l/min **(Table 1)** at 1.5 m head with 4.9 km/h animal (bullock) speed. At this work load the total draft requirement was 16 kg.

On the average, the pump, when drawing water from underground source at Mirzapur discharged 170 l/min at 2.95 m head with an animal (bullock) speed of 3.8 km/h. The pump delivered 225 l/min at about the same pumping head (3 m) when a buffalo was employed. The speed of the buffalo was approximately 4.5 to 5.5 km/h. **(Fig. 6)**.

The test results obtained from the Kushtia site are presented in **Table 2**. the pump delivered 213, 231 and 249 l/min when a bullock, a buffalo and a horse was employed at a speed of 3.43, 3.90 and 4.28 km/h, respectively. The range of

Table 3 Cost Parameters of Alternative Pumping Equipment

Parameter	Alternative pumping equipment				
	STW	BRRI Animal driven	No. 6 hand	RDRS Twin treadle	MCC Rower
Capital cost (Tk.)	37 320(1) (1 131)	6 000(2) (182)	1 300(3) (39)	925(4) (28)	1 050(4) (32)
Pump capacity (l/s)	12.00(a)	3.19(b)	0.70(c)	0.92(c)	0.65(c)
Command area (ha/season)	3.50	0.92	0.20	0.27	0.187
Pumping time (h/ha)	232	870	3 968	2 924	4 274

Interest on investment at 16%

Depreciation at 10% salvage value from purchase price

Machine life: STW, RDRS Twin Treadle & MCC Rower 10 years each and BRRI animal driven 15 yrs

R&M at 10% of fuel cost=(5) for STW, Tk.200/ha for animal driven/100/ha for others.

Fuel cost at 0.90 lit/ha-at Tk. 6.9/lit = (6)

Lub. oil cost 2 lit/100 hr at 26.50 Tk./ = (7)

Animal feed @ 0.5 kg/work-day (mustard cake) at Tk. 5/kg = (3)

Hired animal @ 22.00/pair-day = (8) without operator

Labour wage @ Tk. 30.00/man-day = (9)

Irrigation depth 1 000 mm (10 000 m^3/ha) = (10)

Total working days/season 100 (800 h)

Nomenclature: (1) BADC cost without subsidy (2) Cost of fabricated unit (3) Market price (4) MCC price (5) Donald hunt (6) BRRI test (7) M.A. Mazed (8) Custom hire rate (9) Govt. wage rate (10) MPO, 1984. (a) MPO test (b) BRRI test (c) MCC test.

Note: Numbers within parenthesis indicate the costs in US$ (Tk. 33=US$)

draft power for pumping groundwater was 16-20 kg, which is some 33% of the pulling capacity, estimated at about 60 kg (Hoften, 1969), of an averaged sized-bullock.

Compared to other manual pumps (drawing water from underground source) the total pumping time is the lowest (870 h/ha) **(Table 3)** for the animal-driven pump and thus a command area of about 0.92 ha is found to be appropriate. This area is very close to the average landholdings of Bangladeshi farmers.

The potential command area of a shallow tubewell, estimated at 3.50 ha/season, is well above the average farm size of Bangladeshi farmer. This alternative would require forming co-operative and sharing system or custom-hire arrangements for economic utilization of the shallow tubewell. The above preconditions are often difficult to arrange and normally takes time to accomplish.

The estimated cost of irrigation with hired labour, (Tk. 2 487/ha) for the animal-driven pump is the least cost alternative. However, if family labour (bullock) is used the animal-driven pump is next to the cost (Tk. 1478/ha) of using the shallow tubewell only **(Table 4)**. Furthermore, when appropriateness of the command area and the extent of human drudgery are both considered the animal-driven pump becomes more appealing to small farmers compared to other pumps.

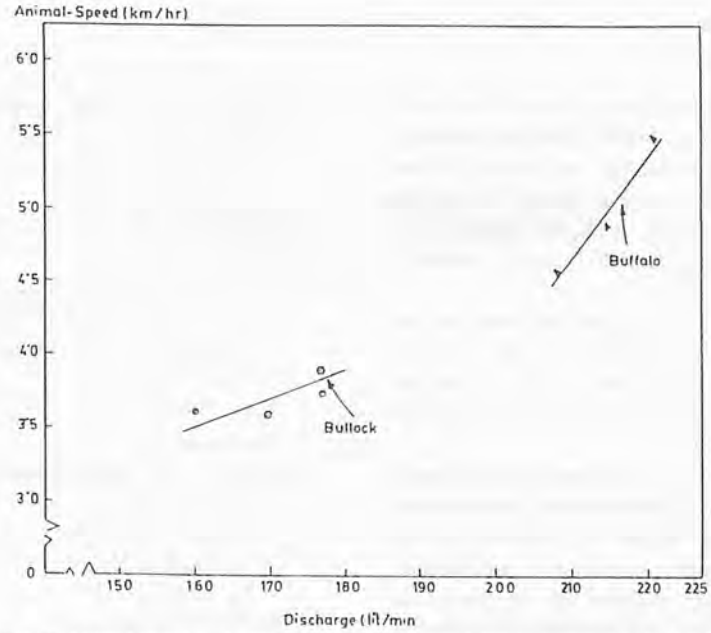

Fig. 6 Animal speed vs discharge curves for animal-driven pump (head: 3 m).

Table 4 Estimated Irrigation Cost (Tk./ha) of Alternative Pumping System at Irrigation Requirement of 10 000 m³/ha/ Season (Dry Season)

	Cost parameter	Alternative pumping equipment				
		STW	Animal-driven	No. 6 hand	RDRS twin treadle	MCC rower
A.	Fixed cost (Tk/ha)					
	1. Depreciation	957	391	588	308	510
	2. Interest	938	574	572	548	494
B.	Operating cost (Tk/ha)					
	1. Interest on running Capital	136	41[a] 122[b]	8[a] 1 198[b]	8[a] 885[b]	8[a] 1 290[b]
	2. Fuel (STW)	1 441	–	–	–	–
	3. Lub. oil (STW)	121	–	–	–	–
	4. R & M	144	200	100	100	100
C.	Wage for manual pumps					
	Using family labour[a] or animal		272 (feed)	–	–	–
	Using hired labour[b] or animal		1 200 (ox)	14 880	10 965	16 028
	Total cost (Tk/ha)	3 737 (113.24)	1 478[a] (44.79)	1 268[a] (38.42)	964[a] (29.21)	1 172[a] (35.52)
			2 487[b] (75.36)	17 338[b] (525.39)	12 806[b] (388.00)	18 422[b] (558.24)

Remarks: a Cost using family labour/animal; b Cost using hired labour/animal; STW–Shallow tubewell; BRRI–Bangladesh Rice Research Institute; RDRS–Rangpur-Dinajpur Rehabilitation Service; MCC–Mennonite Central Committee.

Note: Numbers within paranthesis indicate the costs in US$; (Tk. 33.00 = US$ 1.00).

Conclusions and Recommendations

1. The animal-driven pump was capable of pumping water from surface as well as underground source. Farmers with a pair of bullock or cow to run the pump can supply the water required by about 0.92 ha (2.3 acres) of 'Boro' rice land or 1.8 ha (4.5 acres) of wheat land during the winter season. A sizeable area of land for cultivation to winter vegetables can easily be irrigated.
2. The animal-driven pump can economically substitute for the more expensive STW pumping. Some 209 litres of imported diesel/ha/season required in STW pumping could be saved when the animal-driven pump is used. Considering a projected total area that could be covered by this proposed machine to be about 0.70 million hectare, a maximum savings of some 146

million litres of diesel fuel cost at Tk. 1 000 (US$ 30) million/season could be made. If we could cover at least 50% of the projected area we could save nearly Tk. 500 (US$ 15) million/season.

3. This very simple machine can be manufactured in an average workshop with local materials using the average skills available thereat.
4. The animal-driven pump is more dependable than a shallow tubewell which is constrained by frequent disorder, insufficient repair facilities and service availability, and general shortcomings in spare parts supply.

The following research areas are further planned to improve the performance of both the animal and the pump.

a) Improvement of the working conditions for the animal so that long work periods can be sustained.
b) Training of the animal with minimal human supervision.
c) Improvement of design and the fabrication of quality parts, especially those needing precision alignments, rigidity and balance; an arrangement for a flywheel is alternative.
d) Reduction of friction by proper design of sprockets, and those parts subject to extraneous wearing and rubbing of surfaces.

Appendix, Sample Cost Calculations

Cost calculation for BRRI Animal-driven pump:

1. Using own bullock
2. Using hired bullock.

Operating hours needed per cropping season/ha at pump capacity

Q = 191.5 l/min (average discharge at two sites)

= 11.49 m^3/hr.

Operating hrs/ha

= (10,000 m^3/ha) x (hr/11.49 m^3)

= 870 h

1. Cost using own bullock:

A: Depreciation

= Tk. (6,000 – 600)/15

= Tk. 360/yr

= Tk. 391/ha

(command area/season = 0.92/(ha)

B: Interest on investment:

On fixed capital = ½ (P + S)I

= Tk. ½(6000 + 600) x.16

= Tk. 528/yr

= Tk. 574/ha.

C. Operating cost

i) Interest on running capital (half eyarly basis).

= Tk. 271.88 (Extra feeding) + 200 (R & M)

= Tk. 471.88x.16

= Tk. 37.75/season

= Tk. 41/ha

ii) Extra feeding @ 0.5 kg/8 h – day at Tk. 5/kg

= Tk.271.88/ha

iii) Fuel cost: none for animal driven pump

D. Repair and maintenance: Tk. 200/ha (change of leather buckets).

∴ Total costs = A to D

=Tk. 391.00 + 574.00 + 41.00 + 272.00 + 200.00

=Tk. 1478.00/ha.

2. Cost using hired bullock:

Hiring charge rate Tk. 22/pair/day, ie, Tk. 1.38 (single/h)

∴ A. Depreciation from capital

= Tk. 391/ha

B. Interest on Investment

= Tk. 574/ha

C. Operating cost:

(i) Interest on running capital

= Tk. 1200.60 (hire charge) x.16 + (200 R&M)x.16

= 1400.6x.16

= 224.106/yr

= Tk. 112/season

= Tk. 122/ha.

(ii) Hire charge

= Tk. 1.38 x 870

= Tk. 1200.60

D. Repair and maintenance

= Tk. 200/ha (change of leather bucket)

Total cost = A to D

= Tk. (391.00 + 574.00 + 122.00 + 1200.60 + 200.00)

= Tk. 2487/ha.

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Development of a Power-operated Paddy Thresher

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Abstract

A power-operated paddy thresher was designed and developed with a view to increasing the threshing efficiency and to reduce the cost of threshing in comparison with conventional pedal thresher. It was observed that the higher output and maximum threshing efficiency can be achieved by threshing the paddy crop at 16.5% moisture content at peripheral velocity of 622 m/min. It was also found that net unit threshing cost per quintal of paddy was Rs. 2.11 when threshed by this thresher as compared to Rs. 3.96 per quintal when threshed by a pedal thresher.

Introduction

Power-operated threshers are available whether they are operated by oil engines, tractors or by electric motors. No doubt they have adequate capacity and good threshing efficiency but their cost is prohibitive for small farmers. The farmers of eastern India hardly get time for threshing operations due to the introduction of high yield varieties and multicropping system. The scarcity of farm labour and farm animals compounds the problem. Manually-operated pedal threshers which have low output and are time-consuming are the only means available to these farmers. Pedal threshers require manual operation, cost of threshing is high, human energy which is very costly is under-ultilized and causes discomfort to the operator. Therefore, a need was felt to develop a simple and low cost thresher that would have a high capacity with good threshing efficiency and operated by electric motor.

The International Rice Research Institute (IRRI) designed a table type thresher (4) with a capacity of 250–350 kg/h. An axial flow thresher was developed at IRRI and claimed to have an output of 100 kg/h. A similar thresher was fabricated with some modification in G.B. Pant University (6). It could thresh 8-12 quintals of paddy and 3-4 quintals of wheat per hour. The Mysore minithresher (1), a low-cost machine requiring about 3 hp was giving an output of 6 quintals of paddy per hour. Hota et al (2) designed a set-up to compare the operators' comfort in threshing paddy using two power application modes. It was found that the rotary mode for threshing paddy was more comfortable to the operator and also gave better outturn. Prakash (5) designed a pedal-operated multicrop thresher which was tested for paddy and wheat. It was reported that the peripheral velocity of 750 m/min and with peg height to tip clearance as 6/3.2 cm, the paddy output was 140 kg/h.

Design and Development

The material for threshing drum was used as pedal thresher as standardised by the Indian Standard Institute (IS 3327–1962). The cylinder diameter is 35 cm at the tip of the wire loops. The length of the shaft between two bearings is 130 cm but the length of the cylinder between two end disks is kept 110 cm. Twelve equally spaced wooden slats of 7 cm width, 1.5 cm thickness and 110 cm length are fixed on the end disks over a rim of 3 mm thickness and 25 mm width welded to the disks. The diameter of the end disks is 31 cm and made of mild steel plate of 6 mm thickness. The threshing teeth of 4 mm diameter G.I. wire were curved and fixed to the slats in such a way that the distance between the bottom ends of each tooth is 3.5 cm. The threshing teeth project 5 cm above the surface of the slat. The distance between the tip of the two adjacent teeth is 4.4 cm. There were 25 wire loops in each slat.

Testing Methods and Material

The thresher was connected to a 1 hp single-phase electric motor. The motor had a 75-mm diameter V-pulley and rotating at 1425 rpm. Four V-pulleys were fabricated in order to rotate the threshing cylinder at different speeds. The diameter of the pulleys were 275 mm, 225 mm, 175 mm and 150 mm. The corresponding rpm obtained were 380, 440, and 560, respectively. As the cylinder diameter at the tip of the wire loop is 45 cm, the four ranges of peripheral velocity used were 537.2 m/min, 622 m/min, 791.68 m/min and 989.6 m/min.

The variety CR 1009 of paddy was used for the test. Its grain-to-straw ratio was 1:1.7. Three levels of moisture contents were obtained: 22% (w.b.), 165% (w.b.) and 13.6% (w.b.). The crop was air-dried.

The moisture content of the grain was determined by air oven method at 130 ± 2°C and a sample of 5 g clean grain being put for 16 h. Also for quick determination the moisture content was found with the help of a universal moisture meter at the time the test was conducted.

A known weight of 50 kg crop were taken each time. Twenty bundles (approximately equal) were prepared and piled near the machine. Two persons fed the bundles simultaneously to the machine and a third man was engaged to supply the bundles to both. The threshing time for each test run was recorded. Threshed grains were collected.

Unthreshed broken earheads were separated from the grain. The unthreshed earheads were also collected from the threshed bundles. The total threshed grains were cleaned manually and weighed. Unthreshed grains from the front side and from the threshed bundles were separately threshed manually, cleaned and weighed. The above procedure was repeated three times for all the combinations of cylinder speed and moisture content of the crop.

Considering the need for field preparation and sowing operation of the next crop, the maximum threshing days available was limited to 36 days. Annual hourly use of the thresher was determined by considering the effective working time of 8 hours per day. The labour charge was assumed to be Rs. 7.00 per day of 8-hour work. For calculation of unit cost of operation it was assumed that the electric motor will be used for other agricultural operations by the farmer in idle days. Other cost factors assumed for calculation of unit cost of operation are salvage value which is 10%, and interest at the rate of 15% per annum for all three machines. The repair and maintenance charge for both the threshers are assumed to be 1% whereas for electric motor it was 4.5%.

Table 1 Cost Factors of Thresher, Electric Motor and Pedal Thresher

Machine	Initial cost/purchase price (Rs.)	Useful life	Annual use h
Developed thresher	740	10	288
1 hp electric motor	2 000	15	228
Pedal thresher	940	10	228

Results and Discussion

It was observed that the threshing efficiency mostly varied within the range from 91.67 to 98.50% though these variation in most of the cases were very small. Maximum threshing efficiency of 98.50% was obtained at peripheral velocity of 622 m/min and was minimum at 91.67% at peripheral velocity of 989.6 m/min. This shows that threshing efficiency decreases with the increase of peripheral velocity. This is due to the fact that at high peripheral velocity of the cylinder, the impact force exerted by the wire loop to the crop detaches

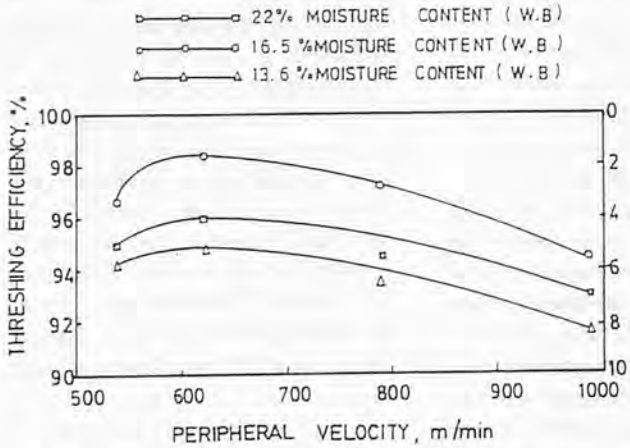

Fig. 1 Effect of peripheral velocity on threshing efficiency.

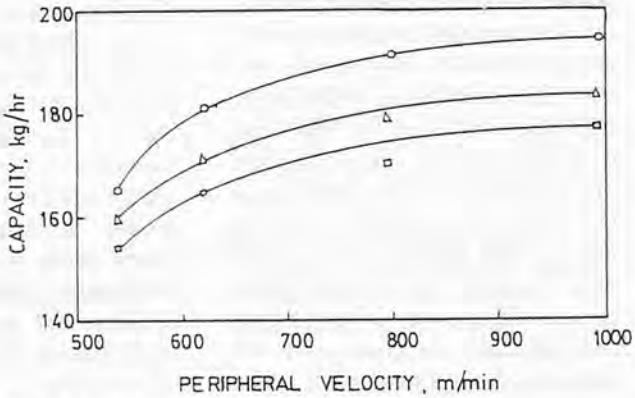

Fig. 2 Effect of peripheral velocity on capacity.

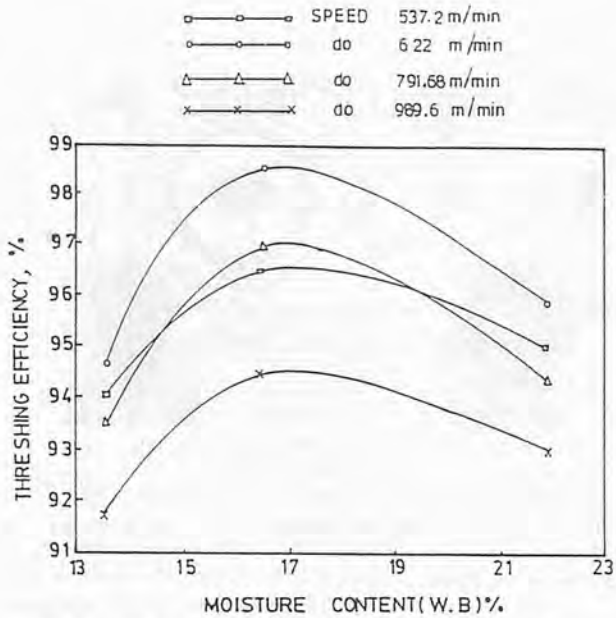

Fig. 3 Effect of moisture content on threshing efficiency.

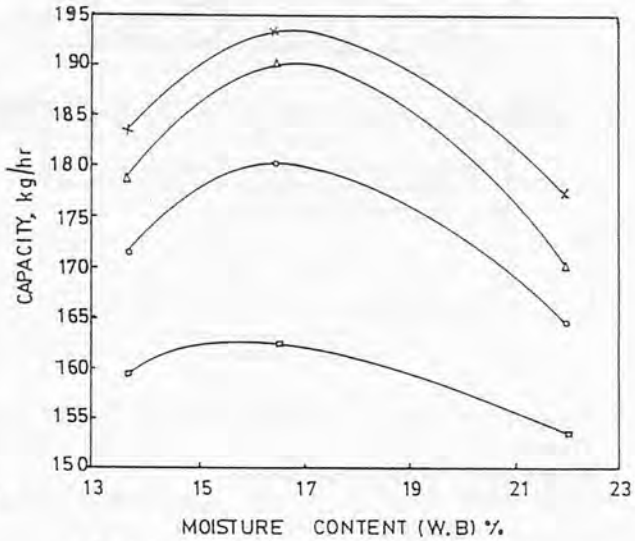

Fig. 4 Effect of moisture content on capacity.

the earhead along with the grains. The low peripheral velocity of 537.2 m/min is not sufficient to cause the impact force by the wire loop to detach the paddy grains from the earheads.

It is apparent from **Fig. 1** that the threshing efficiency is maximum at 16.5% (w.b.) of moisture content and at peripheral velocity of 622 m/min. The threshing efficiency is less at moisture content of less or more than 16.5% for all four peripheral velocity of the cylinder. This behaviour of the designed thresher may be due to the fact that, as it is hold-on-type, at high moisture content (22%), the crop requires high threshing force in order to separate the grains. But at low moisture content (13.6%) greater number of earheads broke thereby increasing the amount of unthreshed grain.

The range of output (capacity) was 153.07 kg/h to 193.28 kg/h **(Fig. 2)** when the peripheral velocity was varied from 537.2 m/min to 989.6 m/min. However, the increase in capacity is non-linear. This type of behaviour may be due to the fact that, because of the hold-on-type of thresher, the losses increased with the increase of peripheral velocity of the thresher. At low peripheral velocity, the losses were greater due to less threshing force.

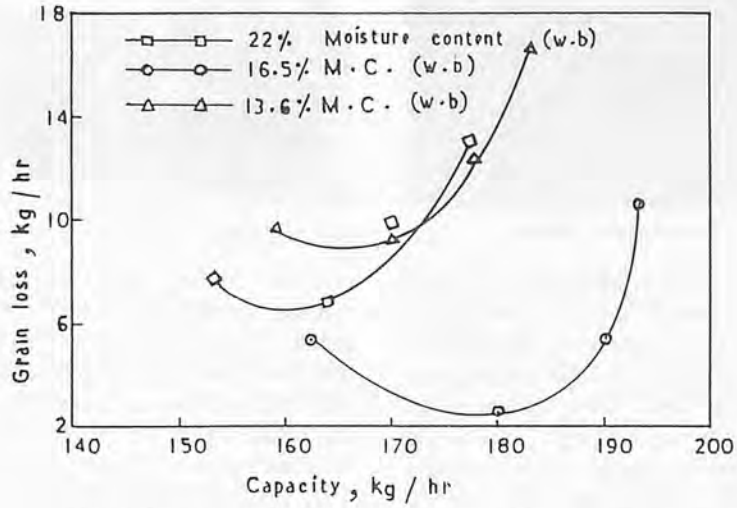

Fig. 5 Grain loss and capacity at different moisture content.

At 16.5% moisture content, the capacity of the thresher ranged from 162 kg/h to 193.13 kg/h, whereas at 13.6% moisture content it was 159.15 kg/h to 183.29 kg/h **(Fig. 4)**. This shows that a higher capacity can be achieved by threshing the paddy crop at 16.5% moisture content. High moisture content (22%) reduces the capacity because of the requirement of more impact force and more grains remain unthreshed. At low moisture content (13.5%), the capacity is reduced due to the fact that more earheads break thereby increasing the losses.

The unthreshed grain loss was minimum at 16.5% moisture content and 622 m/min peripheral velocity **(Fig. 5)** corresponding to the capacity of 180 kg/h. Though the capacity increased at higher peripheral velocity at particular moisture content, the unthreshed loss also increased due to more breakage of earheads. At lower peripheral velocity, the unthreshed loss was greater because more grains remain unthreshed.

