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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.XIII, NO.2, SPRING 1982

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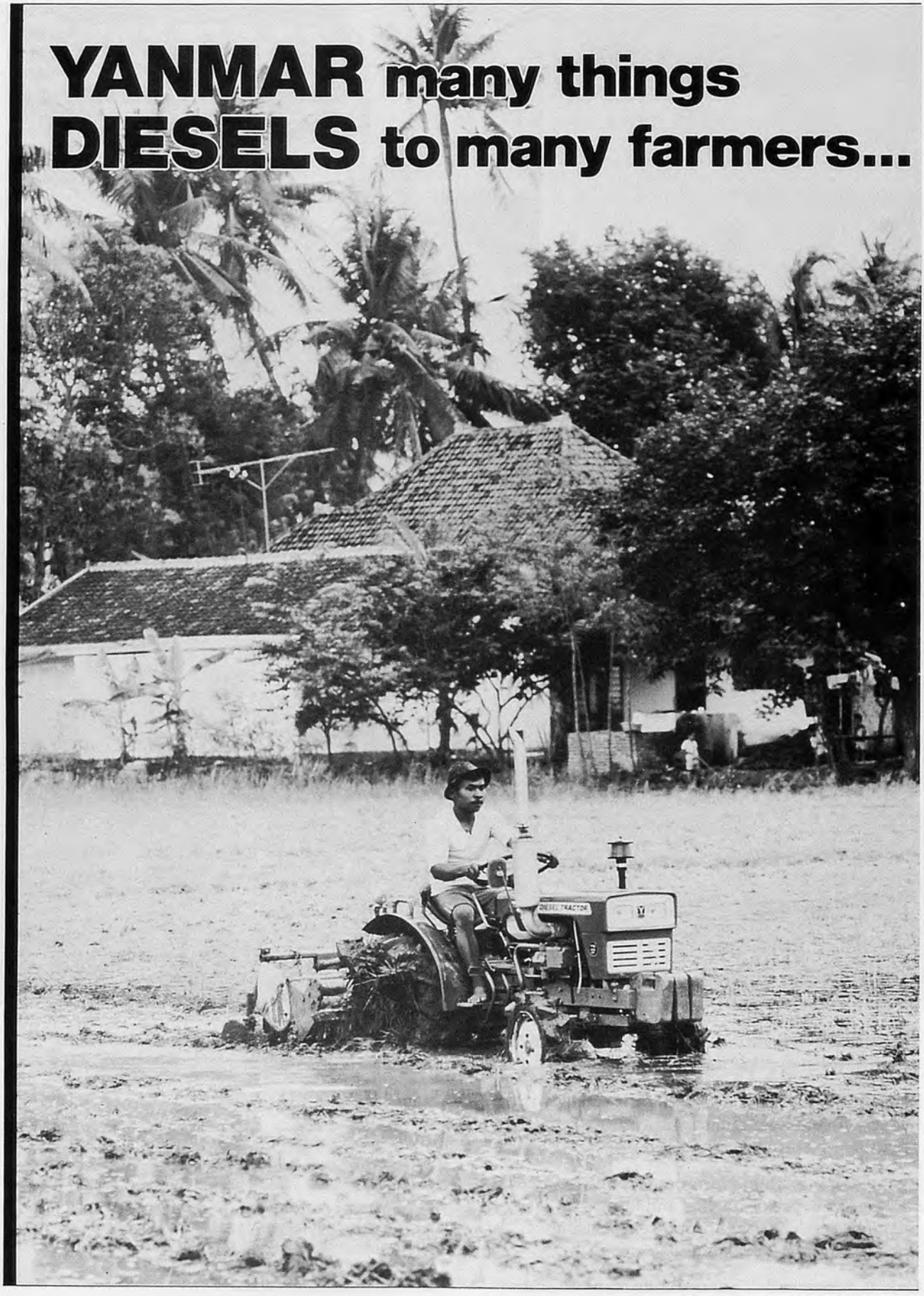
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EDITORIAL

Food Production and Farm Mechanization

A recent USDA estimate indicates that the world's production of food in 1981 increased by 3 percent over the previous year. In contrast, per capita food production declined by 1 percent annually over the last three years, particularly in West Asia and many African countries. This minimal growth rate in food production in densely populated countries continues to be aggravated by the vagary of Nature such as the development of a cold front in the northern hemisphere at the start of 1980 and the recurrence of such calamities as floods, typhoons and drought in many places of the world in recent years. This is indicative of the fact that the imbalance between the world population and the aggregate food production continues to be precarious.

To a large extent, this threat can thwarted by timely field operations through the use of appropriate farm machines. And this approach can be enchanced with the help of developed countries in the promotion of farm mechanization to the less developed and developing countries as evidenced by recent successes in agricultural mechanization in many Southeast Asian countries, notably the Republic of China, Republic of Korea, Philippines and Thailand. In these countries agricultural mechanization and the establishment of agricultural machinery industries have in recent years made remarkable headways.

A case in point is the recent establishment of agricultural research facilities in Thailand by some enterprising machinery manufacturers in Japan with the aim of designing and developing machines adapted to local conditions. This is a commendable type of technical assistance and technology transfer from a developed to a developing country, in particular relation to promoting agricultural mechanization that should accomplish tangible effects in raising the productivity levels in agriculture, hence increase in food production.

On the part of the AMA, the management will, as in the past many years, carry on the crusade of disseminating useful information on agricultural mechanization to farmers, engineers and specialists, including concerned policy-makers in the countries of the world.

Chief Editor
Yoshisuke Kishida

April, 1982
Tokyo

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Performance of a Tractor-Mounted Oscillating Soil Working Tool



by
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Abstract

An analysis of the operation of a simple harmonic, quick return and quick-cutting motions of an oscillating soil-working tool shows that the quick-cutting motion is superior to the other two-tool motions with regard to draft and power requirements at lower velocity ratios. High-oscillating speeds causing higher velocity ratios are limited by the dynamic balancing of the oscillating tools. On this basis, a tractor-mounted tillage tool oscillating with quick-cutting motion was developed. The tool was tested under actual field conditions, oscillating it at two amplitudes, two frequencies and running it at three forward speeds. The draft requirements and the soil break-up were measured during the tests.