The unit cost of operation of the developed thresher and the pedal

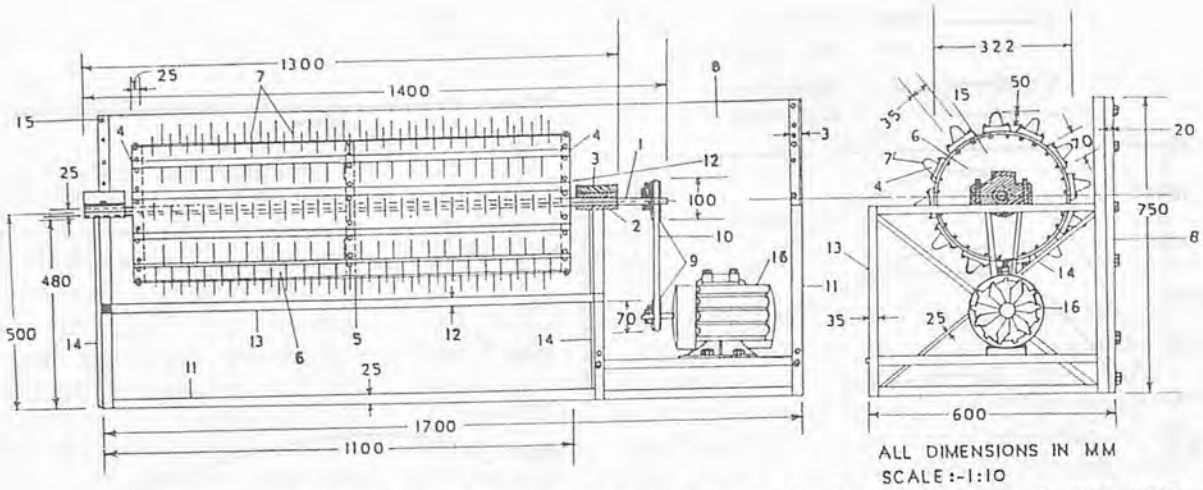

Fig. 6 Details of developed thresher, unit: mm.

Fig. 7 The developed thresher.

Fig. 8 The developed thresher in operation.

Fig. 9 Pedal thresher in operation.

thresher were calculated by adding the overhead cost and variable cost. The pedal thresher is operated by two labourers and the capacity was 60 kg/h. With three labourers, the capacity was 180 kg/h. Due to the increase in length of the threshing cylinder two labourers could perform the threshing operations. The analysis of the economics of use of the developed thresher and the pedal thresher shows that the cost of the developed thresher, including the cost of fabrication and prime mover was Rs. 2740 and the cost of threshing of paddy was Rs. 2.11 per quintal whereas the cost of threshing by pedal thresher was Rs. 3.96 per quintal.

Conclusion

Paddy crop with high moisture content requires high cylinder peripheral velocity in order to minimize the total unthreshed loss. Low moisture content requires a slow cylinder peripheral velocity for similar total unthreshed loss. A peripheral velocity of 622 m/min was optimum for maximum threshing efficiency of 98.5% at 16.5% moisture content of paddy crop.

A capacity of 180 kg/h could be obtained at 16.5% moisture content and 622 m/min peripheral velocity with minimum total unthreshed loss of 1.5% only.

The net unit threshing cost of paddy using this thresher was Rs. 2.11 per quintal, whereas it was Rs. 3.96 per quintal when threshed by ordinary pedal thresher.

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A Solar Tunnel Dryer for Drying Paddy

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Abstract

A solar tunnel dryer was tested for drying wet paddy at the International Rice Research Institute, (IRRI) Philippines. Results show that under adverse weather conditions the dryer was able to dry paddy to moisture contents for safe, short-term storage. Milling recovery and head rice yield from samples dried in the solar dryer were very close to the potential values. In a comparative test the unit showed an advantage over the direct solar drying method.

Introduction and Objective

Conditioning of food crops for safe preservation has engaged the attention of mankind since the beginning of civilization. Due to demand for high quality food standards, ever-increasing high production levels and uncertain favorable climatic conditions for direct sun drying, there has been several attempts to encourage the use of mechanical dryers. Despite these efforts the acceptance of mechanical dryers at farmers' (small scale) level has been extremely low. Some of the reasons attributed to this are summarized below (de Padua, 1985):

a. Dryer capacity too big

b. High fixed and operating costs or limited resources.

Paddy sun-drying is the prevailing practice in many developing countries in Southeast Asia. Although sun-drying is a practical and inexpensive method, it is obviously dependent on weather conditions. Under normal circumstances sun-drying methods lead to lower grain quality (lower milling recovery and head rice yield) and grain contamination.

In the light of the abovementioned problems a solar dryer might be an alternative for mechanical and sun-drying of paddy. For this purpose a solar tunnel dryer was tested for drying paddy at IRRI. The aim was to gather data on the performance characteristics of the unit for drying paddy, especially in unfavorable weather conditions.

Equipment

This solar dryer is a modification of an earlier design (Lutz et al, 1986) consisting of a collector and tunnel drying chambers arranged parallel to each other (**Figs. 1 and 2**). The drying air is driven through the collector by a centrifugal blower with backward curved-blade impeller. By reverse baffles the heated air from the collector is directed into the tunnel drying chamber. The air flowing over the paddy is able to exhaust moisture from the crop. The dryer assembly is raised above ground by brick footings.

The dimension of the collector is 20 m by 1 m while the drying chamber has the same length but with a width of 2 m. The collector and the drying chamber are separated by a gap of 0.1 m. Both the

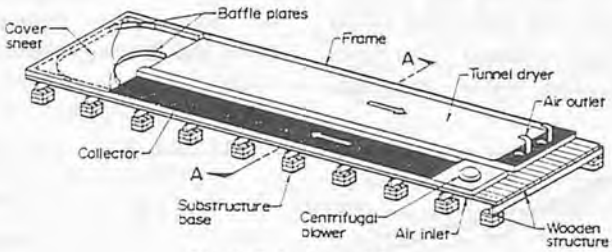

Fig. 1 Solar tunnel dryer.

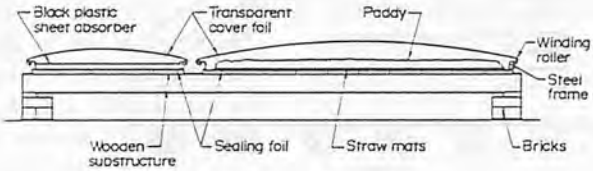

Fig. 2 Cross-section A-A of tunnel dryer.

Acknowledgement: Resources for the study were provided by IRRI, GTZ and the University of Hohenheim for which the authors are very grateful.

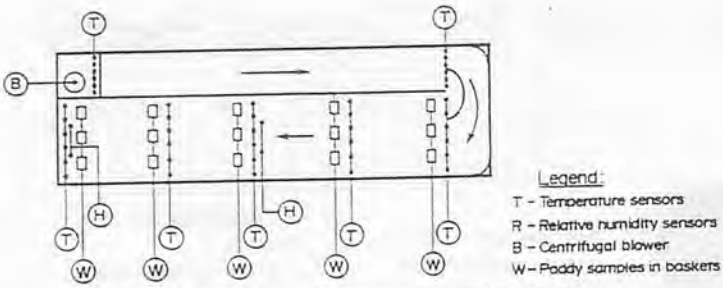

Fig. 3 Locations of sensors on the solar dryer.

collector and the drying chamber are covered with UV-stabilized transparent foil. A black thermostatic plastic material is used as an absorber in the collector.

To characterize the dryer system, readings from sensors were taken with a data acquisition system every five minutes for each of four experiemnts. Temperatures were measured with calibrated NiCr-Ni thermocouples while relative humidities were monitored with capacitance sensors. Global radiation was measured with a pyranometer. Wind speed was determined with a cup anemometer. **Fig. 3** shows the locations of the sensors on the dryer system.

Procedure

The solar tunnel dryer was used to dry freshly harvested paddy (Sinang Domeng) in four experiments. For each test run the drying chamber was filled with paddy (875-980 kg) to about 5 cm layer thickness. The initial and final moisture contents (on wet basis) of the crop were about 26% and 14%, respectively. The crop was mixed each hour during each drying session. To determine the moisture content of the crop, samples contained in baskets in the dryer were weighed every hour.

For comparison, samples were sun-dried on a concrete pavement nearby. In this case a layer thickness of 2 cm and mixing intervals of 30 min were observed. Samples dried in the shade served as control.

For each experiment, samples from the solar tunnel dryer, sun- and shade-drying were stored in sealed plastic bags for two days and then milled in laboratory rice processing equipment to determine milling recovery and head rice. This time lapse was necessary because studies elsewhere have shown that fissures due to high temperatures and moisture adsorption of paddy show up 48 hours after drying (Kunze, 1979 and Sharma, 1981).

Resutls and Discussions

Drying Process

During the drying operations, global radiation received was between 100 and 1 200 w/m^2. Relative humidity registered was 85% to 95%; although in some cases it dropped to 70%. The ambient temperature varied between 28° and 38°C. Intermittent cloudy and rainy weathers prevailed during some of the drying periods. Grain temperature was 42-45°C.

Drying at the air inlet portion of the drying chamber was faster and then reduced towards the middle **(Fig. 4)**. However, the drying rate increased from the middle towards the end of the chamber. This phenomenon was due to the fact that as the air picked up moisture from the crop, its (air) drying capacity decreased. Since the drying chamber was also collecting insolation, additional energy was provided for the drying process. This necessitated mixing of the paddy every hour in order to minimize differentials in grain moisture content.

Reduction of moisture content of the paddy was faster in the case of sun-drying **(Fig. 5)** due to frequent mixing of the paddy and thinner paddy layer used (2 cm). However, drying capacity defined as the weight of paddy dried on 1 m^2 area in 1h was consistently higher for the solar tunnel dryer **(Table 1)**.

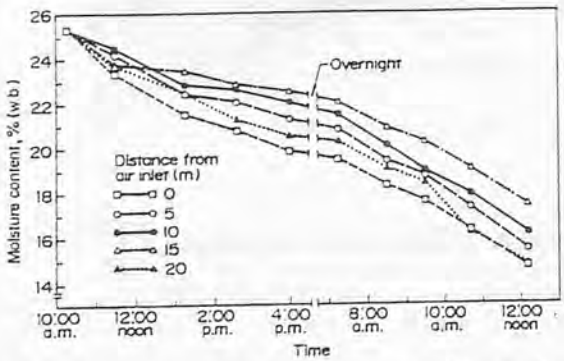

Fig. 4 Paddy moisture content at different solar dryer sections.

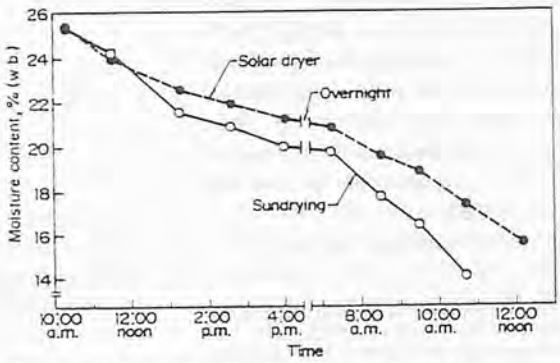

Fig. 5 Paddy drying rates for solar- and sundrying.

Table 1 Drying Capacity and Efficiency for Sun and Solar Drying

Experiment	Drying capacity		Efficiency,*%	
	Sun-drying	Solar dryer	Sun-drying	Solar dryer
1	0.92	1.55	13.1	20.1
2	0.78	1.25	15.6	27.6
3	0.83	1.33	10.8	27.9
4	0.40	0.90	13.8	23.4

*Efficiency: The ratio of the energy required to evaporate moisture from the grains to the insolation received over the area of the dryers.

Table 2 Statistical Analysis of Percent Head Rice

Source	DF	Sum of	Mean sq	F (Cal)	F (Tab 5%)	Remarks
Replications	3	46.86	15.62	2.896	4.781	Not significant
Drying method	2	132.88	66.44	12.317	5.152	Significant @ 5%
Error	6	32.36	5.39			

Factor	Mean, % (Head rice)	Sign*
Shade drying	93.7	A
Solar dryer	87.0	BC
Sun-drying	86.2	C

* Factors with the same letters are not significantly different.

Over-all efficiency obtained for the solar tunnel dryer was at least 7% more than that for sun-drying. Due to relatively slow thermal responses of crop masses, the integrated efficiency over the entire drying period is a more meaningful parameter than an instantaneous drying efficiency.

Since drying efficiency is dependent on the type of crop being dried (Norton, 1988), the efficiency can thus be used to rate the performance of a particular dryer system for a specific crop over given climatic conditions.

Milling Quality

Milling quality is normally characterized by two parameters:

a. milling recovery; percentage of milled rice from a given quantity of paddy rice, and
b. head rice; percentage of whole grains of total milled rice.

Any grain which is three-fourths the kernel size or larger is termed as whole grain (Wimberly, 1983).

Milling recovery for samples from all test runs ranged between 70.4 and 73.4%. There was no significant difference between them.

In contrast, shade dried samples gave higher head rice yield than samples from solar dryer and sun-drying tests (at 5% significant level). However, solar- and sun-drying gave almost the same rice head yield values, i.e., they were not significantly different (Table 2).

As expected, the shade-drying resulted in the highest milling qualities since it was a low temperature and slow drying process. In general, values obtained by this method are regarded as the potential of the crop. Normally, sun-drying on pavement reduces recovery and head yield of paddy due to over-heating and over-drying. In this case the adverse effect of sun-drying was minimized by maintaining a thin drying paddy layer and frequent mixing, as suggested by earlier studies at IRRI (Gayanilo, 1988).

Conclusions

The solar tunnel dryer evaluated was able to dry paddy (Sinang Domeng) from moisture content of 26% down to 14% (wb) within drying periods between 6 and 8 h under weather conditions which were normally unfavorable for direct sundrying.

Milling recovery obtained for paddy samples dried in the solar dryer was very close to the potential values. However, head rice yield values compared less favorably.

The solar dryer exhibited an advantage over sundrying in terms of drying capacity (kg/m^2/h of paddy) and efficiency.

For further studies, it is suggested that parts of the solar tunnel dryer be fabricated with locally available materials. Evaluation of the system should include economic feasibility tests.

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Unit Cost of Operations of Farm Tractors

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Introduction

Agricultural mechanization in Pakistan is being encouraged to boost agricultural production as a means of making the country self-sufficient in food grains and to earn much needed foreign exchange. Farm tractors are the main source of farm energy in the country. The number of tractors on the farms has been increasing since the last 30 years. At present different makes and models of tractors are available. Major inputs such as fixed and operating costs are made available to farms through tractors. It is important to estimate the cost of operation of the tractor to enable the farmer to determine whether or not he has earned or lost in the farm business using tractors.

Tractor costs have great influence on profit. Most farmers are unable to determine how tractor cost could be estimated. This is one reason that stands in the way of complete agri-mechanization in the country: lack of technical know-how.

This paper reports on various factors that contribute to the cost of use of farm tractors and various techniques of estimating tractor cost. In this way, farmers can make full use of the techniques, hence derive maximum profit. The study will also help in the selection of more appropriate farm tractor.

Method of Study

Machinery costs are of two categories: fixed costs and variable costs. Fixed costs pertain to depreciation, interest on investment, housing, insurance and taxes.

Variable or operating costs refer to fuel, lubricants, repairs and operator's wages. When an operator is employed permanently, his wages are included in the fixed costs but if he is appointed on seasonal basis his wage is included in the operating costs. However, in the present paper the operator's wage is included in the fixed costs.

Depreciation, often the largest cost of farm machinery, measures the amount by which the value of the tractor decreases with the passage of time whether used or not. There are three specific methods of calculating the depreciation as suggested by the Internal Revenue Service (IRS) which are: straight line method; declining balance method; and sum of years-digits method.

Engineering economists use the sinking fund method. The straight line method is the simplest as it charges an easily calculated amount each year. The depreciation by this method is calculated from the following formula.

$$D = \frac{P-S}{L}$$

where,

D = Depreciation charge in rupees.
P = Purchase price in rupees.
L = Estimated economic life in years.

The economic life of the tractor is a more permanent measure of the period of time for which depreciation should be estimated. Therefore, it is the time from purchase of the tractor to that point where it is more economical to replace with a second than to continue with the first tractor.

The straight line method of depreciation was used in the study as it is more easily understood by the farmers. The pertinent data for the selected tractors were collected and tabulated for further analysis (Table 1-4).

Interest on investment in a farm

Table 1 Unit Cost of Operation of Farm Tractor (MF 135)

Unit: Rupee

Year	Total hours used	Fixed cost per year							Operating cost per year				Total cost (fixed and operating) per year	Cost per hour
		Depreciation	Interest	Rent of housing	Insurance	Operator salary	Repair labour	Total fixed costs	Fuel cost	Lubrication cost	Repair & maintenance cost	Total operating cost		
1980	856.0	7 026.47	4 336.34	1 200.00	30.00	4 956.00	5 352.00	22 900.75	7 616.75	465.37	479.00	8 560.94	31 461.75	36.75
1981	759.0	7 026.47	4 336.34	1 200.00	30.00	5 209.00	5 658.00	23 458.81	7 824.95	775.15	77.00	8 677.10	32 135.91	42.34
1982	683.0	7 026.47	4 336.34	1 500.00	30.00	5 460.00	5 964.00	24 316.81	7 648.03	978.60	684.00	9 310.63	33 627.44	49.23
1983	774.0	7 026.47	4 336.34	1 500.00	30.00	9 240.00	10 095.00	32 227.81	11 716.05	1 386.00	4 930.00	18 032.50	50 260.31	64.94
1984	753.5	7 026.47	4 336.34	1 800.00	30.00	9 600.00	10 440.00	33 232.81	11 821.36	1 504.63	2 055.00	15 380.99	48 613.80	64.52

Purchase price of tractor: Rs. 62 242.00, Date of purchase: 18. 1. 1980.

Table 2 Unit Cost of Operation of Farm Tractor (Ford 4600)

Unit: Rupee

Year	Total hours used	Fixed cost per year							Operating cost per year				Total cost (fixed and operating) per year	Cost per hour
		Depreciation	Interest	Rent of housing	Insurance	Operator salary	Repair labour	Total fixed costs	Fuel cost	Lubrication cost	Repair & maintenance cost	Total operating cost		
1981	640.00	9 320.72	5 752.22	1 200.00	30.00	5 208.00	5 658.00	27 168.94	9 213.07	849.03	144.00	10 206.10	37 375.04	58.40
1982	674.00	9 320.72	5 752.22	1 500.00	30.00	5 460.00	5 964.00	28 026.94	10 268.61	1 345.00	257.00	11 870.61	39 897.55	59.20
1983	715.05	9 320.72	5 752.22	1 500.00	30.00	9 240.00	10 095.00	35 937.94	16 473.72	1 653.00	9 505.00	27 631.72	63 569.66	88.85
1984	1 272.00	9 320.72	5 752.22	1 800.00	30.00	9 600.00	10 440.00	36 942.94	27 062.44	4 841.00	1 961.00	33 864.44	70 807.38	55.67

Purchase price of tractor: Rs. 85 218.00. Date of purchase: 21.7.1980.

Table 3 Unit Cost of Operations of Farm Tractor (MF-265)

Unit: Rupee

Year	Total hours used	Fixed cost per year							Operating cost per year				Total cost (fixed and operating) per year	Cost per hour
		Depreciation	Interest	Rent of housing	Insurance	Operator salary	Repair labour	Total fixed costs	Fuel cost	Lubrication cost	Repair & maintenance cost	Total operating cost		
1982	869.5	9 396.88	5 737.5	1 500.00	30.00	5 460.00	5 964.00	28 088.38	13 844.60	684.57	1 390.00	15 919.17	44 007.55	50.61
1983	1 160.0	9 396.88	5 737.5	1 800.00	30.00	9 240.00	10 095.00	36 299.38	28 753.04	981.00	3 057.00	32 791.04	69 090.42	59.56
1984	1 170.0	9 396.88	5 737.5	1 800.00	30.00	9 600.00	10 440.00	37 004.38	25 493.82	1 747.88	11 435.00	38 676.70	75 681.08	64.68

Purchase price of tractor: Rs. 85 000.00. Date of purchase: 12.3.1981.

Table 4 Unit Cost of Operations of Farm Tractor (Fiat 480)

Unit: Rupee

Year	Total hours used	Fixed cost per year							Operating cost per year				Total cost (fixed and operating) per year	Cost per hour
		Depreciation	Interest	Rent of housing	Insurance	Operator salary	Repair labour	Total fixed costs	Fuel cost	Lubrication cost	Repair & maintenance cost	Total operating cost		
1975	760.00	3 500.00	2 700.00	900.00	30.00	2 469.00	2 658.00	12 248.00	1 611.52	36.98	160.00	1 808.50	14 056.50	18.50
1976	441.25	3 500.00	2 700.00	900.00	30.00	2 580.00	2 796.00	12 506.00	2 991.64	41.17	30.00	3 062.81	15 568.81	35.28
1977	600.75	3 500.00	2 700.00	900.00	30.00	4 428.00	4 680.00	16 238.75	3 581.60	294.86	415.00	4 291.46	20 530.21	34.17
1978	616.50	3 500.00	2 700.00	900.00	30.00	4 644.00	4 950.00	16 724.00	3 714.40	307.43	293.00	4 314.83	21 038.83	34.13
1979	617.00	3 500.00	2 700.00	1 200.00	30.00	4 788.00	5 148.00	17 366.00	5 121.21	254.18	192.00	5 567.39	22 933.39	38.17
1980	505.50	3 500.00	2 700.00	1 200.00	30.00	3 956.00	5 352.00	17 738.00	4 784.23	434.31	1 386.00	6 604.54	24 342.54	48.16
1981	484.05	3 500.00	2 700.00	1 200.00	30.00	5 208.00	5 658.00	18 296.00	5 154.85	255.51	3 679.00	9 089.36	27 385.36	56.52
1982	405.00	3 500.00	2 700.00	1 500.00	30.00	5 460.00	5 964.00	19 154.00	4 182.09	267.91	239.00	4 689.00	23 843.00	58.57
1983	368.50	3 500.00	2 700.00	1 500.00	30.00	9 240.00	10 095.00	27 065.00	4 866.36	383.78	4 906.00	10 156.14	37 221.14	101.00
1984	416.00	3 500.00	2 700.00	1 800.00	30.00	9 600.00	10 440.00	28 070.00	11 337.72	1 004.88	3 376.00	15 718.60	43 788.60	105.26

Purchase price of the tractor: Rs. 40 000.00. Date of purchase: 17.7.1974.

machine is usually included in fixed cost estimates, since money used to buy a machine cannot be used for other productive endeavor. The suggested interest rate is 6% but other rates may be more appropriate. Interest charges are usually desired when operating costs are being determined; and be calculated so that the result will be constant or so there will be an equal yearly charge throughout the life of the machine. According to Hunt (1965) the annual interest charge is the product of the interest rate and the average investment. In the present study the interest rate was kept at 12% of the average investment.

Table 5 Unit Cost of Four Selected Tractors

Tractor	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Average unit cost
M.F. 135	–	–	–	–	–	36.75	42.34	49.23	64.94	64.52	51.56
Ford 4600	–	–	–	–	–	–	58.40	59.20	88.85	55.67	67.78
MF 265	–	–	–	–	–	–	–	50.61	59.56	64.68	58.28
Fiat 480	18.50	35.28	34.17	34.13	38.17	48.16	56.52	58.57	101.00	105.26	52.27

Insurance must be included in any tractor operation costs. Although insurance rates vary according to local conditions and other factors, Fenton and Fairbanks (1954) suggest an annual insurance charge of 0.25% of the original cost of the machine. But this is not universal practice. In Pakistan the insurance on farm machinery has not yet been imposed by the government nor introduced by the private sector.

Shelter is another cost factor of farm machinery which must be included while determining the operating cost. The average total expected life of the machinery is consistently greater when shelter is provided. The average annual estimated repair expense is also consistently smaller for sheltered machines. The cost of shelter varies according to the type of the shelter. Mostly cheap structures have been used as a shelter and the cost is likely no more than 0.5% of the purchase price of the machine. In the present study the cost of the shelter has been determined at various rates due to inflation.

To enhance revenue, the government charges property taxes. Like other farm property, farm machinery is also taxed. Assuming a 10-year life of the machine the tax fixed in the U.S.A. is 1.5% of the purchase price of the machine. However, in Pakistan the rate is Rs.30 per year irrespective of the original purchase price of the machine.

Fuel is one of the major items affecting tractor operating costs. Estimates of fuel consumption are of interest to most tractor operators. Fuel and oil consumption varies according to the size of the tractor. In the present study data pertaining to fuel and oil consumption, including data on repair and maintenance were collected from records available in the workshop of the faculty of Agricultural Engineering, Sind Agriculture University, Tandojam for further analysis.

The total cost of use of farm machineries is determined from the following equation.

$$\text{Total cost} = Fc + VcX$$

where,

Fc = Fixed cost
Vc = Variable cost
X = Number of hours the machine has been used

$$\text{Cost per hour} = \frac{Fc}{X} + \frac{VcX}{X}$$

$$= \frac{Fc}{X} + Vc$$

In the present study data pertaining to the following wheel-type farm tractors were collected to determine their unit cost of operations: Massey Ferguson 135, Ford 4600, Massey Ferguson 265, and Fiat 480.

Results and Discussions

Table 1 shows that the unit cost of operation per hour of the MF 135 has increased from Rs. 36.75 to Rs.64.52 during five years life. Ford 4600 has increased from Rs.58.40 to Rs.88.85 during three years life **(Table 2)**; MF265 increased from Rs50.61 to Rs.64.68 during three years life **(Table 3)**; and Fiat 480 increased from Rs.18.50 to Rs.105.26 during 10 years life.