Introduction

Many researchers have reported in the past that the oscillating tillage tools reduce draft requirements and better soil break-up compared to identical non-oscillating tillage tools. In almost all the studies only the tool motions with equal time periods for forward and backward strokes of an oscillating cycle were investigated. Verma (1971) and Smith (1972) suggest the possibility of reducing the draft requirements further by keeping the time period or wave form of the forward stroke different from that of the backward stroke of an oscillating cycle. Following these suggestions, quick return and quick-cutting motions along with the simple harmonic motion of an oscillating tillage tool were analyzed and the analytical results were verified experimentally in an indoor soil-bin by Narayanarao (1979). It was found that the draft requirements decreased sharply from a velocity ratio* of 1.0 to about 4.0 for all the tool motions. The draft requirements were lowest at any given velocity ratio for quick-cutting motion and highest for the quick-return motion. The tractor power requirements of all the tool motions were almost equal to that of an identical non-oscillating tool between velocity ratios of 1.0 and 2.0. As the attainment of high velocity ratios in a prototype is limited by the dynamic balancing of the oscillating tools, the quick-cutting motion is superior to that of the other two tool motions with regard to draft and power requirements at lower velocity ratios. Hence, a tractor mounted prototype with soil-working tool oscillating with quick-cutting motion was designed and its performance was evaluated under actual field conditions by Narayanarao (1979).

* Velocity ratio is the peak oscillating velocity of an oscillating tool in its backward stroke divided by the forward velocity of the tool carriage/tractor.

Materials and Methods

A tractor-mounted prototype with two bottoms, each comprising of an inclined blade 35 cm x 15 cm was designed and developed (Fig. 1). The kinematic linkage provided in the prototype imparted quick-cutting motion to the blades. The field tests were carried out under existing field conditions at the Agricultural Engineering Farm of the Punjab Agricultural University, Ludhiana. It was tested at three forward speeds, viz, 30.57 and 88 cm/sec., two amplitudes viz., 2 and 4 cm and two frequencies viz., 4 and 5 cps. Depth was maintained at 15 cm. The draft was measured by means of the 'Amsler' recording type hydraulic dynamometer connected between two tractors (Fig. 2). The prototype was mounted on the three-point linkage of the rear tractor and connected to its power-take-off through a telescopic shaft. The front tractor pulls the rear tractor and the

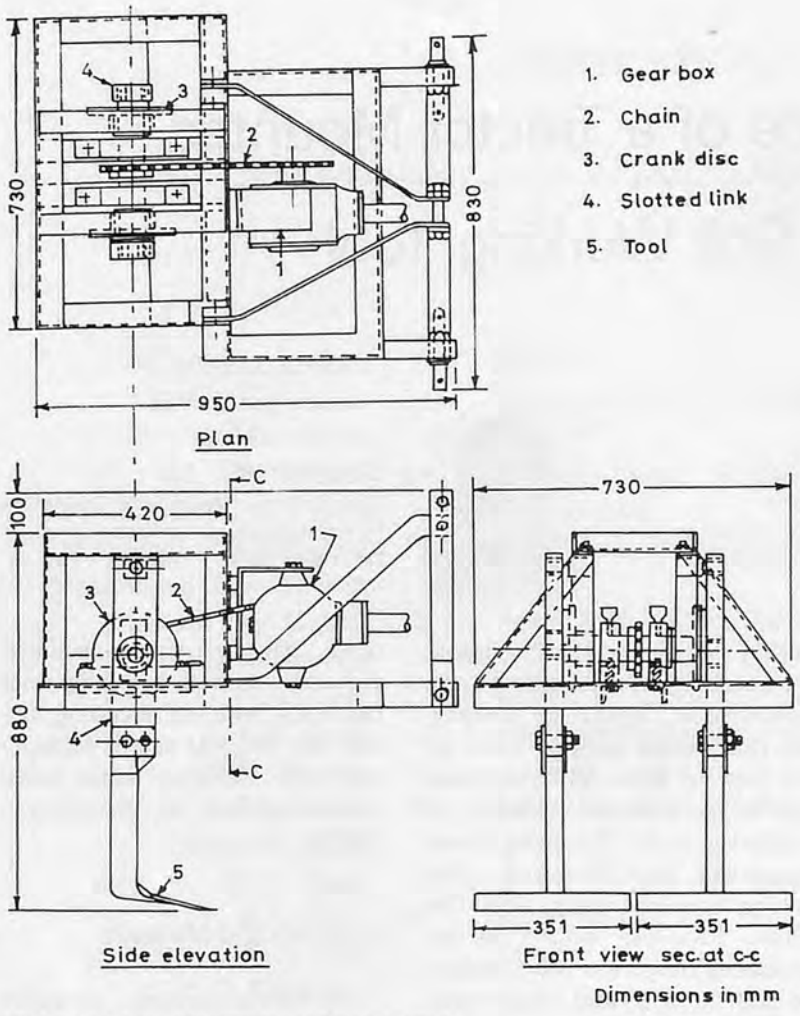


Fig. 1 Prototype of oscillating soil-working tool



Fig. 2 Draft measurement of prototype during field work. (1) Front tractor; (2) Dynamometer; (3) Rear tractor; (4) Tractor-mounted prototype.

prototype through the dynamometer at desired forward speeds. The idle draft was recorded first by keeping the prototype in the lifted position and operating the front tractor at the desired forward speed. Subsequently, the tests were carried out at the desired frequencies and amplitudes and the values of working draft were recorded. The actual draft for each test was obtained by subtracting the idle draft from the working draft. After each test, the disturbed soil was passed through a set of nested sieves and the mean weight diameter D_m of the soil aggregates was computed using equation (1) suggested by Youker and Mc Guiness (1957).

$$D_m = 0.876\, X_m - 0.079 \quad \ldots(1)$$

where

X_m = sum of the product of the mean aggregate size and the fractional weight of the aggregates in that size range

The observed draft and the mean weight diameter of soil aggregates were converted into respective ratios* and were used as parameters for measuring the performance.

The power requirements of the prototype could not be measured for want of appropriate instrumentation.

Results and Discussion

The performance of the tractor-mounted prototype with soil-working blades for quick-cutting motion was evaluated. The observed draft ratio corresponding to various oscillation parameters are shown in Fig. 3. Draft ratio decreased with an increase in frequency at all amplitudes and tractor speeds. The draft ratio also decreased with an increase in amplitude at a given frequency and tractor speed. This could be explained by the phenomenon that as the frequency and/or amplitude at a given tractor speed increase, the velocity ratio increases and the time period during which the oscillating tool cuts the soil in one cycle decreases thus reducing the frictional forces on the tool. As the tractor speed increased, the draft ratio increased at both amplitudes and frequencies studied. This is because with an increase in the forward speed, the velocity ratio decreases and the time period during which the tool cuts the soil in one cycle increased leading to an increase in the draft ratio. The general effect of the velocity ratio on the draft ratio is shown in

* Draft ratio is defined as the draft of an oscillating tool divided by the draft of an identical non-oscillating tool. On the other hand, the mean weight diameter ratio is defined as the mean weight diameter of soil aggregates produced with the oscillating tool divided by that produced by an identical non-oscillating tool.

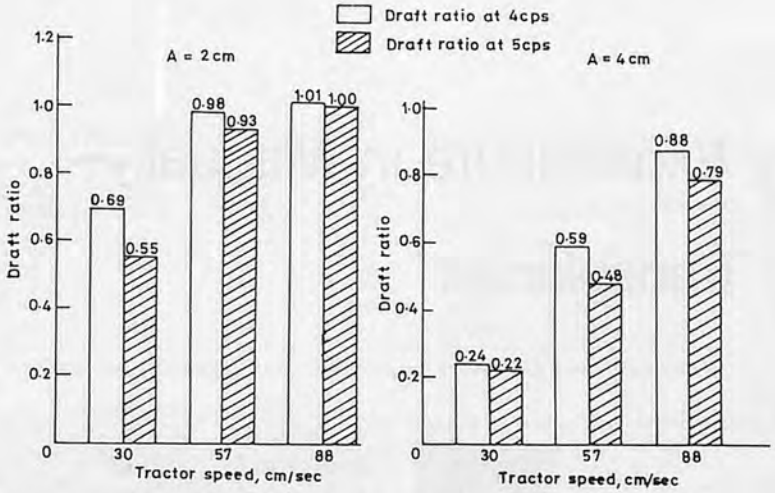


Fig. 3 Effect of oscillations on draft ratio during field testing of prototype

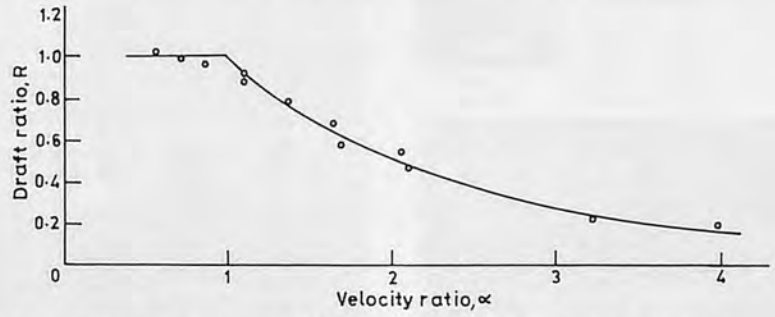


Fig. 4 Effect of velocity ratio on draft ratio during field testing of prototype

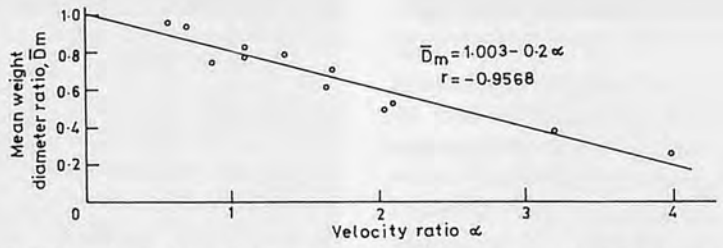


Fig. 5 Effect of velocity ratio on mean weight diameter ratio of soil break-up during field testing of prototype

Fig. 4. There was a steep reduction in the draft ratio as the velocity ratio increased from 1.0 to 3.0 beyond which the draft ratio curve showed little decrease with further increases in the velocity ratio.

The observed effect of the velocity ratio on the mean weight diameter ratio of the soil aggregates is shown in Fig. 5. The mean weight diameter of the soil aggregates decreased linearly with an increase in the velocity ratio. The soil fragmentation was better with an increase in the velocity ratio because the soil was cut at high velocities when the velocity ratio of the tool was increased.

The general pattern of soil break-up achieved in the non-oscillating and the oscillating modes of cutting with the prototype is shown in Fig. 6. In the non-oscillating mode of cutting the soil was broken mostly into bigger clods exposing the finer aggregates upward. Contrary to this, the soil was broken mostly into finer aggregates exposing the larger aggregates upward for the oscillating mode of cutting. This indicates that the oscillating tillage tool acted like a sieve as argued by Zonenberg (1968). The soil break up pattern shown in Fig. 6 also indicates that it would be advantageous to use the oscillatory



Fig. 6A Soil fragmentation after working the prototype tool with non-oscillating blade once



Fig. 6B Soil fragmentation after working the prototype tool with oscillsting blade once

mode of cutting because the larger aggregates which retard or minimize soil erosion were exposed upward covering the finer aggregates.

Conclusions

1. The draft requirements of tractor-mounted prototype decreased with an increase in the velocity ratio. The draft reduction was about 52% at an amplitude of 4.0 cm, frequency of 5 cps and forward speed of 2.05 km/h which correspond to a velocity ratio of 2.10.

2. The mean weight diameter of soil aggregates decreases with an increase in the velocity ratio.

(Continued on page 33)

Human Energy Expenditure in Manually-Operated Rice Transplanter



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Abstract

An experiment was conducted at the Bangladesh Rice Research Institute (BRRI) to determine the human energy expenditure in rice transplanting using the IRRI manual rice transplanter (model TRI) and the traditional hand transplanting method. Energy expenditure was determined by indirect calorimetry. The maximum energy expenditures were 3.79 and 3.09 kcal/min in machine and hand transplanting, respectively. However, the energy expenditure per plant was much lower in machine (0.019 kcal) than in hand transplanting (0.069 kcal).

Introduction

Transplanting rice by hand is considered as one of the most laborious operations which demands a high labor for only a few days in a season. Several countries recognize the need for design, development and adoption of a suitable transplanter for mechanizing this tedious job. Engine-driven transplanters have been designed and introduced in some developing countries in Asia. In 1977, the International Rice Research Institute (IRRI) started developing a manually-operated rice transplanter



Fig. 1 The IRRI manual rice transplanter

(Fig. 1) for small farmers keeping in view the reduction of labor requirement in terms of man-hours per hectare and the farmer's drudgery and fatigue in transplanting rice.

The adoption of machinery sometimes create new problems and lead to some undesirable consequences on the part of operators. To ensure a desirable adoption of the transplanter in Bangladesh this study was undertaken in order to assess and compare the physical work load on the operators based on physical parameters such as energy expenditure, while transplanting rice using the traditional hand transplanting method and the IRRI rice transplanter.

Materials and Methods

The experiment was conducted in October, 1980 at the BRRI experimental farm with clay loam soil. The range of penetrometer



Fig. 2 Measurement of expired air by direct readings from gas meter

readings varied from 6 to 15 cm.* This range of value was considered normal for puddled soils. Four male farm workers of approximately the same age, weight and work experience were assigned to this experiment. The workers were physically examined by a physician. Their physical characteristics are shown in Table 1. Two weeks prior to this experiment, the workers (operators) transplanted about two ha of land using both the traditional and machine methods. Thus extra energy cost due to non-familiarity with the task was minimized.