Conclusions and Suggestions

From **Table 5** it is concluded that the MF135 is most economical followed by Fiat 480. Therefore, it is suggested that for small farms, MF135 may be used and for large farms, Fiat 480 is recommended. ■■

ERRATA

AMA Vol. 20, No. 1, Winter 1989 Page 55. The title should read: "Status of Mechanization of Harvesting and Threshing of Soybean."

Microwave Energy: A New Concept in Paddy Parboiling

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Abstract

Conservation of energy is a prime concern of every one all over the world. Utilization of microwave energy for parboiling paddy at small-scale level could be convenient and economical. The possibility of using microwave energy for paddy parboiling is reported in this paper. Paddy samples, soaked in water and freshly harvested at high moisture level were placed in a domestic cooking microwave oven for parboiling. The exposure time of 180 seconds was required to parboil the paddy in microwave oven and achieve maximum head rice yield. The required exposure times for maximum head rice yield were obtained as 90 and 15 seconds, respectively, when paddy samples were placed close to the air-driven fan and magnetron tube in the oven. There was no change in the colour of rice kernels after parboiling in microwave energy.

Introduction

Parboiling of paddy (rough rice) is an ancient process practised in many rice producing countries in order to improve the head rice yield and nutritive quality of milled rice. Parboiling process consists of three steps: soaking, steaming (gelatinization of starch) and drying before milling the paddy. Based on these steps several modern methods have been developed and being practised for large scale parboiling at commercial levels (Gariboldi 1973 and Ali and Ojha 1976).

Modern parboiling methods are capital- and energy- intensive and are not suitable for village-level and small scale operation. Approximately 249 000 Kcal heat is required to parboil a ton of paddy using the modern methods. A major portion of this energy, about 612 400 Kcal/t, is consumed during steaming and subsequent drying operations (Ali and Ojha 1976 and Wimberly 1983).

With the rapidly increasing cost of energy, more efficient parboiling methods must be found. If gelatinization and drying operations could be combined, one step could be eliminated from the parboiling process, which can result in considerable savings in energy. The elimination of soaking paddy in water and combining the steaming and final drying steps were first suggested by Jones (1946). This means that paddy may be harvested even when moisture level is high. Very little work, however, has been done so far to simplify the modern parboiling methods which are extensively practised in many parts of Asia.

In the late 1960s some work was done on accelerated conduction drying of paddy in the Agricultural Engineering Department of the International Rice Research Institute (IRRI) in the Philippines. In these experiments, moisture was reduced to 10-15% in a few seconds by exposing paddy to heated sand (Khan, 1969). Wet paddy was also exposed to a direct flame and a rapid decrease in its moisture content was achieved (Khan, 1969 and Arboleda, 1973). During these experiments it was observed that some samples of paddy were being partially parboiled, some 20% higher than the control (shade dried) sample.

Based on previous experiments on accelerated drying of paddy at IRRI, the experiments were again undertaken in order to understand the different parameters involved in parboiling of paddy with heated sand (Shukla and Khan, 1984). It was found that a minimum grain moisture* level of about 27% which can be achieved by soaking paddy

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*Unless otherwise stated, moisture content in this paper is expressed in wet basis (W.B.).

in water at ambient temperature for 24 hours, was essential for gelatinization of starch granules. A heated sand temperature of 200°C, sand-paddy ratio (on weight basis) of 15, and a paddy-sand exposure of 10 seconds were found to produce optimum results with 20% increase in head rice yield over control (unparboiled paddy).

A substantial saving of energy, about 65%, compared to modern parboiling methods as suggested by Ali and Ojha (1976) and Wimberly (1983) was estimated with heated sand parboiling method (Shukla and Khan, 1984) as gelatinization of paddy starch and subsequent drying of paddy would essentially occur in single operation, thereby reducing the extra handling and drying operations.

It was not easy to develop a machine with metering arrangement to handle heated sand and high moisture paddy accurately together for such a short perid (10 seconds) and dry the grain after gelatinization of starch granules. Attempts were made at IRRI to design such unit but without success. Metering of heated sand flow to meet the requirement of parboiling and drying of paddy has been a most difficult task. It requires sophistication in equipment which would be very expensive and may not be suitable at small scale level operation. However, the sand can be eliminated by using microwave energy in quick parboiling of paddy. The application of microwave energy would simplify the complicated hot sand parboiling system and final product would be of better quality.

Microwave is a new concept in energy which is popularly used for drying food, textile and wood (Anthony, 1983). Experiments were conducted to dry cotton seeds (Wasley et al. 1974) and determine the moisture content (MC) of agricultural products using the microwave energy (Click and Baker, 1980 and Click and Mobley, 1982). However, no attempt has been made to utilize the microwave energy for parboiling and drying the paddy though it has a good potential in the development of a simple machine and obtaining improved quality of rice after parboiling. Therefore, the preliminary studies were carried out to parboil the paddy using microwave energy with the following objectives:

(1) To evaluate the possibility of using microwave energy for parboiling paddy.
(2) To determine the possible gelatinization time using microwave energy, and
(3) To compare the head rice yields and quality of parboiled rice in microwave energy with unparboiled rice.

Experimental Procedure

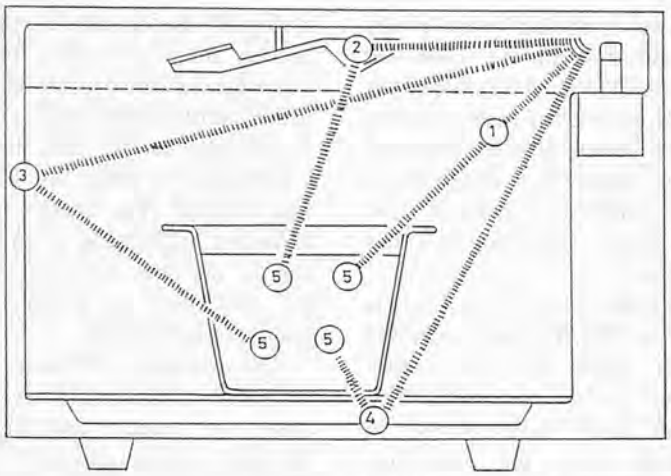
IR-36 paddy variety was used throughout this experiment to maintain uniformity in the results. The optimum grain moisture level of about 27% after soaking the paddy for 24 hours at ambient temperature has already been established for IR-36 paddy during the experiments of heated sand parboiling at IRRI by Shukla and Khan (1984). Therefore, paddy was soaked for 24 hours and used for microwave parboiling experiments. Some trial experiments were also conducted with freshly harvested paddy at high moisture level (about 27%) obtained from IRRI Farm.

A microwave oven (Kenmore, Serial No. E 173456 and Model No. 564-9938010) for domestic cooking was used for evaluating the basic parameters of paddy parboiling. General specifications of microwave oven used in experiments are given in **Table 1** and **Fig. 1**.

Paddy soaked in water or harvested paddy at high moisture level was placed in the oven for varying exposure durations. A bimetalic gauge type thermometer was placed in the grain bed into the oven and grain temperature at the end of exposure time was recorded. After taking out from oven, the paddy was cooled at room temperature and then MC was measured. The microwave-treated paddy sample was placed for another 24 hours tempering in a room at 24-26°C temperature

Table 1 General Specifications of Microwave Oven Used in the Experiments

Control panel	**Construction features**
25-minute timer with signal bell	Wattage: 600 for cooking and 300 for defrost
Cook and defrost buttons	Side swing door
Recipe guide for oven and defrost	Operates on regular 120 circuit
Start Buttons	Acrylic painted steel oven cavity
Oven	**Dimensions**
Automatically operated for time selected	Overall: 24"W x 19-3/4"D x 15-3/4"H (609.5 x 501.65 x 400.04 mm)
Removable glass cooking tray	Oven capacity: 14-3/4"W x 15-3/4"D x 9-3/4"H (1.4cu.ft (0.039 m³) interior dimensions
Oven light operated by start button	Net weight: 70 lbs. (31.7 kg)
Safety features	
NEW Compliance	
4-foot long, 3-wire cord with grounding type plug	
Full plastic window over door screen	
Dual interlocks with monitor system	



1. Microwave energy generated only when the door is closed, Timer is set and start button is pressed
2. Metal stirrer is an air driven fan- it reflects energy wave even cooking.
3. Metal walls reflect energy waves- back to the food.
4. Microwave energy passes through cooking tray and reflects from - oven bottom to allow food to - cook on the sides, top and bottom
5. Microwave energy heats food.

Fig. 1 Understanding microwave energy.

and relative humidity of 60-65%.

The standard milling analysis procedures used by the Grain Testing Laboratory of the IRRI Plant Breeding Department were used for milling quality evaluation. Exposed paddy sample of 125 g was hulled in a Satake Laboratory Huller (THU 35 A). The weight of brown rice sample was recorded before it was polished in a McGill Laboratory Polishing Mill No. 2 for a total time of one minute. The weight of total milled rice (mixture of brokens and head rice) was recorded.

The head rice and brokens were separated with a Satake Laboratory Rice Grader (TRG 05A) and the weight of brokens and head rice were separately recorded. The weight of head rice sample and the weight of total milled rice were used to determine the head rice recovery. The control sample of paddy which was not parboiled, was also milled in the same way as parboiled samples. Parboiling was evaluated by examining the degree of gelatinization of head rice under a microscope and by counting the number of grains with white bellies. Three replications were done for all the experiments.

Results and Discussion

A form of high frequency radio wave energy is called microwave energy which is produced in the magnetron tube attached in the oven. A stirrer fan attached at the top inside the oven and near to the magnetron tube, distributes the energy inside the oven (**Fig. 1**). Microwaves are either reflected by the metal walls, transmitted through the paper cooking container or absorbed by the food material placed into the oven.

Water plays an important role in cooking the foods with microwave oven. Microwave energy excites the food molecules internally and causes friction which creates the heat wave, hence, the food is cooked uniformly without disturbing its texture.

Paddy soaked in water was placed in oven in a glass cooking tray for varying exposure durations. The results are shown in **Fig. 2**. It is observed that moisture from paddy kernels are removed very fast during the first 30 seconds and then slowly declined with respect to time. The grain temperature is directly proportional to exposure time. Hence, the moisture from the paddy kernels was not removed with the same rate as the grain temperature was increasing. It appears that increasing thickness of grain layer decreased the moisture removal rate.

In general, microwave energy

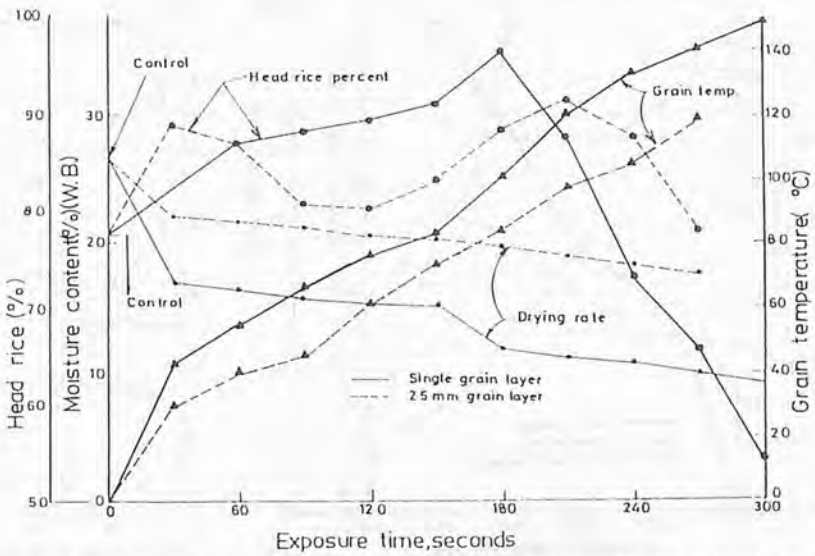


Fig. 2 Rate of water removed with respect to exposure time and increasing grain temperature when soaked paddy (in water for 24h) placed in microwave oven for parboiling. The head rice recovery is highest for single grain layer at 180 sec exposure time.

causes dipolar molecules to vibrate at very fast rate and the resulting kinetic energy creates an area of high vapour pressure (Anthony, 1983). On application of microwave energy, the high absorption characteristics of water in material cause thermal gradients to form at internal locations having high moisture concentrations (Wasley et al 1974). Due to these conditions, vapour pressure gradients inside the material is established and tends to move the moisture to area of lower vapour pressure. Thus, microwave heats throughout a product with consistent moisture level and dries it uniformly (Click and Baker, 1980 and Click and Mobley, 1982).

As shown in **Fig. 2**, the head rice recovery was highest when single layer of paddy was exposed with microwave energy in the oven for 180 seconds. With the same exposure time, however, the head rice yields were reduced when paddy layer thickness in the oven was increased (2.5 mm). Perhaps the required amount of heat to gelatinize the starch granules was not available when the thickness of paddy grains was increased and hence proper parboiling had not taken place.

A similar type of results (as shown in **Fig. 3**) were obtained when a single layer of freshly harvested paddy grains at high moisture level were placed in microwave oven for parboiling. In this case the head rice yields about 14% higher than the control sample and was 4% less than the water-soaked paddy samples. Similarly, the exposure time required to obtain the maximum head rice yields was obtained at 120 seconds in freshly harvested paddy as compared to 180 seconds in water-soaked paddy. There could be some biological factor which might be causing these differences between water-soaked and freshly-harvested paddy. Both paddy samples belong to the same variety. Also, there was a difference in initial MC between water-soaked **(Fig. 2)** and freshly-harvested paddy **(Fig. 3)** and probably in the later case, the MC was not sufficient to complete the gelatinization process.

The maximum 600 watts power available in the microwave oven could not provide sufficient heat for quick gelatinization of starch. This is similar to the accelerated parboiling of paddy using heated sand at 200°C in 10 seconds exposure time (Shukla and Khan 1984). Probably the low wattage in microwave oven needed to be compensated by a longer exposure time.

A separate experiment was conducted using a single layer of soaked paddy and placed close to the air-driven fan (about 80 mm away). The idea was to utilize maximum possible microwave ener-

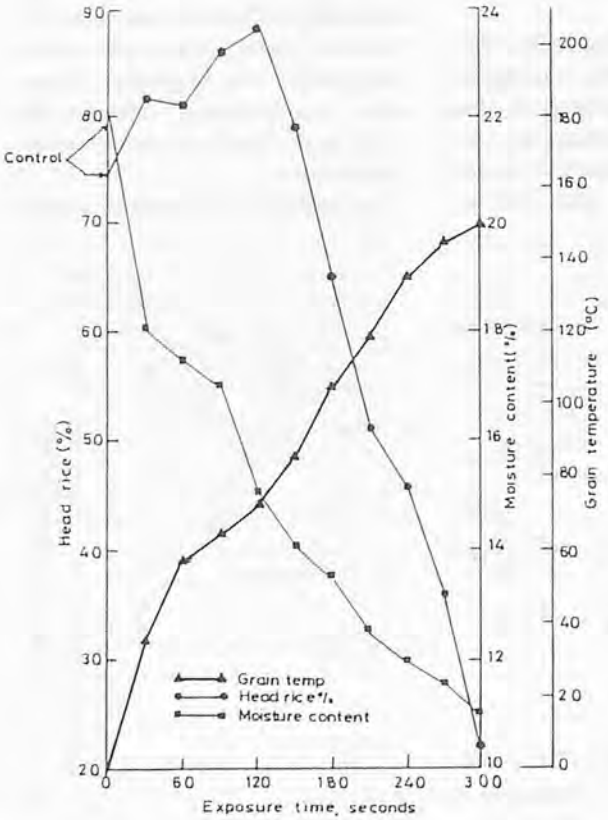


Fig. 3 Drying rate with respect to grain temperature and head rice yield when single layer of fresh harvested IR-36 paddy was placed in microwave oven for parboiling.

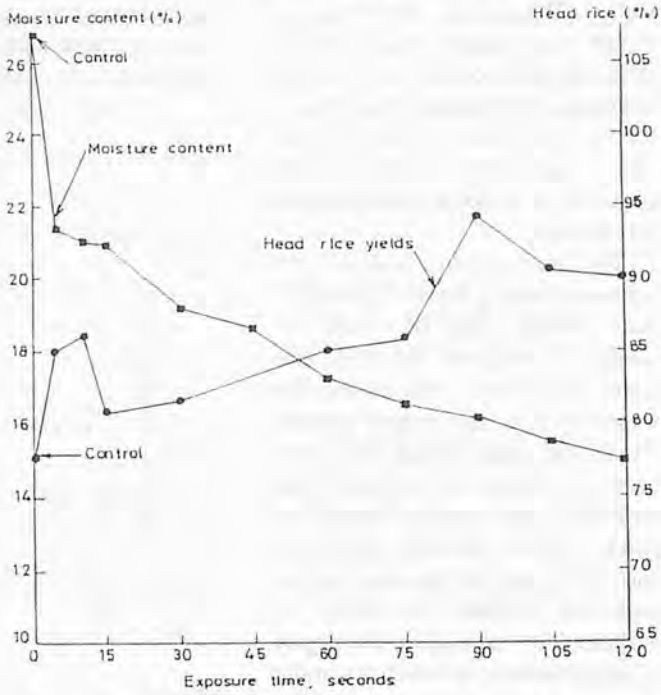


Fig. 4 Head rice yields and exposure time when single layer of water-soaked paddy was placed close to air driven fan. Drying rate is increased compared to Fig. 2.

gy by placing the paddy sample near the fan and see its effect on reducing the exposure time. The results are presented in **Fig. 4**. It appears that close to the fan, the temperature was higher (which was difficult to measure) and more heat was available to gelatinize the starch. Thus, the best head rice yield was obtained when the grain was exposed for 90 seconds, which is just half the time in the previous experiment (**Fig. 2**).

Similar type of results were also obtained when freshly-harvested, high moisture paddy in single layer thickness was placed close to the air driven fan. The results are shown in **Fig. 5** and are similar to those in **Fig. 4**. A higher head rice recovery from parboiled paddy was obtained in the sun dried, shade dried and non-parboiled paddy.

In another experiment, a single layer of soaked paddy was placed very close to the magnetron tube (about 50 mm away) after removing the air-driven fan. Hence, the paddy grains were directly in contact with microwave source in oven. The results are plotted in **Fig. 6**. The exposure time was markedly reduced (as 15 seconds in **Fig. 6**) compared to other previous experiments (180 seconds and 90 seconds in **Fig. 2** and **4**, respectively.) Also, head rice recovery increased (almost equal to that obtained in heated sand parboiling method by Shukla and Khan 1984). When the thickness of the paddy layer was increased (2.5 mm), the exposure time for maximum head rice recovery also increased (30 seconds) but the head rice yield were declined (**Fig. 7**).

Thus, it can be concluded that the exposure time can be reduced by increasing the power in the microwave oven and hence increase the temperature in short duration.

The absence of white bellies in rice kernels confirms a complete gelatinization of starch granules and thus the paddy was actually parboiled. There was no visual difference in the whiteness of milled rice vis-a-vis the parboiled paddy using microwave energy nor the control lot. Microwave-treated paddy samples after 24 hours tempering do not require further drying as they attained the moisture content of 12-14%, which is required for milling.

Microwave energy can be used to reduce the time required in parboiling process. The steps in commercial parboiling process can be minimized by combining the gelatinization of starch in paddy and drying operations simultaneously. A simple parboiling system can be developed which would require less space and reduce handling operations.

Conclusion

1. Microwave could be an economical source of energy for paddy parboiling as it requires less space, minimizes handling cost, reduces the steps of parboiling and yields better quality rice.
2. In microwave oven, an exposure time of 180 seconds was required to achieve maximum head rice yields. When the paddy samples were placed close to air-driven fan and magnetron tube in the oven, the exposure time of 90 and 15 seconds, respective-

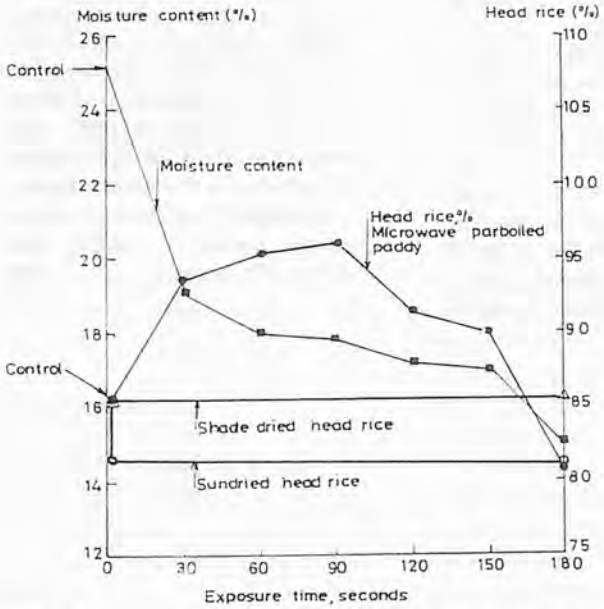


Fig. 5 Comparison of head rice yields of parboiled paddy with non-parboiled, sun-dried and shade-dried paddy. The paddy was freshly harvested at higher moisture content and placed in single layer close to air driven fan in microwave oven for parboiling.

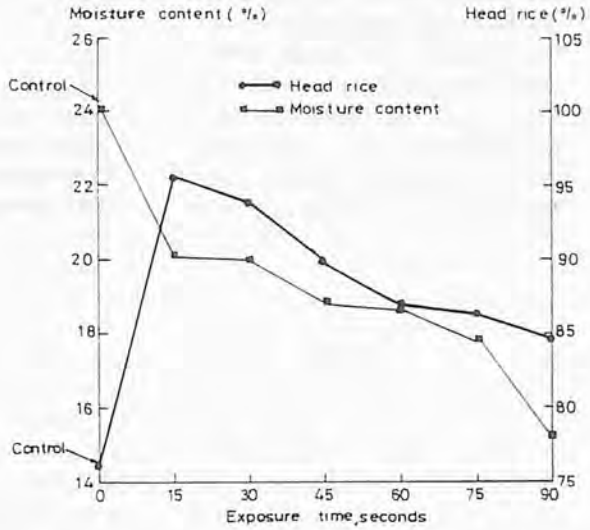


Fig. 6 Exposure time, moisture removal rate and head rice yields when single-layer water-soaked paddy was placed close to magnetron tube in microwave oven for parboiling.

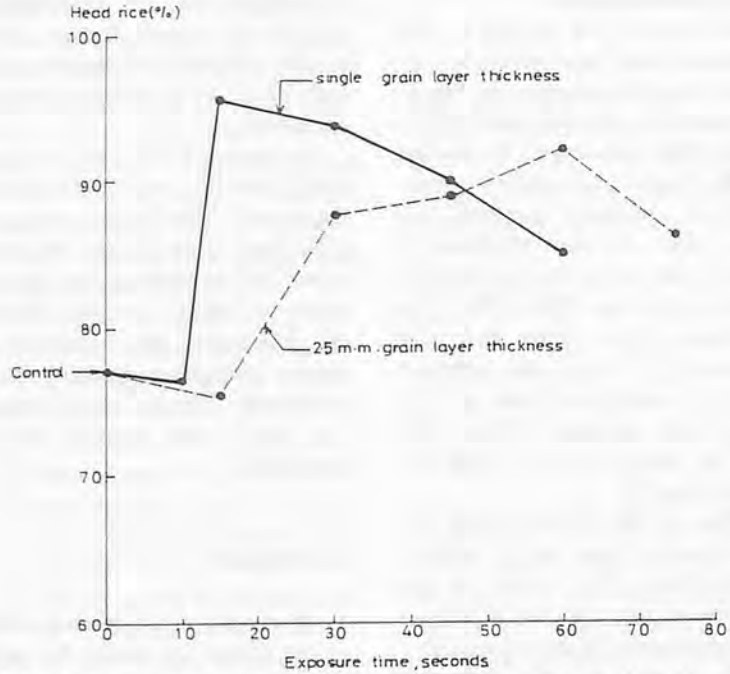


Fig. 7 Head rice recovery with respect to exposure time close to magnetron when single and 25 mm thick grain layers of paddy was placed for parboiling. The paddy was placed for parboiling. The paddy was soaked in water for 24 hours and had achieved the initial MC of 27%.

ly, were obtained to achieve maximum recovery of head rice.

3. The highest head rice recovery (96.5%) was obtained in 15 seconds exposure time close to the magnetron tube.
4. Microwave-treated paddy after 24 hours tempering period does not require further drying as it achieves the equilibrium moisture content of about 14%, which is required for milling.
5. There was no difference in whiteness between the parboiled rice using microwave energy and the control, unparboiled rice.