Energy expenditure was determined by indirect calorimetry. A portable open circuit respiration apparatus coupled to a dry gas meter manufactured by Parkinson and

* A drop-type, cone soil penetrometer having a cone base diameter of 3.3 cm and apex angle of 45°, and total weight of 135 g was used to describe the soil hardness. The readings were noted after 24 hours of sedimentation.

Table 1 Physical characteristics of test operators for Rice Transplanter

Test Operators	Age (year)	Experience (year)	Height (cm)	Weight (kg)	Blood Pressure	Anaemia	Heart & Lung	Liver	Average Pulse Rate at Rest (beat/min)	Resting Energy (kcal/min)
1	28	4	173	56.77	130-80	nil	NAD	NP	76	0.80
2	28	4	160	49.95	115-75	nil	NAD	NP	80	1.04
3	25	7	168	49.95	110-75	+	NAD	NP	64	0.98
4	24	3	165	49.50	105-70	+	NAD	NP	72	1.06

+ = present insignificantly; NAD = no abnormal disease; NP = nothing pertinet



Fig. 3 Collection of expired air in polyethylene bag

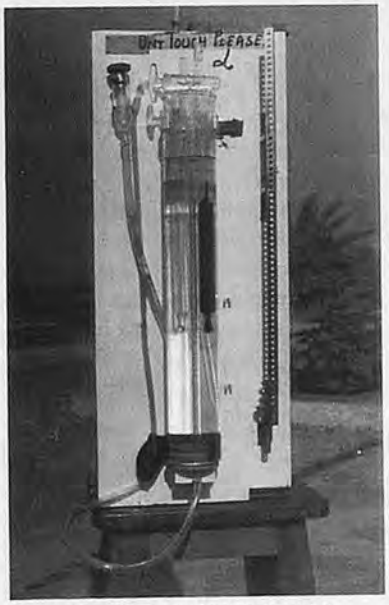


Fig. 4 Lloyd gas analysis apparatus

Cowan Measurement, Manchester, England (Fig. 2) was tightly fitted unto the operator's face to measure the expired air volume. The effect of the mask on the respiration of the operators was determined from the pulse-rate readings taken 5 min before and 5 min after fitting the mask on operator's face. Then the actual gas samples were collected.

A preliminary experiment determined the resting energy of the operators. The operators had their supper and a restful night. In the following morning expired air samples were collected 30 minutes after their arrival in the laboratory. Five 1-min readings of the discharged gas volume were recorded for energy calculation. The temperature of expired air was registered by a thermometer inserted into the delivery hose of the apparatus.

Samples of the expired air were taken in a polyethylene bag (Fig. 3) for determining its oxygen and carbon dioxide contents in the laboratory using a Lloyd modification of the Haldane gas analysis apparatus (Fig. 4).

On every test day the operators worked from 0700 to 1300 h with 1 h break from 0800 to 0900 h for their breakfast. In order to study the effect of the environmental stress, climatic data were recorded from the instruments installed at about 20 m away from the test field (Table 2).

Table 2 Weather data during the test period

Test day	Weather Element			
	Atmospheric pressure (mm Hg)	Air temperature (°C)	Relative humidity (%)	Solar radiation (g cal/cm²)
First	755.0 – 757.5	26.09 – 34.66	62 – 83.0	319.4
Second	758.0 – 760.0	22.22 – 28.89	69 – 85.5	269.3
Third	760.0 – 762.0	21.60 – 28.88	59 – 93.0	334.0
Fourth	760.0 – 760.5	21.11 – 31.11	65 – 97.0	347.2

The job assignment during the test period for each of the operators was as follows:

Test day	Operator	Transplanting method
First	1	Machine
	2	Hand
Second	3	Machine
	4	Hand
Third	2	Machine
	1	Hand
Fourth	4	Machine
	3	Hand

The following data were recorded at hourly interval during the experiment:

1. Pulse rate (beats/min)
2. Transplanting rate (hills/min)
3. Temperature of expired air during the measurement of volume (°C)
4. CO_2 and O_2 contents in the expired air (%)
5. Oral temperature of operator (°C)

From the data collected the energy expenditure was calculated using the following modified formula of Weir, 1949 (cited by van Loon, 1976):

$$E = [\ 1.05 - 5.015\ PO_2/100]\ V$$

where:

PO_2 = percentage of oxygen content of expired air; V = volume of expired air in liters/min; E = energy expenditure in kcal/min.

Results and Discussions

There were variations in the individual values of resting energy among the operators inspite of their homogeneity: equal body weights, age and sex. The values of resting energy ranged from 0.8 kcal/min to 1.06 kcal/min.

The energy expenditure per

minute was higher in machine transplanting than in hand transplanting (Fig. 5). The energy expenditure per plant, however, was much lower in machine than in hand transplanting (Fig. 6). During the first hour of operation, energy expenditure increased to a high level and tapered off to an almost constant lower level. This abrupt increase may be due to the initial warming up of the body of the operators. There were also individual variations in energy expenditure among the operators. Before resuming the work after a one-hour rest, energy expenditure decreased to about 1.4 kcal/min indicating that they were substantially but not fully rested. Again, a gradual increase with time was observed in energy expenditure in high environmental stress (high temperature and solar radiation) among the operators for both transplanting systems.

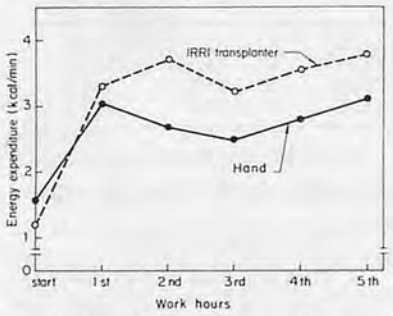


Fig. 5 Average energy expenditure of four farm workers using alternative transplanting methods (except resting hour)

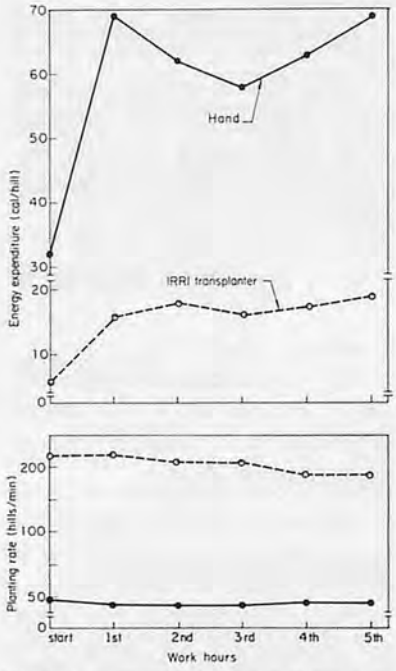


Fig. 6 Average energy expenditure per plant at average planting rate of four farm workers using alternative transplanting methods (except resting hour)

The values of resting energy (0.80 kcal/min to 1.06 kcal/min) of the operators are closely related with those of the Bangladesh laborers (0.98 to 1.06 kcal/min) reported by Ahsanullah (1974). In the present study the operators spent 1.5 kcal/min to 3.09 kcal/min in hand transplanting and 1.21 to 3.79 kcal/min in machine transplanting, while 3.09 kcal/min was required in hand transplanting as reported by Beeghly (1971) in the Philippines. However, energy expenditure using both systems did not exceed the tolerance limit (6 kcal/min, van Loon, 1976). The maximum work load of 3.09 kcal/min from hand and 3.79 kcal/min from machine transplanting falls under the range of light work load (2.5 to 5.0 kcal/min) based upon the classification made by Passmore and Durnin (1955).

Conclusions

Although the energy expenditure for operating the manual rice transplanter was higher than for hand transplanting, the energy expenditure per plant in machine transplanting was much lower than in hand transplanting. The IRRI manual rice transplanter increases the planting capability of a person without expending excess energy outside the human tolerable limits. However, even light work done with repetition may entail fatigue which can only be gauged from individual reactions on the machine use over a long period of time. By getting used to the operation, a person may also find the work not so tiring. Only with prolonged use will this be confirmed. Hence, it is recommended that extensive tests of acceptability be further done.

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Sprinkler System Evaluation: A Case Report



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Abstract

Farm water should be distributed at maximum uniformity from any irrigation system for maximum efficiency. This distribution uniformity in a sprinkler system depends on many factors, including the characteristics of the sprinkler used, operating pressure and wind speed, etc. The distribution characteristics of a sprinkler, under the expected working conditions, form an important subject from operation and management points of view.

The study was carried out on a sprinkler system at the Agricultural Experiment Station of the Agriculture College, Riyadh University in Dirab. It consists of a solid set system where water is supplied to 4 blocks (each having 36 sprinklers) at one time.

A can grid test was performed on an average sprinkler. By superimposition of the catches in various quadrants, the values of coefficient of uniformity and distribution uniformity were determined at different spacings. The best values were found at 48′ x 36′; 40′ x 40′ which gave slightly low but good coefficients. Hence, these spacings can be adopted for maximum uniformity.

The drop size diagram indicates that proper breakup of the jet is not accomplished even under maximum pressure.

Sufficient non-uniformity exists in the rotation speed of the sprinklers. The one with the maximum deviation was opened and inspected. Coarse material that usually does not pass the filter screen was detected.

The system is found to operate at low levels of distribution uniformity both at high and low wind speeds. The sprinklers in the last fourth block were under low pressure and the pattern is doughnut-shaped with radius of spread as 30′, small as compared to the spacing 40′ x 40′. Hence, a barren area is noted to surround the sprinklers in this block.

Introduction

In many cases where irrigation is practised, and particularly where sprinkler irrigation systems have been installed, water supplies are limited and the cost of water is high. It is, therefore, of paramount importance to identify the factors influencing sprinkler irrigation efficiency, to design functional equipment, methods and systems and to define the conditions for sprinkling which will lead to increased efficiencies (7). Ideally, farm water should be distributed uniformly over the entire area to be irrigated. However, a sprinkler which will do this has not been developed (3). The uniformity of coverage has been found to be influenced by such factors as rotation uniformity, speed of rotation, type of geometric pattern, pressure at the nozzle and spacing distances (5). An excessive pressure difference causes considerable non-uniformity in water application using a conventional system (4). Wind distorts the water distribution from the sprinkler nozzles, and the amount of distortion depends upon the wind speed and size of water drops (5). The uniformity item in a sprinkler irrigation system which tends to smooth out is the non-uniformity of operation of the sprinklers depending upon the turning speed irregularities, discharge between sprinklers (caused by variations in nozzle size and wear) and the trajectory angle or riser straightness (2). To secure a uniform application of water over an irrigated area, the sprinkler must be set to overlap the wet circular pattern for another sprinkler, the degree of overlapping required will vary in accordance with the sprinkler application pattern and wind conditions (5). Some sprinklers may vary in their performance characteristics, and it is important to watch for

variations in the patterns produced by presumably identical sprinklers (6).

This study was carried out to gather information on water distribution characteristics of sprinklers and, hence, evaluate the performance of the sprinkler system at the Agricultural Experiment Station of the Agriculture College in Dirab. The system employed was the sprinkler - lateral or solid - set, using the 'Toro' heads (5/32 inch nozzle and 26° trajectory angle).

Materials and Methods

Since it is not possible to have true identical sprinklers, it was decided to study the performance characteristics of a single sprinkler that best represents the entire lot. Under the same conditions of weather and pressure, the units would differ by flow rate and speed of rotation. On a still day, keeping the pressure constant, the flow rate and rotation speed from 10 sprinklers were measured and the average was determined. The head nearest to the average was taken and installed in the vicinity of the sprinkler system but outside its area of influence. A pressure gauge was put on the riser and a valve was installed on the lateral side for pressure regulation. The height of the riser was adjusted such that the centre of the nozzle was finally two feet above the top of the four nearest collectors (2).

Flow measurement – The flow was directed to a flask through a flexible hose of larger diameter than the nozzle and the time was measured with a digital stop watch. Average of at least three readings was taken.

Sprinkler pressure – The pressure was measured with a pressure gauge attached to the riser of the sprinkler.

Nozzle pressure – The nozzle pressures were taken by a gauge with a Pitot extension. When the gauge was in the direct path of the jet, maximum reading was given and which was recorded as the nozzle pressure.

Sprinkler rotation – Four quadrants were formed by putting ranging rods in four directions (north, south, east and west) with the help of a prismatic compass. The time taken by a point on the jet to travel from the central line of one ranging rod and cross the next measures the speed of rotation in that quadrant.

Climatic data – Dry and wet bulb temperature readings were taken outside the sprinkler influence area with an aspirated hygrometer. Wind speeds were measured with an integrating type anemometer, having a directional vane, at a height of two meters above ground level.

Collectors – About 200 empty quart oil cans, sharp edged and true to shape, were used. The area covered by a single sprinkler was divided into squares of equal area (6 ft x 6 ft) and the cans were placed in the centre of each square. Catch containers were also used in the area, between adjacent laterals, bounded by four sprinklers of the system.