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Determination of Equilibrium Moisture Content for Two Varieties of Peanut

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Abstract

An experiment was conducted to determine the adsorption and desorption isotherms for two varieties of peanuts, namely; MH 383 and Barberton at four temperatures (20, 30, 37.8, 50°C). The effect of the relative himidity, temperature and variety on the variability of the equilibrium moisture content (EMC) was investigated. The results indicate that the relative humidity had a more pronounced effect on the variability of the EMC than temperature had. The variety was found to have little effect on the variability of the EMC. (0.0 – 0.5%). Also, a little hystersis effect ranging from 0.0 to 0.3% (d.b) was found to be associated with the two varieties. The EMC could not be determined at a relative humidity greater than 85% due to mould growth on the tested samples.

Introduction

Peanut (*Arachis hypogaea* L.) is one of the most important oil bearing seeds and is the second largest source of edible oil after soyabeans (Ishag, 1983).

In the Sudan peanut is grown under both rain and irrigation conditions in a total area of approximately 770 588 ha. Peanut fetches about 10% of the foreign currency earning of the Sudan.

In the last few years there was a marked deterioration in the quality of peanuts grown in the country. That was evidenced by the high incidence of aflatoxin contamination and the increased percentage of shrivelled and immature seeds (Ahmed, 1982).

The growth of mould on the peanut is the direct result of too much moisture for safe storage. To control the fungal attack on the peanuts it was recommended by Woodroof (1966) that the moisture content of the peanuts should be maintained below 8% (w.b.). However, in storage the moisture content is controlled by the circulation and the control of the relative humidity of the air. The moisture content at which the crop exists in equilibrium with its surrounding air conditions is defined as the EMC. Hence, determination of the EMC is of great importance because of its direct relationship with storage and drying problems.

The objectives of this study were to determine the desorption and adsorption isotherms of the EMC for two varieties of peanuts, and to study the effects of relative humidity, temperature and variety on the EMC.

Procedure

The two varieties of peanuts used in the experiment were obtained from the University Farm. They were washed to clean off the mud, sun-dried for two weeks and were then wrapped with aluminum foil. The wrapped peanuts were placed inside plastic bags to maintain their moisture content.

Representative samples of 200.05 and 200.02 g of MH 383 and Barberton varieties, respectively, were taken from the variety lot using the Boenrner sampler. The method used for determining the moisture content of the representative samples was as described by the ASAE (1983). A sample of 200 g was shelled and the shells and kennels were kept separately. Both shells and kernels were oven-dried at 130°C for 6 h. From the individual moisture content of the two portions (shells and kernels) the moisture content of the entire lot of pods was determined. The moisture contents of the representative samples were 3.7% and 3.9% (d.b.) for MH 383 and Barberton varieties, respectively.

The static method was used for the determination of the EMC. Saturated salt solutions of the salts shown in **Table 1** were used to control the relative humidity in the desiccators. The amounts of salts re-

Table 1 Relative Humidity as Controlled by the Indicated Salts

Isotherms °C	LiCl	$K_2CH_3O_2$	$MgCl_2.6H_2O$	K_2CO_3	$Mg(NO_3)\ 2.6H_2O$	$NaNO_2$	NaCl	$(NH_4)_2SO_4$	K_2SO_4	NH_4HPO	KNO_3
20	11.2	23.2	33.6	43.9	54.9	65.3	75.5	80.6	97.2	–	–
30	11.2	22.0	32.8	43.6	52.0	63.3	75.6	80.0	96.6	–	–
37.8	11.2	20.4	32.2	43.4	–	61.8	75.1	–	–	91.1	–
50	11.2	–	31.4	–	46.3	–	74.7	–	95.8	–	85.0

quired to make the saturated solutions at a particular temperature were determined by making use of the data given by Lange (1966) for guidance.

Determination of Adsorption EMC

The peanuts to undergo adsorption test were dried to low moisture content of 2% (w.b.). The pods were placed inside an oven at a temperature of 40°C. Weight readings were taken at an interval of 24 h. It took 4 to 5 days for the various samples of the two varieties to dry to 2% (w.b.). The dried samples were wrapped with aluminum foil and were then placed in plastic bags.

Samples consisting of 30 and 33 pods were taken from the dried lots of MH 383 and Barberton peanut varieties, respectively, for determining the EMC. The sample was put on a petri dish which was then placed on the perforated plate of the desiccator which contained the salt solution. The weight readings of the samples were taken at an interval of 24 h. Whenever the sample reached a constant weight or at least there was a difference of ±0.01 g between two successive readings, it was then taken out of the desiccator to determine its EMC. The method described by the ASAE (1983) was followed in determining the moisture content of the equilibrated samples. Mould growth was observed on samples tested in the desiccators containing salts with relative humidity above 85%.

Determination of Desorption EMC

In order to avoid moulding in the high moisture sample and to hasten the equilibrium process the peanut was conditioned to 4 moisture levels. The 4 moisture levels were determined by making use of the plot of the obtained adsorption data of each variety. The plot was divided into 4 sections by drawing 3 horizontal lines (**Figs. 1** and 2). The two plots were drawn by eye ball method. The moisture levels were 7, 10, 13 and 19% (w.b.) for MH 383 variety whereas the only difference for Barberton variety was in the higest level which was 20% (w.b.). Four desiccators containing saturated salt solutions of potassium sulphate (K_2SO_4) were used. Each desiccator was used for conditioning the samples to 1 moisture level. The desiccators were placed inside an incubator at a temperature of 5°C. The low temperature was intended to safeguard against mould growth on the conditioned samples. The relative humidity controlled by the salt was measured to be 98.5%. The weight readings of the samples were taken at intervals of 24 h. The readings for the samples with 7% moisture content were taken at an interval of 2 h.

The conditioned sample was im-

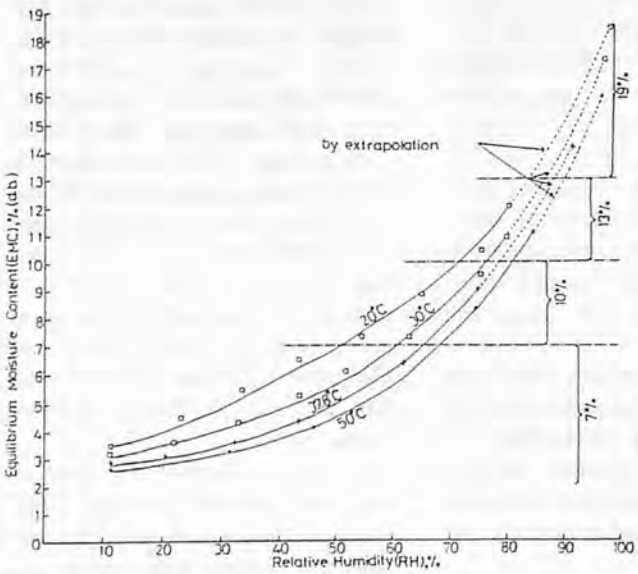

Fig. 1 Sectionalized adsorption isotherms plot showing four moisture content levels required for desorption equilibium, MH383 variety.

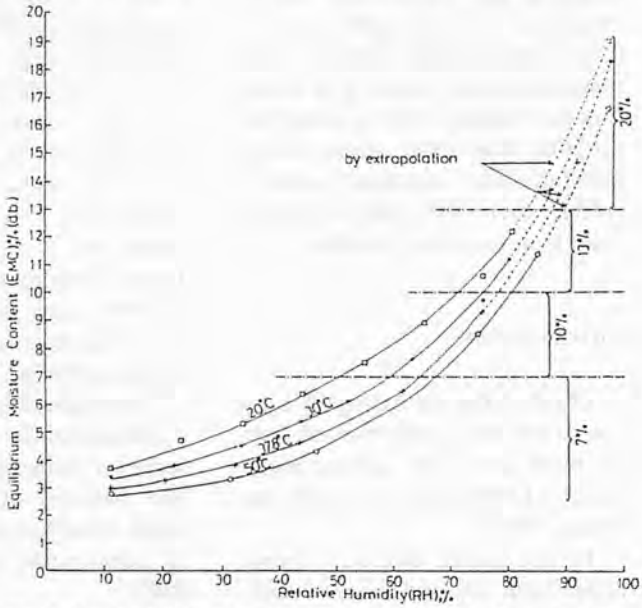

Fig. 2 Sectionalized adsorption isotherms plot shwoing four moisture content levels required for desorption equilibrium, Barberton variety.

mediately used for the desorption EMC determination. The weight readings of the sample were taken at intervals of 24 h. Also, whenever a sample reached a constant weight or at least there was a difference of ±0.01 g between two successive reading it was then taken out of the desiccator for determining its EMC.

Mould growth was observed on the samples tested in desiccators containing salts with a RH above 85%.

Results and Discussion

The collected data of the 4 isotherms (20, 30, 37.8, 50°C) for adsorption or desorption equilibrium are presented on a plot for each variety. The effect of each of the relative humidity and the temperature was analyzed using regression analysis.

Effect of Relative Humidity

Figs. 3 to 6 show the experimental data for the adsorption and desorption equilibria for the 2 varieties. It is clear from the shape of the fitted curves that there is a positive exponential relationship between the EMC and the relative humidity (RH).

Regressing EMC data on RH for each isotherm, it was found that the following form of equation gives the best fit with coefficients of determination ranging between 0.9625 to 0.9971.

$$EMC = A\ e^{\alpha RH}$$

Where A and α are constants given in Figs. 3 to 6.

In an effort to obtain a general relation for EMC versus RH, the EMC was regressed on RH data for adsorption and desorption. The best fit equations were found to satisfy the form:

$$EMC = b + c\ RH$$

Where b and c are constants whose values are shown in Table 2. Those equations are valid for a relative humidity range of 11.2% to 85% and a temperature range of 10 to 50°C. The relative humidity is expressed in decimal and the EMC is in percentage. The regression coefficients of those equations show that the EMC is expected to increase by 0.111 to 0.113% where the RH in-

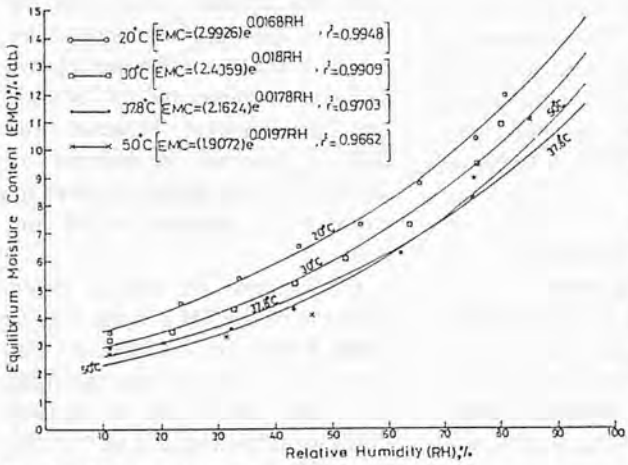

Fig. 3 Adsorption isotherms, MH383 variety.

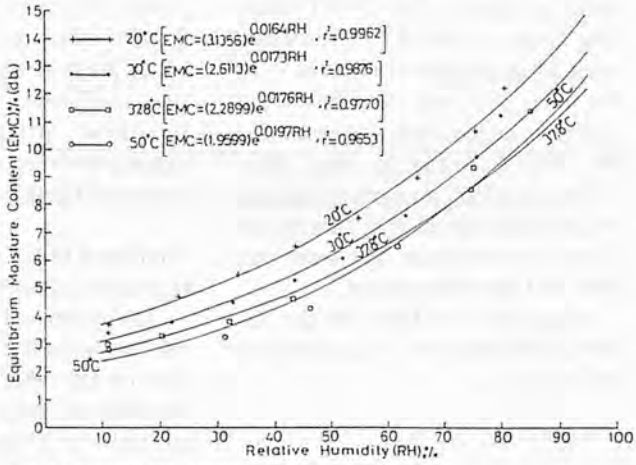

Fig. 4 Adsorption isotherms, Barberton variety.

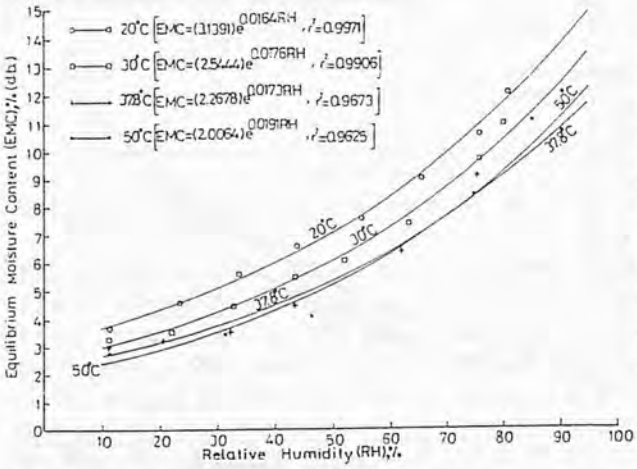

Fig. 5 Desorption isotherms, MH383 variety.

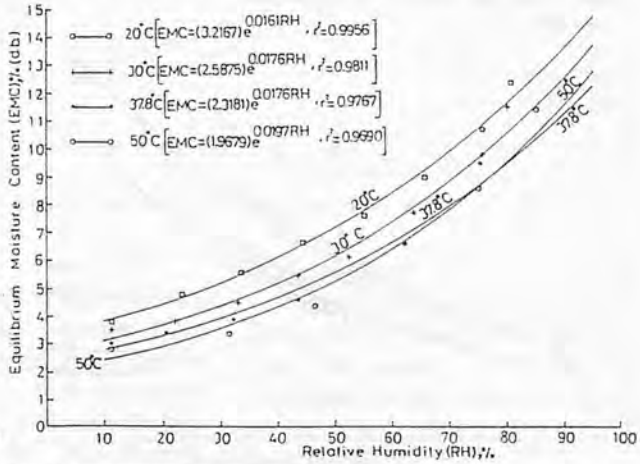

Fig. 6 Desorption isotherms, Barberton variety.

Table 2 Regression Coefficients and Coefficients of Determination

Effect of	Variety	Ads/Des.	b / b / b''	c' / c' / c''	d	r^2
Relative humidity	MH 383	Adsorption	1.020	11.064	–	0.881
	MH 383	Desorption	1.168	11.032	–	0.878
	Barberton	Adsorption	1.147	11.181	–	0.883
	Barberton	Desorption	1.181	11.305	–	0.882
Temperature	MH 383	Adsorption	24.484	0.060	–	0.050
	MH 383	Desorption	25.579	0.063	–	0.055
	Barberton	Adsorption	24.46	0.059	–	0.047
	Barberton	Desorption	25.091	0.061	–	0.049
Relative humidity and Temperature	MH 383	Adsorption	17.913	11.019	0.055	0.923
	MH 383	Desorption	19.029	10.985	0.058	0.925
	Barberton	Adsorption	17.789	11.135	0.054	0.923
	Barberton	Desorption	18.376	11.260	0.056	0.923

creases by 1%.

Effect of Temperature

Figs. 3 to 6 show that the isotherms of high temperatures lie below those of low ones. However, the 37.8°C and 50°C isotherms intersected in the 4 plots. These intersections may be attributed to the high standard errors of estimation of the 50°C isotherms as compared to those of the 37.8°C ones. The errors for the 50°C isotherms, were of magnitude 0.131 and 0.12 for MH 383 and the Barberton varieties respectively; whereas for the 37.8°C isotherms they were 0.074 to 0.085, respectively. It can be generally stated that there is an inverse relationship between the EMC and the temperature.

Regressing the EMC on the absolute temperature, equations of the form:

$$EMC = b' - c' \; T_{abs},$$

were obtained, where Tabs is the absolute temperature in Kelvin. Table 2 shows the values of the b and c constants. The regression coefficients indicate that the EMC is expected to decrease by 0.059 to 0.063% when the Tabs increases by 1°. It must be mentioned here that the coefficients of determination for these fittings are very low, ranging between 0.047 to 0.056 as shown in Table 2.

Table 3 Coefficients of Partial Determination

Function	RH/Temp	MH 383	Barberton
Absorption	Relative humidity	0.9194	0.9188
	Temperature	0.3545	0.341
Desorption	Relative humidity	0.9207	0.9193
	Temperature	0.3861	0.3522

Combined Effect of Relative Humidity and Temperature

The combined effect of both the relative humidity and the temperature on the EMC was investigated. Regressional analyses were conducted and the following model was found most satisfactory:

$$EMC = b'' + c'' \; RH - d \; T_{abs}$$

The values of the constants b'', c'' and d are shown in Table 2. The regression equations show that the EMC is expected to increase by 0.110 to 0.113% when the relative humidity increases by 1%, holding the Tabs constant. However, the EMC is expected to decrease by 0.054 to 0.58% when the Tabs increases by 1°, holding the RH constant.

Coefficients of partial determination of the RH and the Tabs in Table 3 show for the MH 383 that adding RH to the model containing Tabs, the error sum of squares (SSE) would be reduced by 91.94%. Correspondingly, when the Tabs is added to the model containing the

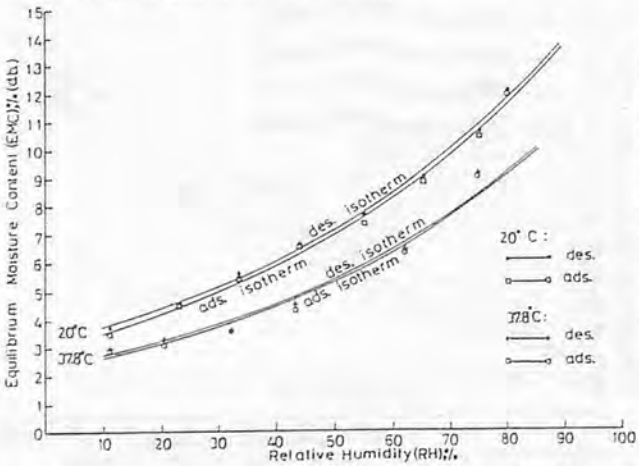

Fig. 7 Hysteresis effect, MH383 variety (20° and 37.8°C isotherms).

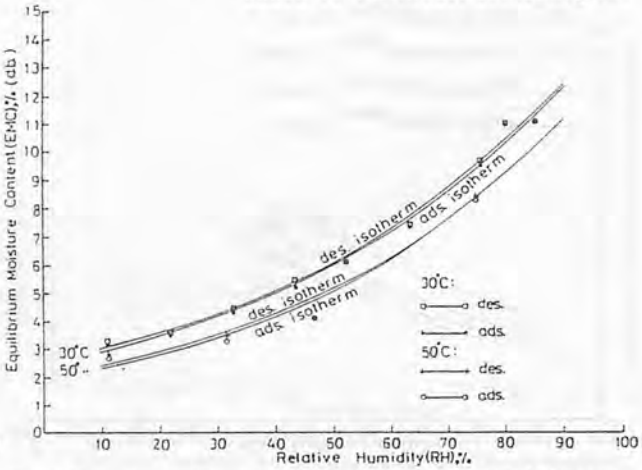

Fig. 8 Hysteresis effect, MH383 variety (30° and 50°C isotherms).

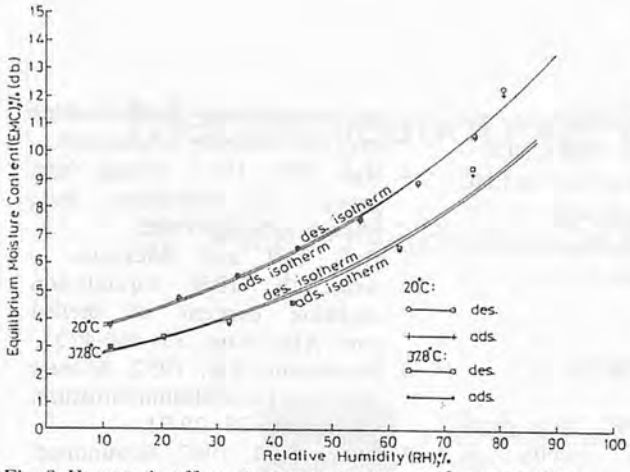

Fig. 9 Hysteresis effect, Barberton variety (20° and 37.8°C isotherms).

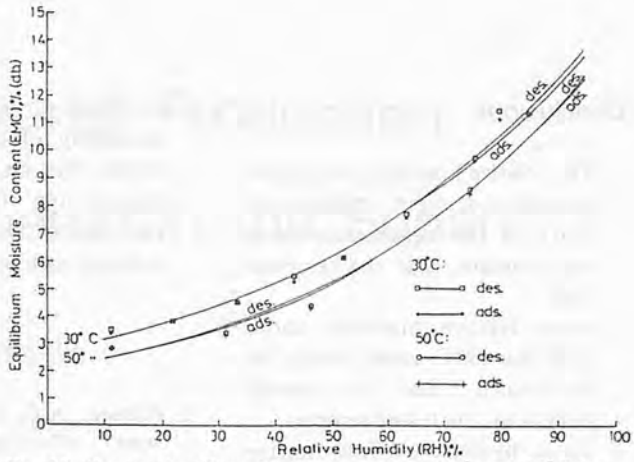

Fig. 10 Hysteresis effect, Barberton variety (30° and 50°C isotherms).

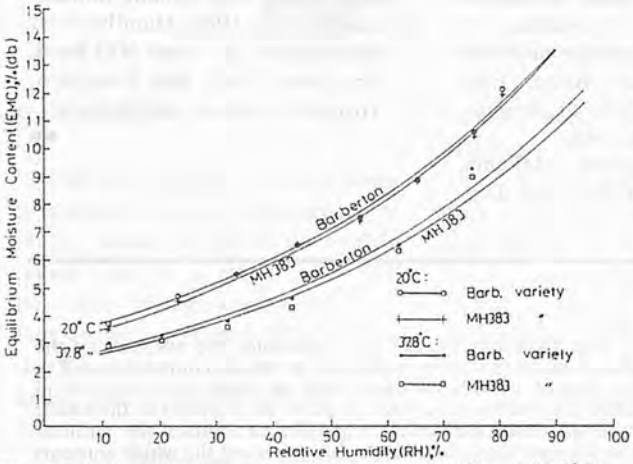

Fig. 11 Variety effect – adsorption isotherms (20° and 37.8°C).

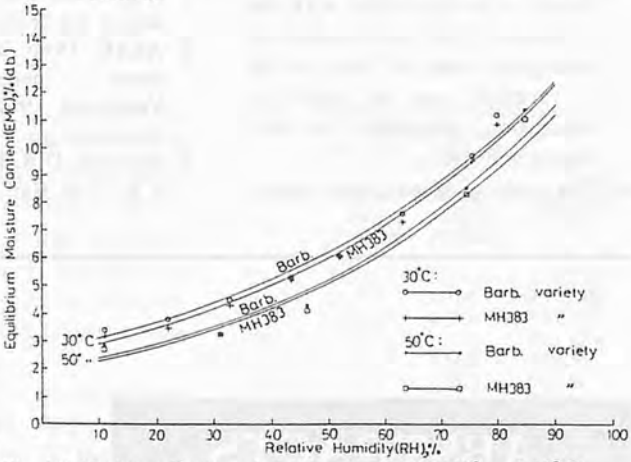

Fig. 12 Variety effect – adsorption isotherms (30° and 50°C).

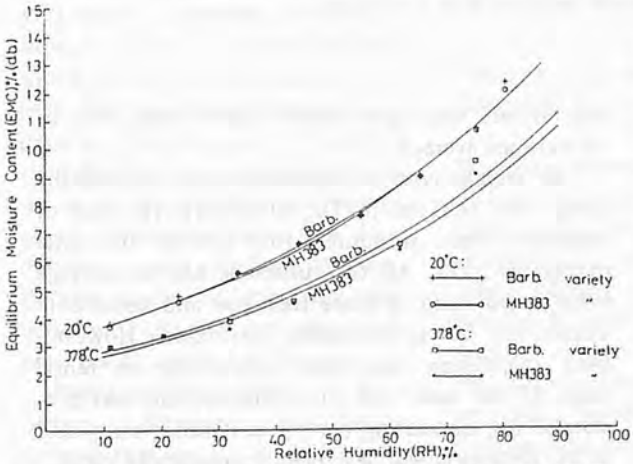

Fig. 13 Variety effect – desorption isotherms (20° and 37.8°C).

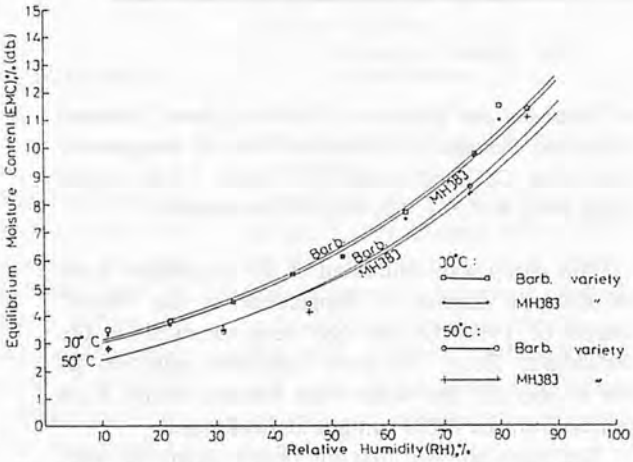

Fig. 14 Variety effect – desorption isotherms (30° and 50°C).

RH, the SSE would be reduced by 35.45%. Similar results could be drawn from Table 3 for the Barberton variety. It is, therefore, concluded that the RH has a more pronounced effect on the variability of the EMC of both varieties than the temperature has.

Hysteresis Effect

Figs. 7 to 10 show the hysteresis effect of the two varieties. It is obvious that a small hysteresis in the range of 0.0 to 0.3% (d.b.) was found to be associated with the two varieties under the experimental conditions used.

Variety Effect

Figs. 11 to 14 show the variety effect of both varieties. It is clear that the variety effect on the variability of the EMC was found to be minor ranging between 0.0 to 0.5% (d.b.).

Conclusions

1. The relative humidity has a more pronounced effect on the variability of the equilibrium moisture content than the temperature.
2. At a relative humidity above 85% the EMC could hardly be determined due to mould growth on the tested samples.
3. Little hysteresis effect ranging from 0.0 to 0.3% (d.b.) was found to be associated with the 2 varieties. This means that the adsorption data of each of the 2 varieties can be used for desorption purposes without significant errors.
4. The variety of peanut is found to have little effect on the variability of the EMC, (0.0 – 0.5%). This means that the EMC data of one of the tested varieties can be used for the other without significant errors.

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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.

A Technical and Economic Profile of Deep Tubewell Irrigation Systems in a Selected Area of Bangladesh:
K.A. Haq, CSO and Head; M.N. Islam, P.S.O., Agric. Engg. Div., B.R.R.I., Joydebpur, Bangladesh.

This study was conducted in the Joydebpur Zone of Gazipur district in Bangladesh in the "Boro" season of 1984. Of the 186 deep tubewells in the Joydebpur Zone, 10 were randomly selected for the study. All the wells were located within 8 km radius from the BRRI campus at Joydebpur.

The study showed that the output from the wells were extremely low with 80% of the wells producing approximately 60% of the designed discharge. Based on actual discharge, 60% of the wells were irrigating well above their designed capacity; in other cases the wells were running at low level of efficiency (in terms of area irrigated) due to the low discharge efficiency and operating hours.

Most of the farmers adopted the modern varieties and the input use was at the recommended level in most of the systems. The average yield obtained by the farmers was significantly higher than that of the national average.

The average cost of production was Tk. 9826/ha (range Tk. 8632/ha to Tk. 10764/ha). The cost of irrigation alone accounted for, 22% of the total production cost. All the tubewells had an average benefit cost ratio of more than one and hence considered to be economically profitable. However, their calculation was made absolutely on rental basis. If the total cost (including capital) was considered for calculating benefit cost ratio, only 60% of the systems would have been economically viable.

The wells which were operated through farmers' organizations, on the average, irrigated 70% more area than those having no organization. There was a significant difference in input use, productivity and water utilization between the well operated with and without it. Thus the study indicated that an effective farmers' organization is essential for successful operation of the tubewell irrigation systems.

(Continued on page 64)

Mechanization of Kenaf Production at Abu Naama Scheme in the Sudan

by
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Introduction

The Abu Naama Kenaf Scheme is situated in the central clay plains of the Sudan. It lies in the central region and is irrigated from the Blue Nile through a network of surface irrigation system. The area of the scheme is 12 600 ha planted to kenaf and groundnut (each 6 300 ha).

Kenaf, *Hibiscuss cannabinus* L., is successfully grown in tropical and subtropical conditions. It tends to flower as soon as daylight becomes shorter than 12 hours and 30 minutes. The strategy of planting is to permit 135-150 days of growing time before short day conditions set in. In the northern hemisphere along 23°N, planting is best done between mid-April and mid-May. Harvesting can be done any time between 120 and 145 days with best quality at the early harvest.

Research conducted by the Agricultural Research Corporation showed that kenaf can successfully be grown in Abu Naama area.

The scheme has been facing a lot of problems since the first productive season. The area alloted to kenaf production (6 300 ha) is not fully utilized (**Table 1**) and groundnut was produced in a limited area (800 ha) in the first season only.

One of the problems facing the scheme is the shortage of hand labour. Kenaf and groundnut are produced at the same period of time. The harvesting of both kenaf and groundnut coincides with the harvesting of other crops produced in the area (sorghum, sesame, etc). There is, in fact, a severe competition for the limited labour available at harvest time.

The management of the scheme decided from the beginning to mechanize as much of the operations, for the two crops, as possible.

Table 1 Planted and Harvested Areas and Yield (Abu Naama Scheme), 1975/76 to 1985/86

Season	Planted area Feddan	Harvested area Feddan	Total yield (tons)
75/76	8 185	2 360	455.744
76/77	8 189	3 300	994.506
77/78	8 000	4 000	747.197
78/79	5 493	3 475	927.954
79/80	3 954	1 603	538.46
80/81	3 115	2 603	500.00
81/82	893.5	519	300.00
82/83	785	–	–
83/84	–	–	–
84/85	2 080	1 193.5	350.00
85/86	1 105	–	22.104

1 Feddan = 0.42 ha.

Source: Abu Naama Scheme – Agricultural Section.

Factors Affecting Success of Mechanization

Machinery Selection

Most kinds of farm machinery in common use are made by variety of manufactures. Therefore, in some cases, several machines may be equally suitable for a certain job while in other cases just the slightest difference may be of great importance. Again, similar machines may be quite suitable in one part of the country but not in another part. Therefore, it is advisable to give much thought to the selection of farm machinery to purchase. As a general rule, it is advisable to standardize as much as possible and the fewer different makes of machines there are, consistent with the work to be done, the better. The main point is that the machinery must be suitable for the job it has to perform.

Table 2 shows the types and numbers of machinery selected for the Abu Naama Scheme. It reveals that different makes were selected and the scheme management has to deal with different manufacturers and agents as far as the spare parts, training and maintenance are concerned.

Scheduling of Operations

A system of scheduling field operations must be established taking into account the type of crops to be grown, area for each crop, type of operations and cultural practices required for the crop, date and period of each operation, and expected output from each ma-

Table 2 Inventory of Agricultural Tractors and Machinery

Item	Total purchased	No. operable	No. need repair	Make
Tractors	159	52	107	Stayer 1760
Tractors	8	6	2	MF 185
Disc harrow	24	12	12	Napier
Disc plough	18	12	6	Napier
Chisel plough	4	2	2	– two different makes
Rotogard (harvester)	55	10	45	(Italian makes) Rotogard
Decorticator	135	32	104	(Italian make) Ruggerimi
Groundnut digger	20	19	1	Benthall
Seed drill	20	–	20	NORD ESTPR
Bale press	8	1	7	–
Trailers	63	16	47	(Polland)
Trailers	3	–	–	MF
Ridger	10	7	3	DANISH make

Source: Abu Naama Scheme, Agricultural Section.

Table 3 Mechanized Operation Work Programme

Operation	Period	Effective work days	Average output/ day	No. required
Kenaf 1 500 feddans				
Disc harrow	1.2 – 15.4	55	20	14
Levelling (8 000)	10.2 – 21.4	55	20	7
Ridging (7 000)	5.4 – 15.5	40	30	6
Planting & fertilizer	1.5 – 10.6	40	40	10
Herbicide application	2.5 – 11.6	40	80	5
Cross ridging	3.5 – 12.6	40	150	3
Mech. cutting	1.11 – 15.2	45	10	34
Ribboning	2.11 – 20.12	48	10	32
Groundnut 1 500 feddans				
Kenaf stalk disposal	1.1 – 15.2	45	30	11
Disc harrowing	15.3 – 15.5	50	20	15
Ridging	15.5 – 15.5	30	30	17
Planting	15.5 – 30.6	40	25	15
Herbicide application	15.5 – 30.6	40	80	5
Cross ridging	15.5 – 30.6	40	150	3
Digging	1.11 – 15.12	45	20	17
Stripping	5.11 – 20.12	45	20	17

1 Feddan = 0.42 ha.

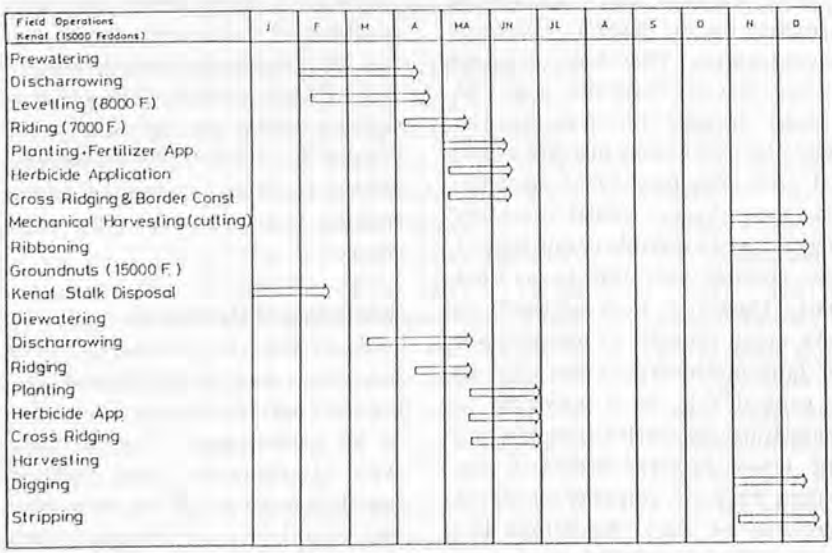

Fig. 1 Work programme: Mechanized field operations programme.

chine based on previous machinery records in the area or in areas of similar conditions. Based on this system the number and specifications of tractors and machinery required can be determined.

Table 3, and **Figs. 1** and **2** show the scheduling of the agricultural mechanized operations, and the number and distribution of machinery requirement based on utilization of the maximum area for both kenaf and groundnut (6 300 ha for each). **Figure 3** indicates the bi-monthly number of machinery required based on production of kenaf alone in an area of 6 300 ha. **Table 4** is a comparison of actual machinery available and the number required for both kenaf and groundnut production in two rotations and kenaf alone. In both histograms the peak usage of power is during the harvest period. Between 90 and 55 tractors are required for kenaf plus groundnut and kenaf alone, respectively.

Tractor Size

There is no general answer to the question of tractor size. For every individual case a decision has to be made separately. The minimum tractor size will be determined according to the operation for which the highest power requirement is needed. Tractor selection should be based on other factors such as previous experience and performance under similar conditions and availability of spares and support service. In most instances the tractor needed has to be an "all-purpose machine" which can do almost any kind of farm work, including ploughing, cultivation, sowing, harvesting, transport and p.t.o. work.

Staff Requirement

The key to success for any machinery use is competent people to carry out the tasks planned. In selecting staff members it should be remembered that the main purpose

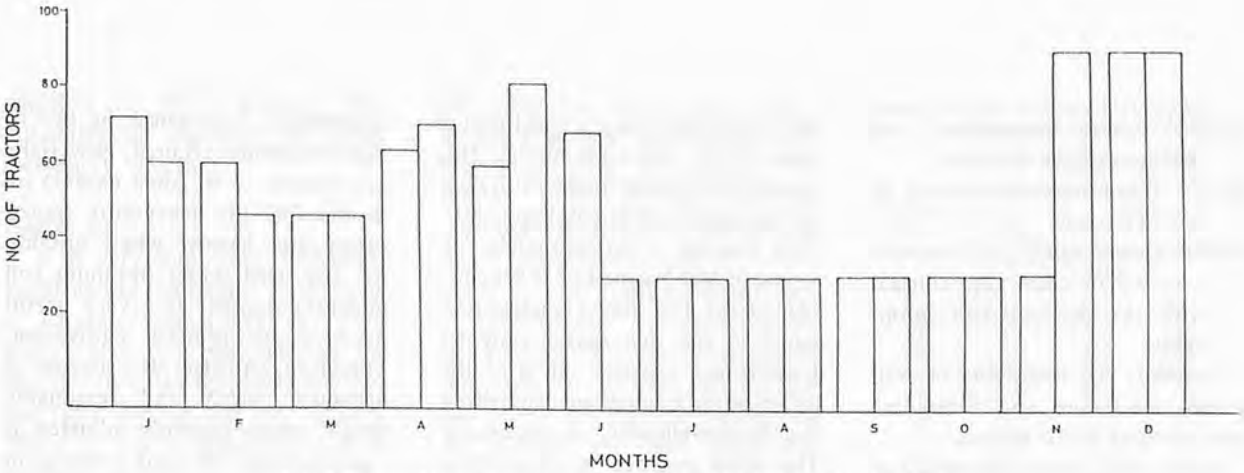

Fig. 2 Bi-monthly tractor requirements (Kenaf 15 000 F, GN 15 000 F).

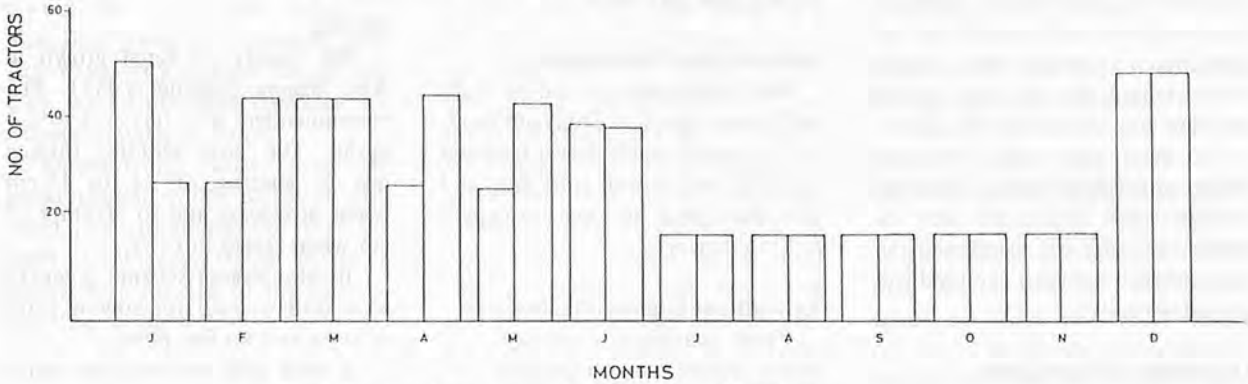

Fig. 3 Bi-monthly tractor requirements (Kenaf 15 000 F).

Table 4 Requirements and Availability of Tractors and Agricultural Machinery for Kenaf + Groundnut vs Kenaf alone

Type of machine	No. Available	Requirement Kenaf + GN	Requirement Kenaf alone	Difference
Wheel-tractor	167	90	56	+ 77, + 101
Disc harrow	24	29	14	– 5, + 10
Levellers	–	7	7	– 7
Ridger	10	23	6	– 13, + 4
Row planter	10	15	–	– 5, + 10
Seed drill	20	10	10	+ 10
Tractor-mounted sprayer	–	5	5	– 5
Disc plough	18	6	3	+ 13, + 15
Kenaf harvester	55	34	34	+ 21
Ribboning machine	135	132	132	+ 103
GN digger-shaker	20	17	–	+ 3
GN combine harvester	–	17	11	– 17
Chiesel plough	8	11	11	– 3
Trailors	66	20	20	+ 46
Abu IV ditcher	6	6	3	+ 3

is the performance of field work and that the quality of this work should always be kept at a high level. The responsibility for meeting this objective is in the hands of the chief agricultural engineer or the machinery manager. He must be a good organizer and should possess the relevant knowledge for machinery and also have a good knowledge of agriculture.

In order for the machinery manager to carry out his duty efficiently he must be supported by field supervisors, operator, mechanics and store keepers of good caliber and well trained.

Training in Machinery Operation

As mechanization develops there will be a growing demand for more and more skilled operators and mechanics capable of keeping pace with new and more intricate kinds of machinery as they are introduced. It is important to stress that adequate training in the operation, repair and maintenance of farm machinery is a fundamental requisite for the successful introduction of mechanization. In the case of Abu Naama Kenaf Scheme, harvesting and processing machinery are new machines, introduced in Sudan for the first time. Therefore, training of operators and mechanics is very crucial. This was not given much attention and reflected badly in machinery performance.

Repair and Maintenance Services

The objective of maintenance can be summarized as follows:

i) To extend the useful life of the machine.

ii) To ensure availability and readiness of the machine.
iii) To obtain maximum return on the investment.
iv) To ensure safety of personnel who use or come into contact with the machine and equipment.

Certainly the availability of well-trained mechanics and fitters are very essential in this respect.

In the Abu Naama Scheme and in most of the agricultural schemes in Sudan the maintenance, especially preventive maintenance, is not given much attention which results in shortening the life time of the machine and increase in the quantity of spare parts used. On-work repair and maintenance facilities (mobile work shops) are very essential due to rough roads and the long distance between the field and central workshop.

Availability of Spare Parts

The supply of spare parts is a constant source of delay and expenditure. It may happen that the machinery can be supplied in the first instance under an aid or loan agreement and spare parts are ordered under the same contract. But, spare parts are the responsibility of the scheme management. Spare parts involve the use of valuable foreign exchange and, therefore, it is likely to be restricted. Due to restriction in use of foreign exchange, stock levels of spare parts are far lower than desirable for efficient maintenance of the existing machinery and equipment and the cost of spares when available may be four or five times than their cost in the producer country.

The unavailability of spare parts encourages the practice of "canibalization" wherein a tractor (having been laid up awaiting a part) has another part removed from it to replace a faulty component on another tractor. This renders the first tractor less useful as it is now awaiting two parts, with the result that soon a third part is removed for the same reason. This process will finally make future use of the machine virtually impossible. This practice is unfortunately followed in Abu Naama Kenaf Scheme. Out of the 159 Steyer tractors procured in the first season only 52 tractors are operable. Most of the out-of-work tractors are canibalized due to unavailability of spare parts. The same practice is observed in other machines (harvesters, decorticators, disk harrows, etc).

Infrastructure Development

Well maintained secondary roads and access roads to fields are needed to ensure timely travel between the field and central workshop and to reduce wear and tear on expensive machinery.

Agricultural Engineering Research

Farm machinery research is a major component, especially for Sudan with its vast potential areas for agricultural production and scarcity of labour. This is exceptionally essential for a few newly-introduced crops which require new technology of mechanization. Mechanization is very crucial for kenaf when it is grown on large plantations. The selection of the appropriate machinery needs extensive research. Kenaf production in Abu Naama Scheme has a lot of problems which need extensive research to solve them. One of these problems is mechanization of harvesting. A lot of unsuitable tractors and machinery are imported and the country is paying very high price from much needed foreign reserves.

Mechanized Operations

Land Preparation

Soil tillage is defined as any form of soil movement which occurs during the crop production process. Soil tillage is divided into primary cultivation and secondary cultivation. Experience in the irrigated schemes (Rahad, New Halfa and Gezira – to some extent) indicates that the heavy-duty trailed offset disc harrow when suitably set and used under optimum soil moisture content is a very useful machine for primary cultivation. Therefore, an offset disc harrow of optimum width and reasonable weight when carefully adjusted is a good choice for land preparation in Abu Naama Kenaf Scheme.

Sowing

The variety of kenaf grown in Abu Naama Scheme is G51. The recommended seed rate is 3 to 3.5 kg/ha. The crop requires thining out to spacing of 15 to 18 cm when broadcast and to 30 cm x 12 cm when raised in rows.

In Abu Naama Scheme, a general seed drill is used for sowing both in rows and on flat plots.

A seed drill controls the width of the row spacing and the depth of planting but has no definite control of spacing in the row. It was observed that the seeds were unevenly broadcast in the field which resulted in cluster of plants in one area whereas wide spacing between plants in other areas. This resulted in thick plants (2.3 cm dia.) in wider spacing and very thin plants (0.9 cm dia.) in areas where spacing was very narrow.

The widespread use of fertilizer broadcasting machines, which can sow seeds, made it less essential to have special-purpose seed broadcasting machines. Nevertheless, there is still a useful place for various kinds of full-width broadcasting machines most of which have a brush feed. Kenaf in Abu Naama is sown on flat plots but in the regular season (86/87) a small area was planted on 80 cm apart ridges where the recommendation was 30 cm between ridges. The reason was that the only ridging machine available (lister type) was of rigid wings which can only be

adjusted to 80 cm spacing. This illustrates an example of wrong machinery selection.

Harvesting

It is very important to harvest kenaf at the right time. If the crop is harvested too early the fibre yield will be low. By delaying the harvest the yield will be higher but the fibre quality will be reduced. There is lack of agreement among workers as to the best time for harvesting kenaf. It has been reported that with one variety a high fibre yield was obtained after 129 days growth even though the crop would not have flowered for another month or longer.

Experiments carried out on kenaf ribbons which had been sun-dried and stored showed that the most important factor affecting retting was the age of the plant at the time of harvest.

Methods of Harvesting

Since most of the world's kenaf and jute is produced on small holdings, it is harvested by hand. In India and Bangladesh jute is harvested using a sharp sickle-type knife to cut the stems as close as possible to the soil surface.

In Thailand many farmers find it easier to cut the kenaf stems 10 or over 20 cm above the soil surface. However, since the lower 20 cm or so of the stem contain much more fibre than the rest of the stem, high cutting substantially reduces the fibre yield.

It is estimated that 16 worker-days are required to harvest one hectare of jute or kenaf. However, when kenaf or jute is grown on large plantations mechanized harvesting may be practicable.

Kenaf can be harvested with a reaper binder but in many countries these machines have been replaced by combine harvester. The crop can also be cut with a mower equipped with side-delivery attachment such as a reaper. The problem of the ordinary mower is that the plants fall to the ground in an overlapping manner which make the collection a difficult job.

The Gardella Rotogard harvesting machine cuts the plants simultaneously at the base and the top and places the stems in bundles on the ground for hand collection. This machine consists of two discs and two flail knives attached to each disc. The discs rotate at a very high speed (3500 rpm). It is operated from the tractor p.t.o. shaft, has a cutting width of 1.2 m and a working speed up to 7 km/h. The average harvesting capacity is reported to be 0.5 ha/h. A machine has been developed in the USSR for use on green kenaf stems that harvests, separates the fibre and spreads it on the ground to dry. However, it appears that more development work is needed before the machine can be widely used.

In Abu Naama Scheme the Gardella Rotogard harvesting machine is used. The field efficiency of the machine is very low (16%) due to continuous stoppage due to breakdown and failure of parts. The output per day was reported to be 1.2 ha. Out of 53 machines only 5 machines are in operable conditions. Hand harvesting is practiced with swords. On observation runs the height of kenaf stems left on the ground in hand cutting and machine harvesting were compared (**Table 5**). The height of stems left in case of machine harvesting was longer than in case of hand cutting.

Between 20 and 30 workers are required to harvest (cut) one hectare of kenaf plants. Due to shortage of labour and severe competition for labour at harvest time, harvesting of kenaf in Abu Naama Scheme has to be mechanized. The problems of mechanization in this area has to be solved through intensive research.

Table 5 Height of Stems Left in Field after Harvest (Hand vs Machine)

Sample no.	Height (cm)		
	Hand (on flat plot)	Machine	
		on flat plot	on ridges
(1)	10	31	26
(2)	5.5	27	23
(3)	11.0	24.5	26
(4)	13.0	20.5	28
(5)	16.0	23.0	30
(6)	8.5	20.5	29
(7)	7.5	22.5	31
(8)	12.5	23.0	22
(9)	14.5	28.0	28
(10)	15.0	24.5	25
Average	9.85	24.45	24.40

Decortication or Ribboning

The traditional method of retting is to immerse the whole stems of kenaf in ponds, ditches or rivers. An alternative method to retting of the whole stem is to ret the outer fibre containing part of the stem. The operation, known as ribboning, produces strips (ribbons) of fibre containing bast.

The advantage of ribboning are:

(1) Less water required for retting.
(2) Less weight to transport.
(3) Retting may be carried out at any time.
(4) Fibre washing is easier.

The disadvantages are:

(1) Additional labour is required for green stem stripping by hand.
(2) High capital is needed (enough ribboning machines must be available to enable the crop to be harvested and ribboned within the optimum period).

Simple Ribboning Machines

Simple hand operated labour-saving devices are used in some countries.