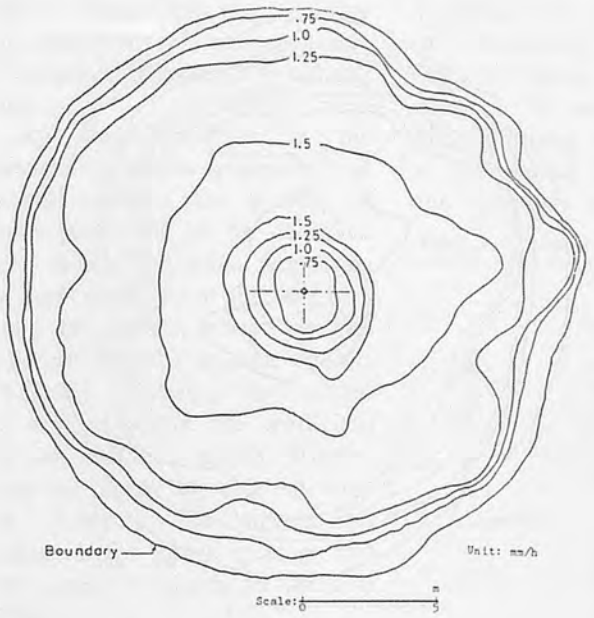
Drop size – Small cans were partially filled with flour and placed at various distances from the sprinkler. The cans were carefully removed after the sprinkler was passed over them. The diameters of the spots formed were measured. The average diameter was then determined and recorded.

Evaporation – No evaporation suppressant was used in the experiment. To minimize the effect of evaporation from the cans, the experiment was carried out during the early hours of December. A separate collector was installed to determine any evaporation taking place during the test run.

Other details – Can diameter = 3.91 inch; Volume of catch per mm depth of can = 7.75 ml; Vertical distance from riser gauge to nozzle = 2 ft (61 cm) and Riser height = 5 ft 9 in. (146 cm)

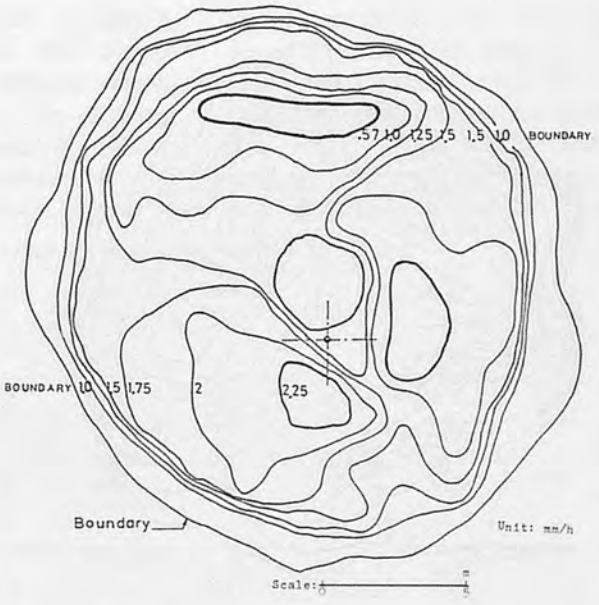
Discussions and Results

The distribution patterns under different pressure heads and wind conditions are given in **Figs. 1 to 7**. They have been drawn by converting the catch volume in the cans to depth in mm and plotting the isohyetals. A fairly good distribution takes place at a pressure of 20 psi (maximum available pressure) and an average wind speed of 2 km/h (**Fig. 1**). A tendency towards a doughnut pattern is visible in **Fig. 4** at a pressure of 18 psi (wind speed = 2.5 km/h) which enlarges as the pressure reduced to 15 psi (**Fig. 6**). Hence, the pressures below 18 psi are not at all suitable for good distribution of water. When the wind blows and the spray is on the windward side (with respect to the sprinkler), it is deflected towards the sprinkler and hence more water is deposited near it (**Figs. 2, 3, 5 and 7**). An intense storm would carry and deposit water well beyond the sprinkler, on the other side. When the spray is on the opposite side (with respect to the windward), it is thrown farther away by the wind, now blowing from the rear. However, the finer particles of the spray near the sprinkler are not thrown at the same distance as the coarser particles (or drops) outwards. This unequal travel of the drops results in a very low catch (as in **Figs. 2 and 3**) and even the zero-catch area some distance from the sprinkler (as in **Fig. 5**). Thus, under windy conditions, catch concentration takes place in the



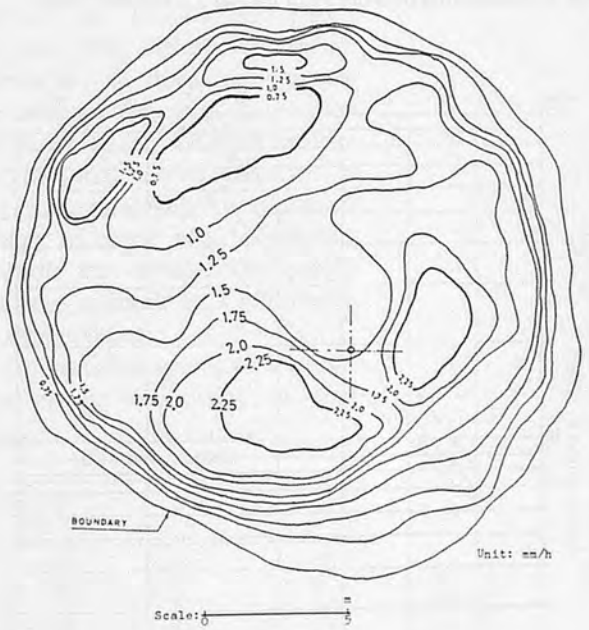
a Sprinkler flow rate, 168 ml/s
b Sprinkler rotation (Time taken in each quadrant, s: 32.1 | 32.9 / 32.2 | 32.8
c Temperature, at 9.00 AM DB = 15.5 WB = 11.5 ; RH = 60%
at 11.00 AM DB = 25 WB = 18.5 ; RH = 55%

Fig. 1 Distribution of water from a single sprinkler at 20 psi and 2 km/h wind



a Sprinkler flow rate, 187 ml/s
b Sprinkler rotation, s: 32.67 | 29.9 / 30.0 | 32.35
c Temperature, at 8.30 AM DB = 15.5 WB = 11.5 ; RH = 62%
at 10.30 AM DB = 23 WB = 17.5 ; RH = 58%
d Evaporation from nearby container = Negligible.

Fig. 2 Distribution of water at 20 psi and 3.51 km/h wind



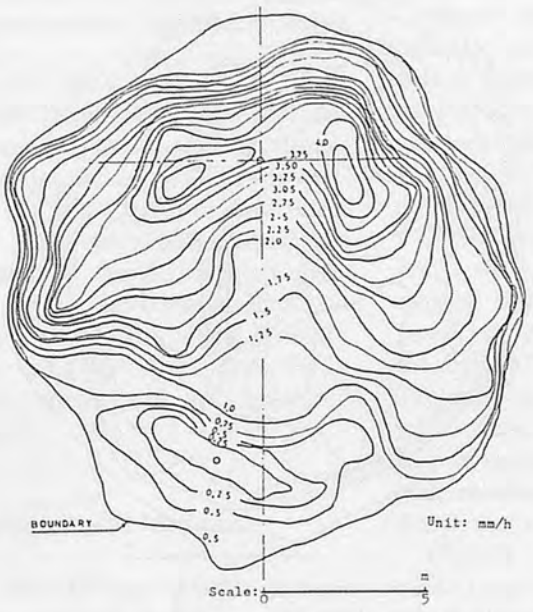
a Sprinkler flow rate, 184 ml/s
b Sprinkler rotation, s: 31.52 | 32.54 / 32.03 | 32.5
c Temperature: at 8.45 AM DB = 13.5 WB = 9 ; RH = 55%
d Wind velocity and direction = 6 km/h ; mostly S.E.
e Evaporation from extra container = Nil

Fig. 3 Distribution of water at 20 psi and 6 km/h wind



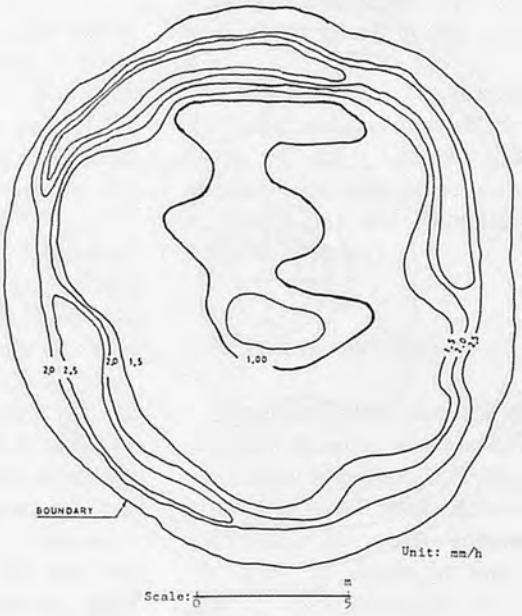
a Sprinkler flow rate, 180 ml/sec
b Sprinkler rotation, s: 36.0 | 35.4 / 35.0 | 36.39
c Temperature: at 8.45 AM DB = 8 WB = 5.5 ; RH = 70%
at 11.10 AM DB = 22 WB = 17 ; RH = 60%
d Wind speed and direction: 2.5 km/h; mostly S.E.
e Evaporation from extra container = Nil

Fig. 4 Distribution of water from a sprinkler at 18 psi and 2.5 km/h SE wind



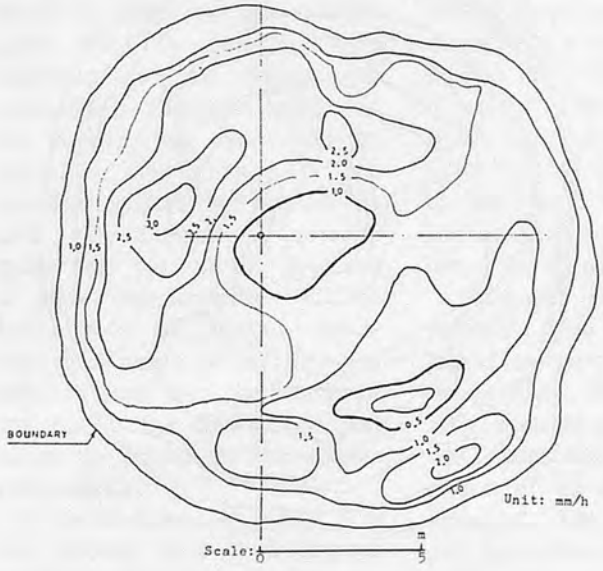
a Sprinkler flow rate, 216 ml/s
b Sprinkler rotation, s: 38.0 | 34.36 / 35.42 | 37.0
c Temperature: at 08.45 AM DB = 16 WB = 9.5 ; RH = 45%
at 10.00 AM DB = 20 WB = 12.0 ; RH = 38%
d Wind velocity = 10.5 km/h mostly North
e Evaporation from extra container = Nil

Fig. 5 Distribution of water from a sprinkler at 18 psi and 10.5 km/h northerly wind



a sprinkler flow rate, 150 ml/s
b Sprinkler rotation, s: 42.95 | 38.3 / 39.59 | 40.55
c Temperature: at 8.45 AM DB = 10.5 WB = 6 ; RH = 50%
at 9.45 AM DB = 13.0 WB = 7.5 ; RH = 45%
d Evaporation from extra container = Nil

Fig. 6 Distribution of water at 15 psi and 2.3 km/h SE wind



a Sprinkler flow rate, 178 ml/s
b Sprinkler rotation, s: 38.0 | 38.68 / 36.4 | 39.42
c Temperature: at 8.55 AM DB = 15 WB = 11.5 ; RH = 65%
at 9.55 AM DB = 19 WB = 14 ; RH = 59%
d Evaporation from nearby container = Nil

Fig. 7 Distribution of water from a sprinkler at 15 psi and 5.2 km/h westerly wind

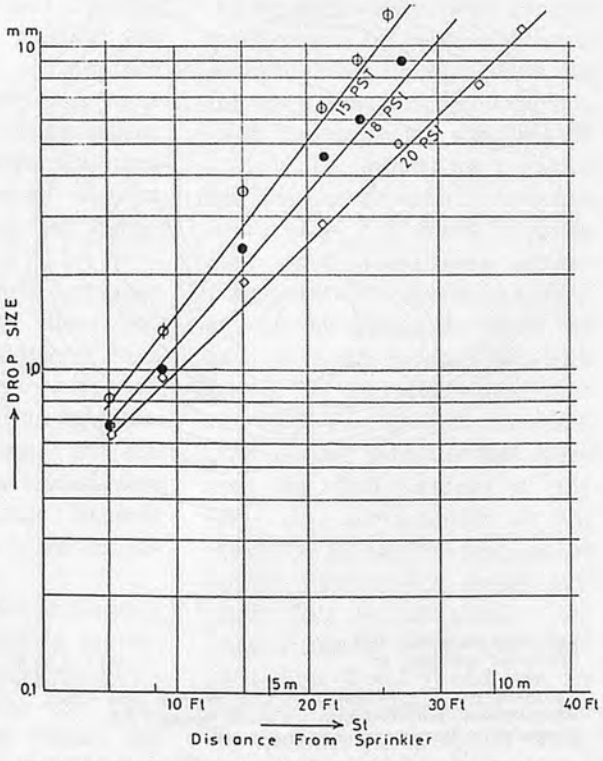


Fig. 8 Actual drop size distribution at various pressures

region surrounding the sprinkler and hence the effective catch area is considerably reduced by a strong current.