Various motor-operated ribboning machines have been developed

over the last 20 years. These machines have been developed into more advanced machines. Example of these machines is the Gardella ribboning machines and associated equipment. The Gardella campo gard ribboning machine is fed with stems, separates the wood from the bast and deliver ribbons ready for retting. This machine is driven by a diesel engine and is designed to be drawn by a tractor.

In Abu Naama Scheme Gardella ribboning machine is used. The efficiency of this machine is very low (0.5 ha/day). The hand labour required for feeding and collection of ribbons is very high (40 workers/ha). Out of the 135 machines only 32 are in fair working condition.

Conclusions

1. The success of mechanization requires a high level of organization and management.
2. Much thought should be given to machinery selection. As a general rule, it is advisable to standardize all farm machineries as much as possible.
3. Availability of trained and experienced personnel to manage and operate the machinery is of vital importance to the success of mechanization.
4. Effective machinery maintenance and repair and timely provision of supplies and spare parts are very essential for the operation of machinery.
5. Adequate training in the operation, repair and maintenance and management of farm machinery is a fundamental requisite for successful mechanization.
6. Farm machinery research is a major component of any national mechanization strategy, hence important in case of newly-introduced crops such as kenaf production.
7. In the Abu Naama Kenaf Scheme, due to shortage of hand labour at peak period (harvesting), kenaf harvesting constitutes a major constraint in production. Practical experience indicates that harvesting machinery selected for the scheme were technically and economically unsuitable.

Recent development in kenaf harvesting machinery suggests that selection of appropriate machinery is possible after careful research and testing.

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(Continued from page 58)

ABSTRACTS

Constraints to Efficient Utilization of Irrigation Water in the North Bangladesh Tubewell Project – Perspective from the Farmers' Side: M.A. Sattar, Sr. Sci. Officer, Agric. Engg. Div., Bangladesh Rice Research Institute, Joydebpur, Gazipur, Bangladesh; S.I. Bhuiyan, Agric. Engineer and Head, Water Management Dept., International Rice Research Institute, Los Baños, Philippines.

A field survey was conducted in five selected tubewell areas of the North Bangladesh Tubewell Project to identify farmer-perceived constraints to increasing the capacity utilization of the tubewell water. In the 1981 and 1982 dry season, the tubewells, on the average, could irrigate only less than 10 percent each of their command areas. The survey results indicate that the major reasons for low performance of the tubewells are water shortage due to frequent interruptions of electric power supply, absence of pump operators at site, high conveyance loss of water and poor functioning of the irrigation committee.

The farmers opined that the major limitations to increasing the irrigation coverage in the dry season are: i) water shortage; ii) high price of fertilizer; iii) non-availability of HYV seeds; and iv) high cost of insecticides. They suggested that in order to solve the water shortage problem, electric power supply must be improved, better service of the pump operator ensured, the main canal lining condition should be improved and rotational water distribution should be planned ahead of time.

Dry Land Agriculture Development in Indonesia

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Abstract

Dry land in Indonesia is estimated at 55.6 million ha, scattered throughout the country with a maximum temperature of 32°C and a minimum of 21°C, relative humidity from 45% to 80% and less than 1 500 mm of rainfall per year. The Indonesian government has endeavoured to develop dry land as a potential agriculture area in its current five year development plan with an aim to increasing farmers' standards of living and to balancing production in the productive or irrigated areas.

In dry land agriculture, secondary crops such as dry field rice, cassava, corn, vegetables, and also vegetable spices such as chilly and ginger are commonly planted. To support agribusiness activity, a cooperative system has introduced an intensification programme that directly grants credits to farmers for production facilities. This cooperative system activity will continue to be expanded for improved farmer guidance in agribusiness and to prepare for an era of new agricultural technology.

Introduction

Indonesia is situated in Southeast Asia and comprises and island group spreading from 6°08′ North latitude to 11°15′ South latitude, and 94°45′ East longitude to 141°05′ East longitude. Indonesia consists of 13 667 islands, including five main islands, known as Sumatra, Java, Kalimantan, Sulawesi, Irian Jaya, as well as the Maluku Archipelago, and Nusa Tenggara Archipelago, including Timor island.

The total area is 5 193 250 km^2 or about 5 times greater than Japan. The equator passes through the Indonesian archipelago and exerts a direct influence on the climate structure, producing climate changes every six months. June to September is the dry season, which is directly influenced by the Australian continent. The rainy season is December to March, caused by influences from the Asian continent and Pacific Ocean, whereby air masses pass over the Ocean, become saturated with water vapour and cause rain to fall on the country.

Given the geography and climate of the region, it is natural that agriculture is the main part of the economy in Indonesia. Rice is the main crop, and it is known as primary crop planted in irrigated or unirrigated areas as a staple food, and is commonly eaten by island occupants throughout Indonesia.

Secondary crops are planted after the rice harvests or in unirrigated areas, and also as a rice substitute in several regions. Secondary crops are commonly planted in dry land and or unirrigated areas. This include dry field rice, soy bean, peanut, green bean, corn, cassava and other vegetables. Dry land in Indonesia is estimated at 55.6 million ha, scattered throughout Indonesia, dominated by East Indonesia and Central Indonesia. Dry land agriculture is being vigorously promoted for bean crops, such as soy bean and peanut as part of the Government Five Year Plan to balance rice production in productive areas.

Dry Land Agriculture

The climate in the Indonesia archipelago is formed by a certain range of temperature and relative humidity. Typical temperatures in each region are as follows.

a. Average temperature of 27°C for coastal areas.
b. Average temperature of 25°C for inland and mountainous areas.
c. Average temperature of 22°C for mountain areas (depending on the height of the mountain).

Dry land has a characteristic temperature profile with a maximum of 32°C which causes a low density of vegetation, and in some conditions is dominated by steppe. Due to low rainfall, some dry land areas in Central Indonesia are uncovered by vegetation, consisting only of barren soil, or small stones covered by herbs or grass. This grassland that has potential for cattle breeding.

Characteristics

Dry land in Indonesia is generally characterized by little rainfall,

soil infiltration ranging from good to very bad, poor mineral resources for crop growth and soil with an acid reaction. In East Indonesia and Central Indonesia, dry land is characterized by a maximum temperature of 32°C and minimum temperature of 21°C with relative humidity from 45% to 80%. Evaporation is relatively high and rainfall is less than 1 500 mm per year.

As previously mentioned, the total area of dry land is estimated at 55.6 million ha, which is scattered over Sumatra (Aceh, Riau, Lampung, North Sumatra, Jambi), Java (North Central Java, Yogyakarta, East Java), Kalimantan (South Kalimantan, East Kalimantan), Sulawesi (Central Sulawesi, South East Sulawesi, South Sulawesi), West & East Nusa Tenggara, Maluku and East Timor. **Figure 1** shows the regional distribution of dry land in Indonesia.

Dry land is characterized by natural soil with yearly top soil, a sub-soil never stagnant with water and soil humidity under filed capacity the whole year. Certain crops, especially rice and some vegetables require water the whole year, and are thus unsuitable for dry land agriculture. Therefore, only crops that have a low water requirement, such as cassava, corn, several beans, etc., are planted in dry land areas. As the soil lacks minerals for crop growth, which additional fertilizer is required to balance the mineral requirements and soil reaction. Dry land areas have been forming since ancient times, as the soil loses its natural vegetation through natural forces and nomadic cultivation. As the fertile soil is washed away by rainfall, all that remains is barren soil.

Dry land in Indonesia can be categorized into Ultisols, Oxisols, Inceptisols, and Vertisols according to the acid reaction of the soil. In uncultivated dry land areas, grass and some herbs can be grown but this vegetation is easily lost through erosion.

Fig. 1 Distribution of dry land in Indonesia.

Land Management

Dry land has a characteristic management system portrait, due to its low rainfall, relatively high environmental temperature, and specific crop cultivation. Crops commonly planted in dry land areas differ according to the stage of the rainy season, enabling dry field rice, to be planted during the rainy season followed by planting of crops such as bean crops, corn, cassava etc.

Implements and machinery – Agricultural Machinery is rarely utilized in dry land areas compared to irrigated areas (fertile areas). Simple tools such as the sickle, hoe, hooked stick, etc. are commonly used. **Figure 2** shows the main tools and agricultural implements which are used for cultivation in dry land areas.

In several areas of Sumatra, Java, and Sulawesi, farmers have used powered machinery such as hand tractors, power threshers and other commonly used machinery for bean harvesting.

Crops – In several dry land areas during the rainy season, dry field rice and some vegetables can be cultivated. After the rainy season farmers commonly prepare land for crops with less water requirements such as cassava, bean crop, and also some vegetable spices such as chilly and ginger.

In developed region such as Sumatra, Java, and Sulawesi, farmers uses pumps or dig wells during the dry season for irrigation.

Cooperatives – Land possesion by farmers in Java averages 0.25 ha per person, and in other island is 1.0 ha on average. A cooperative system has developed throughout Indonesia with the aim to improve land management through better cultivating arrangements, plant protection, fertilizer supply, and also marketing after harvest. Rice farming has been developed in irrigated areas and fertile areas, to balance production. At the present time, bean crops, for example soy beans and peanuts, are being promoted and developed in dry land areas as important crops. Intensification programmes to increase production have been carried out in order to achieve a nutritional balance in dry regions. The cooperative system at the local level is administered by the Village Unit Cooperative (Koperasi Unit Desa, KUD). The village Unit Cooperative is responsible for the arrangement of facilities to achieve increased production directly affecting farmers. Field guidance is directed by the Agriculture Supervisor (Agriculture Instructor) and in conjunction with the village apparatus concerned.

Production

Agricultural development under the Fourth Five Year Development Plan (1984 – 1989) will continue to be stepped up as was done

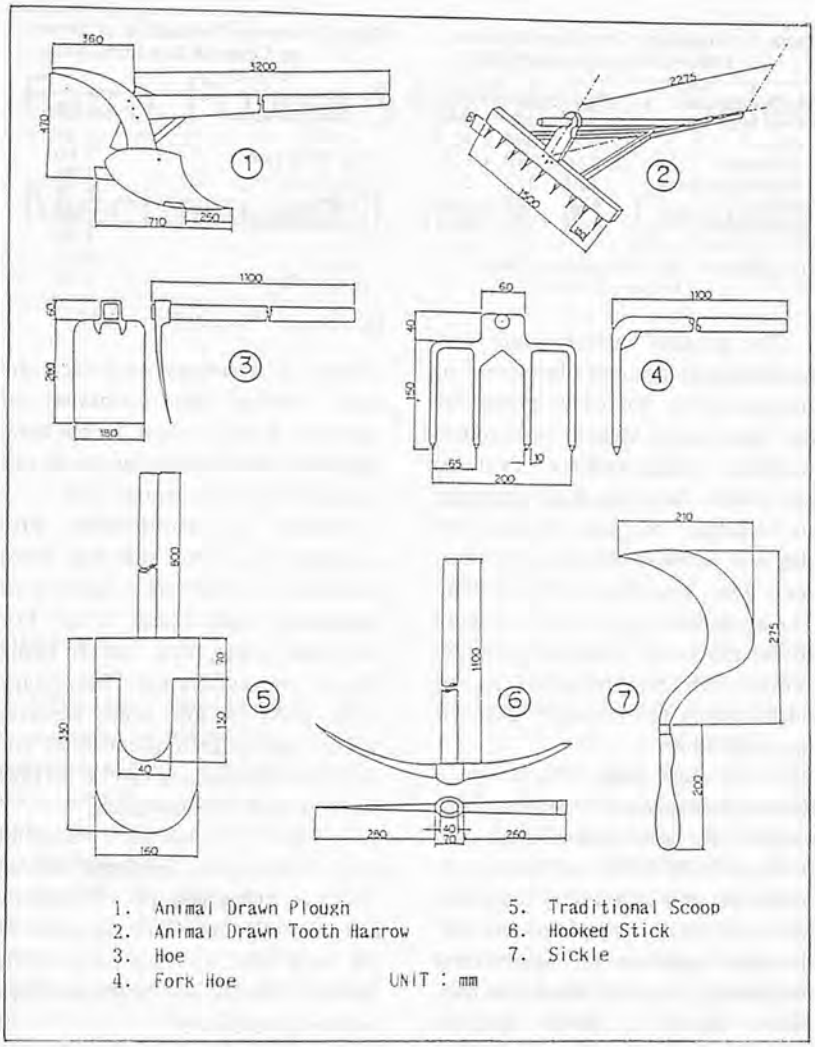

Fig. 2 Tools and implements commonly used in dry land.

Fig. 3 Cassava – One of the important commodities in dry land.

Fig. 4 Corn as staple food and substitution food in dry land.

Fig. 5 Rice field in dry land with irrigation system.

Fig. 6 Rice field nearby sugarcane field in dry land with irrigation system.

during the Third Five Year Development period in order to promote the National Economic Potential for the achievement of physical as well as spiritual welfare for the people and for an equal distribution of the gains of development.

Development Aims – Current agricultural development activities in Indonesia are geared towards:

i. Attaining self-sufficiency in staple foods.
ii. Improving the production of agricultural crops and import substitutes.
iii. Expanding employment opportunities in the agricultural subsector through carrying out transmigration and resettlement programmes.
iv. Enabling farmers and fishermen to have equal opportunities to step up their production through guidance and training, supply of production facilities, provision of credit, dissemination of information on marketing to improve communication facilities and infrastructures.
v. Persuading big agricultural enterprises to contribute to the development of small holder production capacity through a small holder nucleus system based on the transfer of agricultural technology through the supply of high yielding seeds and the processing and marketing of these products.

Secondary crops – Guidance and development activities for secondary crops and horticulture are being specifically emphasized by the Indonesian Government during the Fourth Five Year Development Plan to enhance farmers' standards of living, especially those who cultivate unirrigated areas.

Besides rice, farmers grow secondary crops and horticulture products with the purpose of balancing their income. The average produc-

tion of soy beans, peanuts and cassava rose, respectively, from 896 kg 995 kg, and 10 500 kg per ha in 1984 to 978 kg, 1 044 kg and 10 600 kg per ha in 1985.

In 1985, soy bean production totalled 865 000 tonnes, meaning an increase of 12.5% compared with 769 000 t in 1984.

The soy bean harvest average expanded from 859 thousand ha in 1984 to 884 thousand ha in 1985, an increase of 2.9%.

Table 1 and 2 show the average production from 1983 – 1985 secondary crop harvest areas.

Table 1 Secondary Crop Harvest Areas 1983–1985 (in thousand ha)

Commodity	1983	1984	1985
Corn	3 002	3 084	2 524
Cassava	1 221	1 350	1 333
Sweet potatoes	280	263	271
Peanut	481	537	519
Soy bean	640	859	884

Data Source: An Official Hand Book, Indonesia 1987

Table 2 Average Production of Secondary Crops in Dry Land Areas (in t/ha)

Commodity	Production
Dry field rice	2.10
Soy bean	0.98
Peanut	1.10
Small green pea	0.65
Corn	3.65
Cassava	10.65
Horticulture	5.10

Data Source: Survey Data, 1987

Development

Dry land can be developed as a productive area, although for this purpose it must be supported by an infrastructure, interlinkage management, and good organization. Dry land in West Indonesia formerly was natural forest, and became dry land, due to nomadic cultivation. In Central Indonesia and East Indonesia, formation of dry land has been due to long term natural factors, creating steppe or rare vegetation, as well as nomadic cultivation.

Potential crops have been developed such as cotton, tobacco, pepper and gur. These are known as plantation commodities and help compensate for export commodities. The infrastructure of production necessary for dry land farming consists of irrigation networks, production facilities, machinery and equipment, transportation facilities, processing facilities and store house facilities.

The management system necessary to increase production and stability must include both procedure management credit to facilitate agribusiness involvement from cultivation to harvesting and product marketing and prices which will facilitate marketing but not disturb farmer activity.

The present infrastructure and management systems developed in Indonesia for the development of dry land areas include production facilities, transportation facilities and credit facilities. It is necessary to facilitate this step by step but this will be fulfilled during the current Five Year Development Plan. The agricultural sector is considered to be the main economic base together with the industrial sector, both sectors are mutually supporting each other.

At the local scale of farmer with limited management experience and capital, the government must support credit facilities for production materials and machinery purchase in order to increase production through agribusiness. Agricultural machinery, such as hand tractors, power threshers, power sprayers and dryers are familiar to farmers in agriculture dry land and unirrigated areas. Gradually by increasing farmer income, machinery must be introduced into the milieu of agribusiness activity. Animal power is still used in remote areas where machinery repairing facilities are limited. By the development of transportation, a balance can be achieved between developed areas and undeveloped areas. In the closing decades of the 20th century, it is hoped that farmers will taste greater achievement through development of agriculture technology.

Conclusion

The conservation of natural resources is necessary to attack the cause behind the formation of barren soil and protect fertile land, although even barren land can still be utilized as agricultural land.

Thanks to government programme, dry land still has great potential in achieving a balance of productive agricultural areas. For the time being, this role is being played by cultivation. Secondary crops such as soy bean, cassava, peanut and other commodities for export compensation can be further developed in dry land areas.

A good cooperative system, good management guidance and an effective infrastructure of production directly involving farmers at the local level are necessary to lift farmers' spirits and improve agribusiness provisions.

Agricultural technology in developing countries requires selective introduction in order to achieve as great a success of production as possible while avoiding negative side effects such as unemployment and natural resource destruction.

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Farm Power/Machinery Selection Model for Mechanized Farms in Developing Countries

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Abstract

With the "Back-to-Land" programmes being pursued by different governments of developing countries, business concerns are beginning to show some interest in agriculture. They are, in the main, compelled by economic circumstances to invest in tractors and other agricultural machines for gainful production. This paper presents a model through which optimal selection of farm power and machinery can be made for such farms from available machinery systems. A manual procedure was also developed to facilitate the usage of the model by companies without computing facilities.

Introduction

After many years of subsistence farming usually on small holdings, commercial farms of 100 ha and more are beginning to emerge in the developing countreis of Africa.

In Nigeria, this development arose as a result of governments' encouraging policies on the development of agriculture. The structural adjustment programme formulated to make the Nigerian economy self-reliant has compelled many industrial concerns to seek some of their raw materials locally through investment in commercial farms.

The trend has been for an existing industrial or trading concern to diversify into agriculture through the cultivation of grains such as corn, cowpeas, sorghum, millet, soyabeans, rice, etc. The companies buy large pieces of contiguous holdings from peasant farmers. Initially they hire bulldozers to perform land clearing. Thereafter they proceed to invest in available tractors, farm machineries and implements. In many cases, detailed feasibility studies are only conducted when financing companies such as banks insist on them. These studies when conducted delve more into financial analysis of investment and rarely give detailed thoughts to optimal selection of farm machineries from an available machinery mix.

This paper describes a farm machinery selection model which takes into account value and cost of production, the available machinery mix, timeliness of operations and capital limitations. A manual procedure based on the mathematical model was also developed for those companies without computing facilities.

This paper will help to prevent colossal failures in the newly emerging corporate farms through the adoption of articulate procedures for optimal selection of farm power and machinery.

A Generalized Model

The optimal selection of farm power and machinery on a commercial farm can be modelled as follows:

$$\text{Min } C = \sum_{j}^{J} \sum_{l}^{L} c_{jl} x_{jl}$$

Such that:

$$\sum_{j}^{J} \sum_{l}^{L} c_{jl} x_{jl} \leqslant V \quad \ldots\ldots\ldots (1)$$

$$\sum_{l}^{L} t_{jl} x_{jl} \leqslant T_j \text{ for all } j \quad \ldots (2)$$

$$\sum_{l}^{L} Y_l P_l \leqslant \bar{P} \quad \ldots\ldots\ldots (3)$$

$$\sum_{l}^{L} x_{jl} \geqslant 1 \text{ for all } j \quad \ldots\ldots (4)$$

$$Y_l = x_{11} v x_{21} \ldots v \ldots v\, jl \text{ for all } l \quad \ldots\ldots (5)$$

$$x_{jl}, Y_l = 0,1 \quad \ldots\ldots\ldots (6)$$

where,

c = total cost of production, ₦

c_{jl} = the cost of performing oper-

ation j with machine l, ₦

x_{jl} = a binary decision variable on whether a machine l with its its associated implement is used for an operation j or not.
= 1 if used
= 0 otherwise.

Y_l = a binary decision variable on whether the l th machine is purchased or not.
= 1 if purchased
= 0 otherwise

V = value of all the crops being produced, ₦

t_{jl} = time of performing operation j with machine l, hours

T_j = time available for performing operation j, hours

P_l = procurement cost of l th machine, ₦

$\overline{P}$ = maximum capital available for investment, ₦

J = number of farm operations

L = number of machine systems under consideration

Constraint (1) ensures that the cost of production is not more than the gross value of production. Constraint (2) guarantees timeliness of operations within acceptable limits while constraint (3) ensures that capital investment on machineries does not exceed available capital. Constraint (4) ensures the performance of all operations.

Equation (5) gives the relationship between x_{jl} and Y_l. It is expressed in Boolean algebra. This equation implies that Y_l can only be equal to 1 if at least one x_{jl} is equal to one. In real terms, the equation states that a machine can only be purchased if it will be used for at least one operation. This is a necessary condition.

In the above model, the values of V, P_l, $\overline{P}$ can be obtained from market sources. T_j can be obtained from historical meteorological records while t_{jl} can be determined from the size of the farm and the capacity of individual machines.

The value of c_{jl} is computed as follows:

c_{jl} = (hourly cost of the lth machine + hourly cost of the associated implement for the jth operation) × hours of usage of the machine system for the jth operation.

Detailed methods of calculating machine hourly rates for farm machines and implements are discussed in such works as Hunt (1967), Kampe (1970) and Larson et al (1960).

The above model could have been an integer programming model with binary variables without constraint (5). The introduction of the constraint (5) expressed in Boolean algebraic form makes the model difficult to be solved using standard operational research (OR) computer packages. It is, therefore, important that an appropriate procedure be developed to solve the above model. The development of the procedure is discussed in the next section.

The model in its generalized form will find ready application in a large commercial farm which has enough capital to invest in many machines at the same time. A selective application of the model is also feasible in which few operations are considered rather than the totality of all agricultural operations on a farm.

Development of a Manual Solution Procedure

A major reason why many mechanization models rarely find application in developing countries is that the implementation of such models is usually computer-oriented. Most companies engaged in commercial farming in developing countries are at best equipped with good electronic calculators.

A manual procedure is, therefore, developed to solve the model described in the previous section. The assumptions made in the development of the solution procedure are given in i) while the manual procedure and an illustrative example are given in ii) and iii), respectively.

i) Assumption on Manual Procedure

The following assumptions are made to facilitate the development of a manual procedure:

(a) Preliminary consideration of the technical aspects of available machinery such as its design, operation and serviceability are made before and outside this model. The decisions on these technical considerations are made on a "Yes" or "No" basis. A machine system is either technically suitable or not.

(b) Costs of the non-machine inputs such as seeds, land, financial charges etc; which do not primarily depend on the choice of machinery system are not considered in the procedure. This implies that the procedure deals only with the cost-effectiveness of machine selection.

(c) Timeliness constraints are relaxed. This implies that only machinery system with suitable capacities are considered. In the case of manual operations, it is expected that a company will be able to assemble enough contract farm labour to make the operations timely. This is unlike the small subsistence farmer who is restricted to the few contract labour in his immediate locality.

ii) The Manual Procedure

The manual procedure is described in the following steps:

Step 1: Determine the gross value of production and cost of each operation using purely manual labour.

Step 2: Determine the capital costs of the different machineries with their associated implements.

Step 3: Compute the expected operational times for each machinery system, including the manual system (M_1) and tabulate for each operation. **Note**: All machines are assumed to be purchased as a starting point for the iterative process of optimization.

Step 4: Calculate the cost of production for each machine system based on actual hours of machine usage. The capital investment for each machine system in use are also calculated.

Select the least-cost machine for each operation. If total hours of actual usage of a machine becomes changed after the selection, recompute the cost matrix and repeat the least-cost selection. With the stability of the cost matrix, the usage of each machine is now well defined. All machines which can be used for at least one operation in a year are deemed purchasable. The results here give the most profitable choice of mechanization. If the cost of production is more than the value of production, the farming enterprise cannot be profitable under any machine system. If available capital is more than the optimal capital investment, the selection is optimal. STOP

Step 5: Post-optimality Selection

This selection is made when optimal capital investment is more than the available capital. Using the optimal selection as a base, calculate the marginal savings in cost of a machine operation per investment (CSP) relative to the manual method. Select the machine operation with the lowest CSP and eliminate from selection. GO TO STEP 4.

iii) Illustrative Example

Consider a company going into commercial farming. The expected gross value of production for the planned holding and crop is ₦40 000 per annum. Studies have shown that besides purely manual labour system (M_1), four other machine systems (M_2, M_3, M_4, M_5) are feasible. The major production processes are P_1, P_2, P_3, P_4, P_5. An optimum selection of machinery is required for a capital limitation of (i) ₦70 000, (ii) ₦60 000.

The iteration has converged since the cost matrix can no longer change. The selection of machine M_4 with implements for P_1 and P_3 and the selection of M_5 for P_5 constitutes an optimal machine selection. Other operations need to be performed manually.

For (ii) a capital limitation of ₦60 000, Step 5 needs to be carried out.

Step 1

V = ₦40 000

Operation j	P_1	P_2	P_3	P_4	P_5
Cost of production using manual method (M_1), ₦	10 000	8 000	7 500	6 000	9 000

Step 2 Capital costs of machinery systems

	M_1	M_2	M_3	M_4	M_5
Major machine	–	45 000	50 000	30 000	5 000
Implements for P_1	–	10 000	11 000	12 500	–
P_2	–	–	15 000	–	–
P_3	–	15 000	17 000	16 000	–
P_4	–	7 500	5 000	–	–
P_5	–	–	–	7 500	2 000

Legal rate of depreciation for all classes of machine = 20%.

Step 3 Operational Times (hours)

Operation	M_1	M_2	M_3	M_4	M_5
P_1	400	200	150	100	–
P_2	300	–	100	–	–
P_3	200	150	100	120	–
P_4	300	100	150	–	–
P_5	600	–	–	120	60
Total	1 800	450	500	340	60

Step 4 (i) Cost matrix

Operation	M_1	M_2	M_3	M_4	M_5	Minimum cost
P_1	10 000	6 000	5 200	4 260	–	4 260
P_2	8 000	–	5 000*	–	–	5 000
P_3	7 500	6 000	5 500	5 312*	–	5 312
P_4	6 000	3 500*	4 000	–	–	3 500
P_5	9 000	–	–	3 612	1 400*	1 400
Total cost of production						
Machinery investment						
Effective usage (hrs.)	–	100	100	220	60	–

*Least-cost machine operation.

Step 4 (ii) Revised cost matrix

Operation	M_1	M_2	M_3	M_4	M_5	Minimum cost
P_1	10 000	–	–	5 200*	–	5 200
P_2	8 000*	–	13 000	–	–	8 000
P_3	7 500	–	–	6 440*	–	6 440
P_4	6 000*	10 500	–	–	–	6 000
P_5	9 000	–	–	–	1 400*	1 400
Total cost of production (₦)	14 000	–	–	11 640	1 400	27 040
Machinery investment (₦)	–	–	–	58 500	7 000	65 600
Effective usage (hrs)	–	–	–	220	60	–

Step 5 Post-optimality selection

CSP (M_4, P_1) = (10 000 – 5 200) / (30 000 + 12 500) = 11.3%
CSP (M_4, P_3) = (7 500 – 6 440) / (30 000 + 16 000) = 2.3%
CSP (M_5, P_5) = (9 000 – 1 400) / (5 000 + 2 000) = 108%

Step 5 (i)

Operation	M_1	M_2	M_3	M_4	M_5	Minimum cost
P_1	10 000	–	–	8 500*	–	8 500
P_2	8 000*	–	–	–	–	8 000
P_3	7 500*	–	–	–	–	7 500
P_4	6 000*	–	–	–	–	6 000
P_5	9 000	–	–	–	1 400*	1 400
Total cost of production (₦)	21 500	–	–	8 500	1 400	31 400
Capital investment (₦)	–	–	–	42 500	7 000	49 500
Effective usage (hrs)	–	–	–	100	60	–

Conclusion

A model has been developed for selecting appropriate farm machineries and equipment for an emerging corporate farm. The manual application is primarily based on economical substitution of human power with machine power. This model will, therefore, find extensive application in emerging commercial farms of developing countries but will find limited application in the developed countries where the use of human power is not viable because of its prohibitive cost.

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Energy Consumption and Possible Savings in Tea Processing

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Abstract

Tea processing is an energy-intensive operation (the theoretical thermal energy requirement is 2.7 kWh/kg of black tea at 3% m.c., w.b.). India, the world's leading tea producer (33% of world production), spent around 840 Mt of coal equivalent in 1984 for tea processing. Production is mainly concentrated in the states of Kerala, Tamil Nadu and Karnataka. This paper describes current methods adopted in the tea processing and compares fuel consumption in four tea factories. Some technological proposals for the reduction of fuel consumption through the use of solar energy, cogeneration and energy recovery from dryer exhaust are discussed.

Introduction

Tea processing (black tea production from green leaves) is a critical process from which the highest quality product must be obtained. Two processing methods, "CTC" (crush-tear-curl) and "orthodox" (or "classical"), have generally been adopted by Southern Indian tea manufacturers. An analysis of total production shows that 56% of manufacturers use CTC and the remainder use orthodox (1).

The production of tea from green leaves is essentially a gradual oxidation process (2) involving the following stages: i) withering; ii) rolling; iii) fermentation; iv) firing.

Withering is the first step in the process. The handharvested, tender green leaves (m.c.: 80% w.b.) are spread over wire mesh in specially made wooden troughs (**Fig. 1**), with a bed thickness ranging from 0.2 to 0.45 m (10 – 15 kg of product/m^2). A cross flow of ambient (during favourable atmospheric conditions) or heated air (temperature increase: 3 to 5°C with a temperature limit of 35°C) is maintained by an electric fan during the entire stage, which takes from 16 to 19 hours. The specific flow rate is from 0.1 to 0.25 m^3/s per m^2 of trough. Generally, withering requires 20-25% of the total fuel used for the entire process.

The rolling stage involves tearing, cutting and crushing which causes the leaf to begin to change color from green to copper-red. It also produces a pleasant grassy smell. With CTC process, black tea dust (from the final stage) is added to adjust moisture content to approximately 50% (w.b.). The types and number of rollers em-

Fig. 1 Withering troughs.

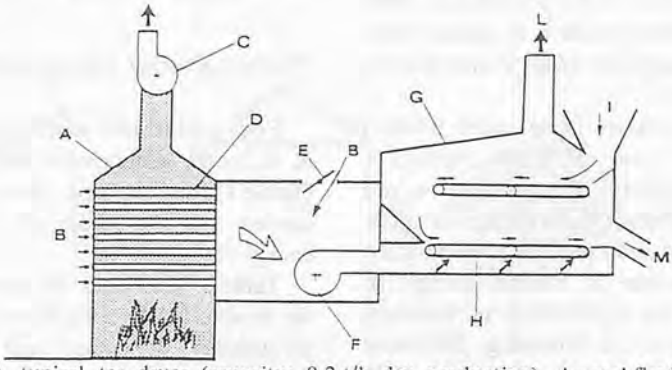

Fig. 2 A typical tea dryer (capacity: 0.2 t/h dry production). A–coal-fired boiler (600-800 kWt); B–inlet of ambient air; C–flue gas fan (2 kWe); D–cast-iron pipes (air-air heat exchanger, 100 m; E–mixing valve; F–dryer fan (7.5 kWe); G–dryer; H–conveyor belts; I–inlet of fermented tea; L–outlet of exhaust air; M–outlet of dried tea.

Fig. 3 Grading in CTC method.

Fig. 4 Coal-fired boiler.

ployed in the CTC and orthodox methods are different.

The oxidation process reaches its maximum intensity during the fermentation stage. It involves placing the rolled leaves on static beds or in slowly rotating drums at room temperature and with increased humidity (90-95% using humidifiers when necessary). One to 2 hours are required for CTC and 3 to 4 hours for orthodox.

In the final stage (firing), the fermented leaves are fed into a cross-flow dryer by conveyors (**Fig. 2**) at a temperature of 90 to 120°C for 12 to 15 min. During the firing stage, the copper-red colour changes to black with a final moisture content of 2 to 3% (w.b.). Then the dried product is graded into leaves and dust (**Fig. 3**) and quickly packaged.

Air heaters (here called boilers) fed by coal or lignite (usually a local variety of coal with a net heat value of 7.8 kWh/kg) or other fuels (wood, oil, etc.) are utilized as a source of thermal energy. In 1982, the distribution in Southern India was the following: 58% were wood-fed plants, 18% and 24% were oil and coal-fed plants (3). At present the most commonly used fuel is coal. Heat exchange between the hot fuel and ambient air is obtained through cast iron pipes (**Fig. 4**).

Table 1 Selected Tea Factories

Site no.	Name of estate and location	Type of process
1	Semnivalley Tea Estate, Haileyburia Company. Elappara, Idduky Dt. (Kerala)	CTC
2	Pasuparai Tea Estate. Pasuparai, Idduki Dt. (Kerala)	CTC
3	Manalore Estate, Padagri, Palghat Dt. (Kerala)	CTC
4	Havukal Tea Estate, Havukal, Nilgris Dt. (Tamil Nadu)	Orthodox

Table 2 Details of Tea Processing in Four Factories

Parameter	Site no.1	Site no.2	Site no.3	Site no.4
Production (t/month)				
Leaves:	10.59	5.82	2.40	70
Dust:	29.62	26.84	50.96	–
Total:	40.20	32.66	53.36	70
Withering				
Initial m.c. (% w.b.):	75-80	75-80	75-80	75
Final m.c. (% w.b.):	70	70	70	45-50
Withering time (h):	19	19	18	16
Bed thickness (m):	0.46	0.30	0.30	0.30
Rolling				
Final m.c. (% w.b.):	50	50	50	45-50
Dryer capacity (t of dry tea/h):	0.2	0.2	0.2	0.2
Exchanger surface area (m^2/kg of fuel per h):	1.25	0.90	0.92	1.00
Inlet air temp. (°C):	115	120	105	110
Oulet air temp. (°C):	80	50	55	55

Table 3 Average Thermal and Electric Consmption at Four Factories

Unit: kwh/kg of tea

Process Stage	Energy consumption: CTC		Energy consumption: orthodox	
	Thermal	Electric	Thermal	Electric
Withering	0.70	0.11	1.08	0.14
Drying	3.80	0.04	3.30	0.04
Others (1)	nil	0.45	nil	0.40
Total	4.50 (2)	0.60 (3)	4.38	0.58

Present Energy Consumptions

Four factories were selected in different geographical locations (**Table 1**) and a spot survey was carried out in order to study energy consumption.

Table 2 illustrates the monthly tea production (practically constant throughout the year) and some particulars of the processes adopted.

In the 3 CTC factories, the processes are very similar. For instance, the exchanger's surface area is between 0.9 and 1.25 m^2/kg of burnt coal per hour and the dryer's inlet and outlet temperatures vary from 105 to 120 and from 50 to 80°C, respectively.

Local coal is used in the four factories. Specific fuel consumption follows:

i) 0.09 – 0.14 kg/kg of tea by withering; and

ii) 0.40 – 0.55 kg/kg of tea by drying.

Therefore, the total varies from approximately 0.5 to 0.7 kg/kg for the complete process.

In **Table 3**, the electrical and thermal energy consumption is reported. This was evaluated on the basis of the time necessary for each

stage and power of the machines (boilers and electric motors). In addition, these data were checked by taking into account yearly fuel and electric consumption.

In brief, approximately 0.55 – 0.66 electric kWh and 4-5 thermal kWh (as opposed to a theoretical requirement of 2.7) are actually needed to produce 1 kg of tea.

In money terms, total energy costs (both for the CTC and orthodox methods) are approximately US$ 0.10 – 0.12 per kg of tea (8% of total production costs). A considerable portion of this figure is related to thermal consumption: US$ 0.05 per kg of product (4). Consequently, the pressing need is to make tea processing more efficient. Some proposals for a reduction in fuel consumption are outlined below.

Proposals for Energy Savings

The amount of fuel needed for withering and drying may be reduced by using:

i) Solar air heaters (SAH) integrated into the roofs;
ii) Solar water heaters (SWH) with thermal storage;
iii) Heat recovery from diesel generators; and
iv) Heat recovery from dryer exhaust.

Solar Heating Systems

Much of the withering is done during the night and drying during the day. Therefore, it would be logical to use SWH systems for the former stage and SAH systems for the latter.

Solar heating plants may be considered for locations where sufficient solar energy is available during the year. Tea factories in Southern India are situated at low latitudes (9 to 11°N) and have large roofs (approximately 250 to 300 m² at 12-14 m above ground level (**Fig. 5**).

This roofing configuration is suitable for the installation of solar systems, although, in some cases its orientation and slope are not ideal. In fact, the variation in the amount of yearly solar radiation collected by a roof facing South and one facing North is less than 10% and this does not justify roof modification (**Fig. 6**).

The roof may be converted into a SAH system by blackening its surface and fitting a transparent cover over it (glass or glass-reinforced plastic). An air gap is obtained between the roof and the cover with metallic or wooden spacers. This jacket should be connected to the boiler fan in order to preheat the air. A possible design is shown in **Fig. 7**.

A SAH system (average efficiency: 0.4; see Appendix) installed on a 300 m² roof can collect 240 000 kWh/year (average global radiation: 2 000 kWh/m²; (5)). The potential energy saving, in terms of local coal, is 44 t/year (average boiler efficiency: 0.7) or

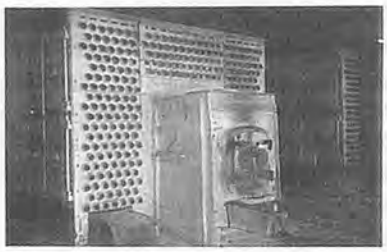

Fig. 5 Havukal tea estate.

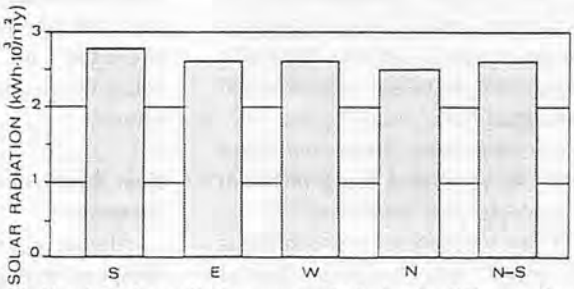

Fig. 6 Yearly solar radiation on roofs facing in different directions (simulated data; latitude 9° N, longitude 75° E, slope 20%).

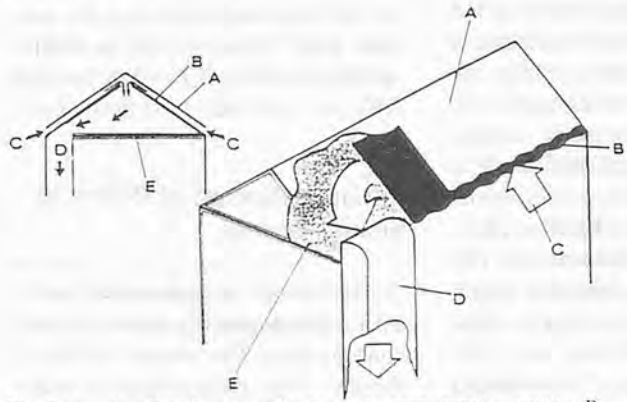

Fig. 7 A simplified air collector. A–transparent cover; B–blackened metallic sheets; C–inlet of ambient air; D–air duct connected to the dryer fan; E–wooden ceiling.

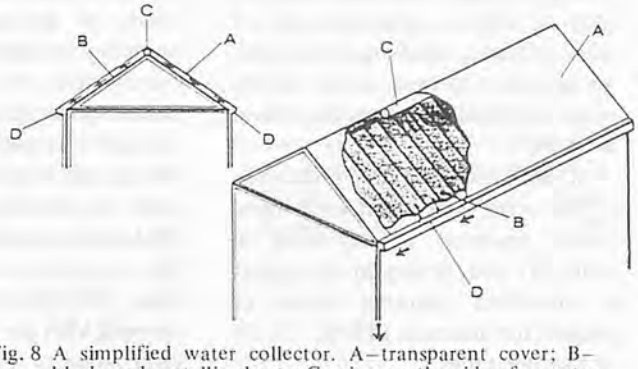

Fig. 8 A simplified water collector. A–transparent cover; B–blackened metallic sheets; C–pipe on the ridge for water distribution on the absorber; D–gutter for hot water collection.

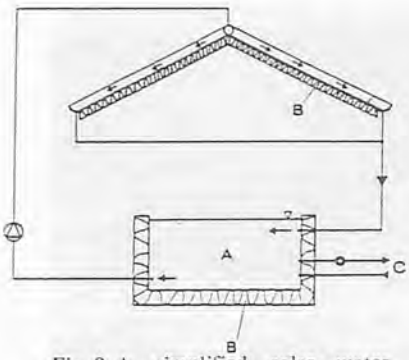

Fig. 9 A simplified solar water heater system. A–open storage tank; B–insulation; C–to/from an air-water heat exchanger.

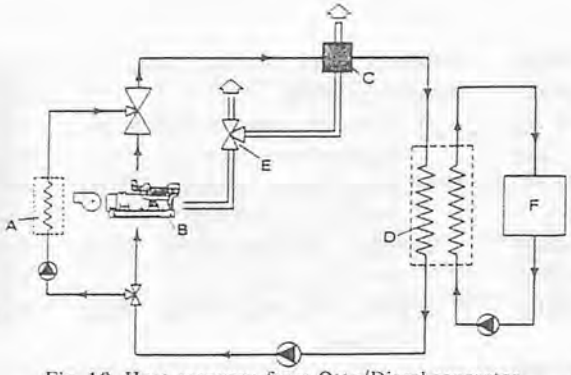

Fig. 10 Heat recovery from Otto/Diesel generator. A–emergency air-water exchanger; B–engine cooling; C–flue gas-water exchanger; D–water-water exchanger; E–emergency bypass for flue gases; F–storage or air-water exchanger.

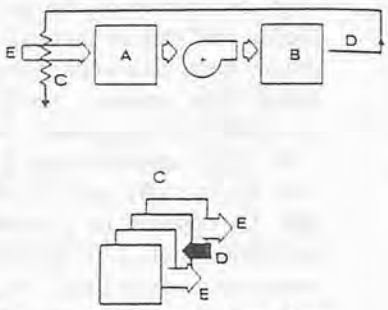

Fig. 11 Heat recovery from dryer exhaust. A–coal-fired boiler; B–dryer; C–air-air exchanger; D–outlet of hot exhaust air; E–inlet of ambient air.

approximately 0.1 kg per kg of tea. This means that actual thermal consumption for drying could be easily reduced by 20 – 25%.

SWH systems could conveniently meet the thermal requirements of withering. They could do away with night use of boilers, thereby increasing process safety.

From an engineering point of view, an SWH is an efficient low temperature water generator. Given this fact, its design should result in the lowest temperature of circulating liquid. This means large storage tanks, simple hydraulic layouts and oversized air-water heat exchangers (6).

A simplified water collector could be produced using different technologies, for instance:

i) By blackening and insulating the upper- and the under-side of the roof, respectively, (generally made with corrugated metalic sheets); fitting a transparent cover over it, with a minimum gap of 20 – 30 mm; installing a hydraulic layout that delivers water at the ridge and collects it at even level (**Fig. 8**);

ii) By insulating the under-side of the roof, covering it with transparent material as explained in point (i) and fitting in the jacket a simplified absorber made of plastic (for instance, EPDM; 7, 8, 9) or metallic pipes.

These simplified collectors can be connected to an open storage tank from which the water is pumped, when thermal energy is needed, to an air-water exchanger (**Fig. 9**). These open hydraulic layouts make it possible to use cheap, locally-made technologies. In order to optimize system efficiency (Appendix), a flow rate of 0.014 kg/s and a storage capacity of 100 kg per m^2 of collector are recommended.

The potential energy savings is practically the same as that provided by SAH systems. This means that the thermal requirements of withering in the CTC process could be completely met by a solar source.

Heat Recovery from Diesel Generators

Almost all the tea factories are equipped with diesel power generators varying from 100 to 200 kVA. The average running time is 6-8 h/day, mainly to meet the electrical needs of drying and rolling. By applying simple exchangers (recovery from the engine's cooling system and from exhaust gases), it is possible to save 1.3 – 1.5 thermal kW per kVA generated. Therefore, with an average demand of 100 kVA and a running time of 6 h/day, the potential total savings is more than 220 000 kWh/year or 0.65 thermal kWh per kg of tea produced (equivalent to 0.12 kg of coal).

This amount of energy is sufficient for CTC withering needs or a 20% decrease in the thermal load of drying (for all processes). For the first case, thermal storage should be considered, while for the latter, thermal energy could be utilized directly by an air-water exchanger. One possible hydraulic layout is shown in **Fig. 10**.

Heat Recovery from Dryer Exhaust

Because of its temperature (50 to 80°C) and relative humidity (80 to 90%), exhaust air from dryers offers the possibility of recovering thermal energy to preheat the ambient air. Heat recovery could be achieved with locally-made air-air exchangers. A simple system consists of corrugated metal sheets arranged paralled to each other to ensure a counter-flow and turbulent air movement (**Fig. 11**). It is reasonable to expect efficiencies of 20 – 30% depending on the design of the heat exchanger and the surface area. Therefore, the potential savings could be 0.7 – 1.2 thermal kWh per kg of tea.

Initial Evaluation of Potential Energy Savings

This study is concerned only with technologies to reduce thermal consumption. The reason for this is simple: these technologies are suitable for the environment considered because they are potentially locally available. In other words,

they make it possible to maximize the ratio between benefits and investment costs.

Table 4 summarizes the savings that could be obtained with the methods described above. Obviously, it should be also possible to reduce electrical consumption with the use of efficient electric motors and generators and the rationalization of the machinery and process stage sequence. Another possibility is offered by biomass gasification with the recovery of waste heat. However, the use of all these technologies has to be postponed because of their advanced technological content.

By applying the three technologies, it is possible to save 1.6 thermal kWh per kg of tea, or approximately 0.29 kg of local coal. This means a reduction of approximately 40-50% (depending on the type of tea processing) in present energy consumption. Thermal energy incidence per kg of product is currently US$ 0.05. Therefore, for an average tea factory producing 45 t/month of tea, the yearly energy bill could be cut from US$ 13 000 to 17 000.

This study clearly indicates the feasibility of investing a considerable sum of money in energy saving technologies.

Table 4 Potential Energy Savings (Average Values)

Technology	Energy saving	
	(thermal kWh/ kg of tea)	kg of coal equiv./ kg of tea) *
Solar air or water heaters installed on the roof	0.10	0.02
Heat recovery from generators	0.65	0.12
Heat recovery from dryers	0.85	0.15
Total	1.60	0.29

* Considering boiler efficiency to be 0.7.

Appendix

The efficiency of a solar collector is given by the following relationship (Bliss' law):

$$\eta = A + B \frac{Ti - Tr}{R} \qquad (1)$$

where:

A and B: parameters depending on collector phisical characteristics

Ti : inlet temperature of air or water (°C)

Tr : room temperature (°C)

R : solar radiation (W/m^2).

In the case of open systems (air collectors), Ti = Tr, thus:

$$\eta = A = \text{constant} \qquad (2)$$

By using clear plastic or glass as cover and blackened uninsulated metallic sheets as absorber, it is not difficult to obtain average efficiencies of 40-50%; however, it is necessary to assure a minimum specific flow rate of 0.012 kg per m^2 of collector. For a simplified water collector, the relationship (1) becomes:

without a clear cover:

$$\eta = 0.8 - 55 \frac{Ti - Tr}{R} \qquad (3)$$

with a cover:

$$\eta = 0.7 - 8 \frac{Ti - Tr}{R} \qquad (4)$$

In the latter case, it is reasonable to assume the following data for the withering stage:

Ti = 35°C (average temperature in storage)

Tr = 20°C (average temperature during the day)

R = 500 W/m^2 (average power of solar radiation).

Thus, efficiency is approximately 50%.

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Mechanization Techniques for Accelerating Afforestation Programmes on Denuded Hillocks

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Abstract

Land belonging to capability class V to VII is found in sub-humid southern hill region of Rajasthan State, India as denuded small hillocks which consist of phyllite rocks. Afforestation with water conservation technique, the "gradonies," along with proper fencing of the area with "thore," shrubs or spiny trees is one of the possible ways open for putting such wastelands under permanent vegetative cover. In the present study a mechanical technique was developed. Time required and cost involved were estimated and compared for construction of gradonies for afforestation and trench for hedge row planting of trees for live fence.

Introduction

A large portion of the sub-humid Southern hill region of Rajasthan State, India is designated as denuded, degraded forest area. Much of this area is under small hills and hillocks which comprise of phyllite rocks. According to land capability classification such land belongs to class V to VII. Further, these lands are badly eroded mainly because of faulty cultivation practices, uncontrolled grazing and indiscriminate cutting of trees. "Reclothing" these denuded areas with vegetation is an important consideration. In order to make up the deficient forest area for the protection of catchment areas of rivers, the agricultural land below these hills and supply of forest products, these areas can suitably be put under a permanent forest cover. Further, these lands with steep slopes and completely devoid of vegetation do not absorb rain water. This results in poor survival and growth of the trees planted on such lands under afforestation programmes.

In general, these areas are under the direct control of the State Forest Department although some areas are owned by the inhabitants of this region. The State Forest Department and Soil Conservation Units of the Agriculture Department under Drought Prone Area Programme are taking up these areas under afforestation programmes by adopting manually constructed gradonies as one of the measures for water conservation. The basic idea behind the heavy investment for construction of gradonies is to conserve most of the rainfall and provide moisture to plants for a considerable time. Further, the check over encroachment of cattle and other animals is a basic need of the area for successful implementation of such afforestation programmes. At present some of these areas are protected either by dry loose stone walls which is very costly due to high cost of labour. This method can easily be replaced by hedge row planting method in which thore, shrubs or spiny tree species are planted in the trench along the ridge line of the watershed.

Gradonies are just like steeply inward sloping, narrow terraces constructed on contours. Vertical interval varies between 1.0 to 1.5 m depending upon the steepness of slope. The width of gradonies is kept about 1.0 to 1.5 m. The material dug from the inner side is

heaped on outer edge so as to form a berm of about 20 cm having an inward slope (Fig. 1). In the middle of the gradonies, pits of 50 cm x 50 cm x 50 cm are dug at an interval of 3 m. If the contour is broken, pitching is done at the end of the contour.

At present hand tools are used for the construction of gradonies and digging of trench for hedge row planting of live fence. This method is very expensive and time consuming. The afforestation programmes are important as the Forest and Soil Conservation Departments have to plant every year targetted areas. Further, it becomes very difficult to undertake moisture conservation projects in such lands. Therefore, a fast and less expensive mechanical technique is necessary when conditions permit so that a large area can be covered.

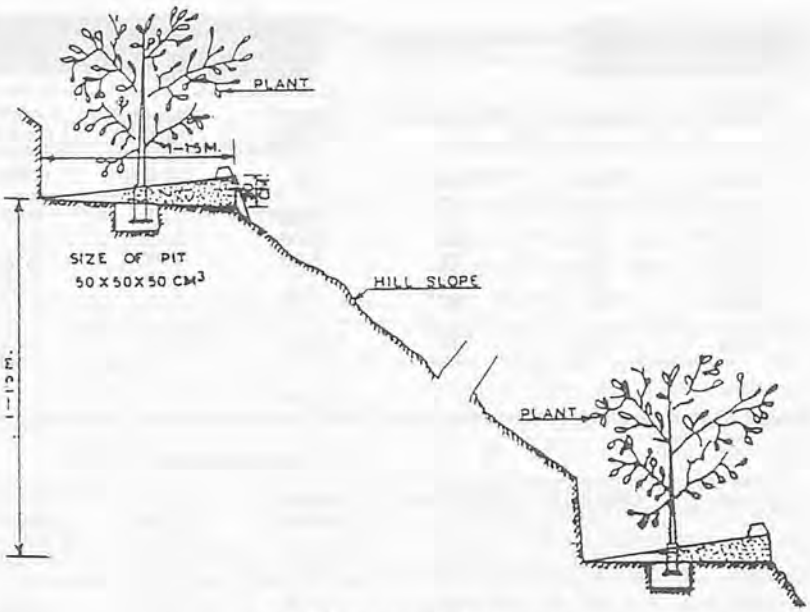

Fig. 1 Cross-section of "grandoni".

Materials and Methods

The present study was undertaken at the Soil and Water Conservation Research and Demonstration Centre, College of Technology and Agricultural Engineering, Sukhadia University, Udaipur, India in 1984-85. The objective was to estimate the cost and time requirement for hedge row planting in continuous trench on ridge line of the watershed and for the construction of gradonies with suitable tractor-drawn implements such as chisel plough and single-bottom mould board plough. These were also compared with those constructed manually by using hand tools. The pits in both methods were dug manually. The data were taken at a slope of 23% on denuded hillocks.

The proposed technique consisted of one run of tractor-drawn chisel plough (rooter) followed by one run of single bottom mould board plough for constructing a continuous trench for hedge-row planting. In the construction of gradonies three runs of tractor-drawn chisel plough each on marked contour line, 30 cm and 75 cm away from first cut, were followed by one run of single-bottom mould board plough. The chisel plough was used for loosening the land so as to enable the mould board plough to excavate and direct the excavated material towards the lower side of the gradonies to form a berm. Final shaping and dressing was one manually.

Results and Discussion

Table 1 shows the time required for chiselling, ploughing by mould board plough and manual dressing for 70 cm wide, 15 cm deep continuous trench for 60, 70, 100, 150 and 200 m long for hedge row planting on ridge line of watershed was noted. The cost of construction for these lengths of trench has also been estimated. Similarly, the time required and cost of labour for constructing 60, 70 and 100 m of trench by hand tools only have also been estimated.

A comparison of the two methods (mechanical and manual) indicates that for a 100-m long trench, the cost of construction were US$4.75 and US$9.00, respectively. The time required for mechanical operation is 7.7 hours and is 95.7 hours for manual operation for the same length of trench. This shows that mechanical method is 1.9 times cheaper and 12.4 times faster than the manual method.

Table 2 shows the time requirements for chiselling, ploughing, manual dressing and cost of construction of 23, 34, 42, 45 and 46 m of gradonies which are about 1.25 m wide and 20 cm deep. The same lengths were also constructed manually for which the required time and cost are also shown in **Table 2**. The mechanical method required 16.06 h and US$4.15 for construction of 100 m long gradonies whereas it was 99.47 h and US$9.37 for the same length when done by hand tools. This indicates a saving of 2.26 times in cost and 6.2 times in time if the mechanical method were used.

The phyllite rocks found in the area become soft when moist in rainy season and working on them with suitable implements becomes easier. In dry condition, these rocks

Table 1 Comparison of Mechanical and Manual Work for Construction of Continuous Trench for Hedge Row Planting

Length of trench	Mechanical work						Manual work	
	Chiselling	M.B. plough	Manual dressing	Cost of Tractor @ 5/h	Cost of labour @ 0.09/h	Total cost	Time	Cost of labour @ 0.09/h
(m)	(min)	(min)	(h)	(US$)	(US$)	(US$)	(h)	(US$)
60	15	14	5.00	2.42	0.47	2.89	60	5.65
70	19	16	6.00	2.92	0.57	3.49	65	6.12
100	26	23	8.00	4.08	0.75	4.83	95	8.95
150	45	33	12.75	6.50	1.20	7.70	–	–
200	49	44	7.75	7.75	0.73	8.48	–	–
580	154	130	39.50	23.67	3.72	27.39	220	20.42

Table 2 Comparison of Mechanical and Manual Work for Construction of Gradonies

Length of trench	Mechanical work						Manual work	
	Chiselling	M.B. plough	Manual dressing	Cost of tractor @ 5/h *	Cost of labour @ 0.09/h *	Total cost	Time	Cost of labour @ 0.09/h
(m)	(min)	(min)	(h)	(US$)	(US$)	(US$)	(h)	(US$)
23	6.0	1.5	6.50	0.63	0.61	1.24	22	2.07
34	7.5	1.7	5.50	0.77	0.52	1.29	32	3.01
42	10.5	2.5	5.00	1.08	0.47	1.55	43	4.05
45	13.0	3.5	7.25	1.38	0.68	2.06	44	4.14
46	11.5	3.5	5.25	1.25	0.49	1.74	48	4.52
190	48.5	12.7	29.50	5.11	2.77	7.88	189	17.79

cannot be worked upon either by hand tools or tractor-drawn implements. Thus for construction of gradonies and trench for live fence on these rocks, the best time is the rainy season when the rock is wet and soft. The Forest and Agriculture Departments start construction of these by hand tools in the rainy season and planting is done the following year at the onset of monsoon. Thus, the time for construction of such work is limited to the monsoon season. Also, the scarcity of labour in the kharif season and the lure of better employment and wages in industries leave very little scope and a slow progress of such afforestation works. An analysis of **Tables 1** and 2 shows that instead of 95.7 man-hours only 6.8 man-hours are required for the construction of 100-m long trench and 15.5 man-hours are needed in place of 99.5 man-hours for the construction of 100-m long gradonies if the mechanical method is adopted.

Conclusion

Tractor-drawn chisel plough followed by single bottom mould board plough and manual dressing for construction of continuous trench for hedge row planting on ridge line of the watershed and construction of gradonies for moisture conservation on small denuded hills and hillocks were tested. The cost and time required were compared between the mechanical and traditional manual methods. It was found that mechanical method is 1.9 times cheaper and 12.4 times faster and 2.26 times cheaper and 6.2 times faster than manual method for construction of trench and gradonies, respectively. The method was tested up to a slope of 32%.

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Asia-Pacific Regional Conference on Engineering for the Development of Agriculture.
June 5-7, 1990, Serdang, Selangor, Malaysia

The objective of the conference is to enable experts from the Asia-Pacific region to contribute their creative ideas and exchange experiences in engineering issues for the better and progressive development of agriculture. The last decade since our first International Conference on Agricultural Engineering, with it's theme, Agricultural Engineering for National Development, has passed with rapid development of the agricultural sector and the engineering contribution has certainly been at the forefront of it.

Modern engineering practices in the high technology era will undoubtedly continue to create an environment for better agricultural production. Subsequent to this conference, will be a first meeting of invited distinguished personnel on cooperation in engineering issues amongst the Asia Pacific countries. Papers are invited on the following topics:

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Oct. 31, 1989 –
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World Agricultural Expo '90
June 11-17, 1990, Hamilton, New Zealand

A major world agricultural exposition is to be held in Hamilton, New Zealand next year as part of New Zealand's celebration of 150 years as a nation. The event will be known as World Agricultural Expo '90 and will be the focus of the 22nd New Zealand Agricultural Fieldays at Mystery Creek from June 14 to 17, 1990.

Expo '90, with a promotional budget in excess of $700,000, will also feature the World Agricultural Forum to be held over the three days preceding the Fieldays. The theme of the Forum will be futuristic, looking at agriculture towards the year 2000, with an emphasis on international marketing and the continuing impact of the European Economic Community. At least 10 acknowledged world authorities on various specialist agricultural areas will be invited to speak. To be held from Monday, June 11 to Wednesday, June 13, the Forum will also link with the traditional New Zealand farmers conference and open days organized by the Ministry of Agriculture and Fisheries' Ruakura Agriculture Centre.

It was appropriate that a "celebration" of agriculture's impact on the national economy, and its contribution on an international basis, should come during an important milestone in New Zealand's history. It was also timely because of growing and renewed confidence in the agriculture sector.

For the first time in 22 years as New Zealand's premier agricultural event, the Fieldays would become a four day exhibition by opening on the Sunday. 19 countries had been invited by the Minister of Agriculture to participate. Organizers are confident that at least eight nations will become involved, providing an opportunity for New Zealanders to see at first hand the very latest in overseas trends, techniques, machinery and ag. related products. A strong New Zealand presence in the Expo area from New Zealand producer and marketing boards, the Ministry of agriculture and Fisheries and the leading dairy companies, is also expected.

With an extra exhibition day and the international focus, organizers are predicting a record-breaking attendance at leat 85,000, up from the regular Fieldays crowd of 65,000. More than 500 New Zealand exhibitors are also expected, making it the biggest event in the history of the Fieldays.

Enquiries: Gordon Chesterman,

Director, World Ag Expo, PO Box 4172, Hamilton,
Telephone: (071) 394-334
Fax: (071) 391-731

The 5th PET Training Course 'Introduction to Ergonomics'

Oct. 7 – Nov. 17, 1990, Wageningen, The Netherlands

The Joint (IUFRO/CIGR/IAAMRH) Working Group PET (Product 'Promotion of Ergonomics in the Tropics and Developing Countries') is organizing the 5th PET Training Course 'Introduction to Ergonomics' for staff members in tropical and developing countries, working in education, training, research, extension and management in agriculture, forestry and agro-forestry, who want to incorporate Ergonomics (A.: Human Engineering) into their regular job.

The Trainingcourse will be held from October 7 to November 17, 1990 (6 weeks) in Wageningen, The Netherlands.

For information write to:
the Secretary PET, F.J. STAUDT, Vakgroep Bosbouwtechniek LUW, Postbus 342, 6700 AH WAGENINGEN, The Netherlands.

IAMFE Celebrated 25th Anniversary

June 15-24, 1989, Ås, Norway

The International Association on Mechanization of Field Experiments (IAMFE) was established on June 19, 1964, at The First International Conference and Exhibition on Mechanization of Field Experiments (IAMFE '64). Its foundation was "A Plan for Efficient Mechanization of Field Experiments", which was worked out by Egil Øyjord between 1958 and 1964 and presented at the opening of the Conference on June 15, 1964. A historical review of the first 25 years of IAMFE will be published.

Gilbert L. Corey Received 1989 Kishida International Award

Gilbert L. Corey, professor of agricultural engineering at the University of Idaho Moscow, and Program Director, Pakistan Irrigation Management Systems Research Program, has been awarded the 1989 Kishida International Award by the American Society of Agricultural Engineers (ASAE).

The award was presented during the Society's 1989 International Summer Meeting, June 25-28, Quebec Municipal Convention Centre, Quebec City, Canada. The Kishida International Award is presented annully to a member of ASAE for "outstanding contributions to food and fiber production, improved living and education of people outside the United States of America."

Established in 1978, the award is sponsored by Shin-Norinsha Co., Ltd. of Japan, publisher of Agricultural Mechanization in Asia magazine and other publications. It is named after Yoshikuni Kishida, founder of the publishing firm and widely acclaimed pioneer in agricultural mechanization in Japan and Asia. Corey is presented the Kishida International Award in recognition of "his contributions in the area of irrigation management systems that have had a marked effect in improving agricultural production and rural living conditions."

Honored for the development of irrigation and water distribution, Corey's analytical approach in defining losses in on-farm systems as well as in the distribution methods has resulted in considerable increase in efficient utilization of available water. He is also cited for "his insistance in working directly with farmers in analyzing irrigation losses, an approach departing from conventional research-governments and technical assistance agencies on three continents."

Corey was named one of America's Outstanding Educators of America in 1970 and was a joint recipient of the 1977 Colorado State University Interdisciplinary Environmental Research Award for his water management research from 1970-1974. He has also authored over 30 publications.

ASAE is a professional and technical organization of members worldwide interested in engineering knowledge and technology for agriculture, associated industries and related resources. Headquartered in St. Joseph, Michigan, the Society's membership includes 11,000 members in 50 states and over 100 countries. ■■

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African Farm Management – Principles and Applications with Examples

(Ghana)

by Kwabena Asomanin Anaman

This farm management book has been written for students and teachers of agricultural science and economics in secondary schools, agricultural colleges, and universities in Africa and other regions of the tropical world. It is also aimed at agricultural extension officers and formally educated people who wish to enter farming or are already in farming. The educated children of illiterate farmers can also gain knowledge to help improve their parents' access to loans from Farmers' Banks and to keep simple records to improve the performance of the farm.

The basic concepts in the book have been carefully tailored to apply to both semi-subsistence farms and commercial farms, whether publicly or privately owned. The uses and limitations of economic theory to the production of farm commodities are stressed. Emphasis has also been placed on traditional institutions and culture, and their role in farming. The examples in this book cover farm production both in the forest and savannah zones of Africa.

Size: 8½ x 6 in, 268pp, soft cover.

Published by Ghana Universities Press, P.O. Box 4219, Accra, Ghana.

Rice Postproduction Manual

(India)

by P. Pillaiyar

The importance of minimizing, if not totally eliminating, the quantitative and qualitative losses in rice handling and processing can hardly be exaggerated. Detailed informations relating to the techniques, methods and devices of doing this is not readily available. This book attempts to fill this gap by providing a comprehensive coverage of the entire spectrum of the rice postproduction system. It offers a detailed and wide-ranging analysis of almost all the aspects of the rice-handling chain comprising harvesting, threshing, processing, drying, storage, milling etc.

It further discusses the various techniques, devices as well as the latest innovations used in rice processing, preservation and storage. The author has also described the nutrient status of rice, different types of cooking methods, the losses that occur at this stage and the techniques of utilizing brokens, husk, bran and germ for various end-uses. It serves as an advanced text book on rice technology.

With its wealth of information based on extensive scientific research and data collected from numerous sources, its analysis of every topic down to the minutest details, and in a style that is simple but vigorous, this book is a must for rice processors, producers, researchers, students and technologists as well as for the procuring and storage agencies.

Size: 24 x 15.5 cm, 437 pp, soft-cover.

Price: Rs. 45.00.

Published by Mohinder Singh Sejwal for Wiley Eastern Limited, 4835/24 Ansari Road, Daryaganji, New Delhi, India.

Japan Agricultural Machinery and Engines

(Japan)

In introduction to state-of-the art, together with general catalog.

Size: 28 x 21.5 cm, 131 pp, soft cover

Published by Japan Machinery Exporters' Association
Kikai Shinko Bldg.
5-8, Shiba-Koen 3-chome
Minato-ku, Tokyo 105, Japan

World Rice Statistics 1987

(Philippines)

This publication draws together statistics on rice production, trade, consumption, prices, and related basic information from various international and national sources.

FAO publications are used as sources of data on production, area, yield, and trade of rice. Tables on rice trade include origin and destination, tariff and nontariff measures on rice, and carry-over stocks of rice.

Size: 15 x 22.8 cm, 257pp, paperback.

Price: HDC US$13.50, LDC US$ 2.00, plus airmail (US$7.00) or surface mail (US$2.00) postage.

Published by International Rice Research Institute, P.O. Box 933, 1099 Manila, Philippines.

A Farmer's Primer on Growing Upland Rice

(Philippines)

by M.A. Arraudeau and B.S. Vergara

This book not only tells how to

use improved production practices in upland rice, it also explains why. The highly illustrated book is published by the International Rice Research Institute (IRRI) and IRAT, a French agricultural development agency. It is patterned after the classic IRRI book *A Farmer's Primer on Growing Rice*, the world's most widely published agricultural text.

But the 280-page book is entirely new. The section on insects, for example, includes dryland pests not mentioned in the first Primer: ants, termites, white grubs, and root aphids. Information on diseases, nutrient management, and cropping systems of upland rice are also included.

Almost no simple literature is available on upland rice farming, even though about 40 million farmers grow it on nearly 20 million hectares worldwide. Few upland farmers know how to use existing cultural practices to minimize cash inputs and maximize returns. Extension workers lack the background to guide them. The Upland Primer should help fill that gap.

About 90% of the world's upland rice farmers grow rice only for their own food. Upland rice farmers can seldom afford fertilizers and other inputs. Yields average only 1 ton per hectare.

But upland rice farmers could harvest a stable 2 tons per hectare by using better cropping practices and improved varieties.

At least 45 editions of the original Primer have been published in 35 languages in 22 countries since its 1979 release. Like its predecessor, the Upland Rice Primer is designed for inexpensive copublication. IRRI makes complimentary sets of text-free illustrations available around the world. Cooperators may translate, strip text onto the drawings, and print their own editions locally. IRRI does not take royalties on translations of its books published in developing countries.

Size: 23 x 15 cm, 284pp, softcover.

Published by International Rice Research Institute, P.O. Box 933, Manila, Philippines.

Potato Storage Technology and Practice — Proceedings of an International Symposium, June 27-29, 1985 Michigan State University, East Lansing, MI.

(U.S.A.)

Edited by B.F. Cargill, R.C. Brook and T.D. Forbush

This special publication brings together 25 key storage-oriented scientists to discuss the numerous variations in designs, requirements, and recommendations for potato storage in North America, Europe, Japan, and developing countries.

They attempt to justify, clarify and support the various potato storage recommendations and design requirements as influenced by local or regional environmental conditions, end use for the potatoes, varieties, nature of the land and soil, managerial skills of the people, construction materials available, environmental control, instrumentation, air handling equipment and more.

Size: 6 x 9 in, 340pp, softbound.

List price: $34.00

Published by American Society of Agricultural Engineers, 2950 Niles Rd., St. Joseph, Michigan 49085-9659, U.S.A.

Agricultural Sensors

(U.S.A.)

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by Glen E. Vanden Berg

Agricultural Sensors documents the efforts of numerous people to list and prioritize research needed to develop sensors designed especially for agriculture. New sensors and sensor technologies will allow the development of automation and optimization of agricultural production, processing, and distribution systems. While sensors are not new, their increasing importance and often special requirements in agriculture combine to make agricultural sensors an emerging field of science.

Thus, it is appropriate that Agricultural Sensors is published by an organization that has pioneered in the application of engineering principles to agriculture. As this new field of science matures, the resources of the American Society of Agricultural Engineers can be used to help guide the development process.

Size: 11 x 8½ in, 81pp, spiralbound.

List price: $35.00.

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

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b. are relevant to the promotion of agricultural mechanization, particularly for the developing countries ;
c. have not been previously published elsewhere, or, if previously published are supported by a copyright permission ;
d. deal with practical and adoptable innovations by small farmers with a minimum of complicated formulas, theories and schematic diagrams ;
e. have a 50 to 100-word abstract, preferably preceding the main body of the article ;
f. are typewritten, double-spaced, under 4,000 words (approximately equivalent to 8 pages of AMA-size paper) ; and those that
g. are supported by authentic sources, reference or bibliography.

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   vi) bibliography
b. The pages must be numbered (Arabic numeral) successively at the top center. Tables, graphs and diagrams must likewise be numbered. Table numbers must precede table titles, e.g., "Table 1. Rate of Seeding per Hectare". Such table number and title must be typed at the top center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e.g., "Figure 1. View of the Farm Buildings".
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e. Express measurements in the metric system and crop yields in metric tons per hectare (t/ha) and smaller units in kilogram or gram (kg/plot or g/row).
f. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
g. Convert national currencies in US dollars and use the later consistently.
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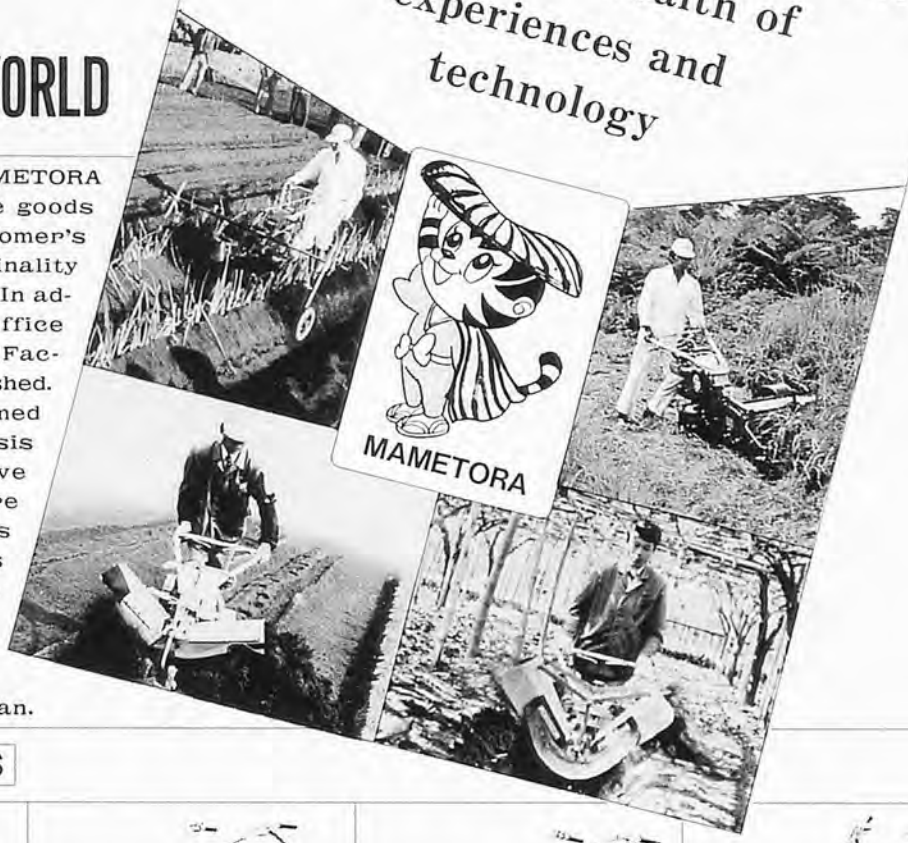

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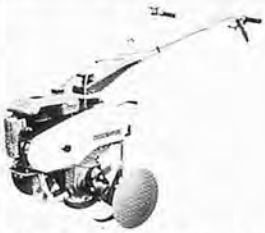

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