By super-imposition of the catches in various quadrants, one would arrive at the quantity of water expected to be deposited by a unit of the system (consisting of four sprinklers in the case of a solid set system, placed on two adjacent laterals) at some spacing (Table 2). Knowing the catches at various points, the coefficient of uniformity C_u and the distribution uniformity D_u were determined (Table 2). The process was repeated for other spacings and the results of which are listed in Table 1.

From the tables, it is seen that, at a lateral spacing of 36 ft, good values of D_u are obtained on keeping the sprinkler spacing at 54, 48 or 42 ft (48 being the best). Changing the spacings to 42 x 42 or 40 x 40 also results in good but slightly low values. Hence any of these spacings may be adopted for good distribution of water under solid set system.

The drop size distribution in Fig. 8 shows that the spray consists mainly of coarse particles specially towards the outside. This implies that the jet break up is not properly accomplished.

The rotation speeds of a unit of the system (consisting of four sprinklers), are given in Table 3, in comparison to the average sprinkler under different conditions. It is seen that sufficient non-uniformity exists, throughout, in the various quadrants. One of the sprinklers (No.4) is seen to run comparatively very slow repeatedly. It does not seem to be due to non-vertical or other factors (such as manufacturing variation and wear). Hence the sprinkler head was taken out for inspection and checking any possible mal-

Table 1 C_u and D_u values at different spacings

Spacing (ft)	C_u	D_u
54 x 42	67	59
54 x 36	77	67
48 x 42	77	54
48 x 39	78	62
48 x 36	81	67
42 x 42	76	63
42 x 39	76	60
42 x 36	79	67
39 x 36	77	66
36 x 36	75	67
36 x 42	76	63
36 x 48	79	66
36 x 54	78	65
42 x 48	76	55
42 x 54	72	61

Table 2 C_u and D_u values of the sprinkler at a 48′ x 36′ spacing

	0.65	1.6	1.85	1.25	1.25	–
	1.2	1.45	1.2	1.8	1.5	0.8
	–	–	–	–	–	–
	–	–	–	–	–	–
	1.85	3.05	3.05	3.05	2.75	0.8
±d* =	0.97	0.23	0.23	0.23	0.07	2.02
	1.45	1.6	1.45	1.25	0.9	–
	1.05	1.65	1.1	1.6	1.75	1.7
	–	–	–	–	–	–
	–	–	–	–	–	–
	2.5	3.25	2.55	2.85	2.65	1.7
±d =	0.32	0.43	0.27	0.03	0.17	1.12
	1.65	1.15	1.05	1.7	0.65	–
	–	1.7	1.35	1.5	1.5	1.45
	1.0	–	–	–	–	–
	–	–	–	–	0.8	0.9
	2.65	2.85	2.4	3.2	2.95	2.35
±d =	0.17	0.03	0.42	0.38	0.13	0.47
	1.35	1.35	1.95	1.7	0.05	–
	–	0.6	1.2	1.5	1.6	1.35
	1.4	1.7	–	–	–	–
	–	–	0.85	1.7	1.4	1.45
	2.75	3.65	4.00	4.9	3.05	2.8
±d =	0.07	0.83	1.18	2.08	0.23	0.02
	1.4	1.25	0.85	–	–	–
	–	–	0.65	1.0	0.8	1.1
	1.1	1.1	1.4	1.6	–	–
	–	1.1	1.45	1.2	1.0	1.35
	2.5	3.45	4.3	3.8	2.2	2.45
±d =	0.32	0.63	1.48	0.98	0.62	0.37
	0.4	0.35	–	–	–	–
	–	–	–	–	0.5	0.75
	1.95	1.7	1.05	1.65	–	–
	0.4	1.5	1.15	1.2	1.7	1.7
	2.75	3.55	2.2	2.85	2.2	2.45
±d =	0.07	0.73	0.62	0.03	0.62	0.37
	–	–	–	–	–	–
	–	–	–	–	–	–
	1.95	1.95	1.6	1.4	1.5	–
	1.05	1.75	1.2	1.6	1.75	1.45
	3.0	3.7	2.8	3.0	3.25	1.45
±d =	0.18	0.88	0.02	0.18	0.43	0.37
	–	–	–	–	–	–
	–	–	–	–	–	–
	0.65	1.8	1.85	1.25	1.5	–
	1.2	1.25	1.2	1.95	1.4	0.65
	1.85	3.05	3.05	3.2	2.9	0.65
±d =	0.97	0.23	0.23	0.38	1.08	2.17

m = mean = $\Sigma X/n = 135.2/48 = 2.82$
*d = deviation from the mean.
$C_u = 100 (1 - \Sigma d/m \cdot n) = (100 (1 - 26.12/2.82 \times 48) = 81\%$
Sum of low quarter catches (Taking 12 low catches) = 22.7
Low quarter average = 22.7/12 = 1.89
$D_u = 1.89/2.82 = 67\%$

function. Coarse material that ordinarily does not pass the filter screen was detected. On cleaning, the performance of the sprinkler improved.

The coefficient of uniformity and distribution uniformity values for the system, as computed from the can grid data, are summarized in Table 4. The wind is seen to have a variable effect on the distribution of water as it blows from different directions. Unexpectedly, the values of D_u are not quite good, being low at a pressure of 18 psi and very low at 15 psi. Recalling that the D_u values below 67 are not desirable for good distribution of water, it is seen that the system is operating at low levels of D_u at both low and high wind speeds.

On checking the nozzle pressures throughout the system, it was found that the pressures of 12 psi (which correspond to a lateral pressures of 15 psi) are quite common in the farthest fourth block of the system. This pressure is inadequate for proper distribution of water as it results in a doughnut pattern. Knowing the shape of pattern for a single sprinkler, at any pressure, the pattern for the system can be arrived at by superimposition. In this case, the single pattern is a doughnut shape with outer radius as the radius of spread (equal to about 30′ from Fig. 6). An area of about 10 ft radius around the sprinkler will have little amount of water. This is why a circular barren area is seen to surround the sprinklers of this block. The values of C_u and D_u for this block were 44% and 31%, respectively, which are very low and hence undesirable.

Table 3 Rate of rotation of sprinklers in various quadrants with respect to average sprinkler

Pressure: 20 psi 31.52 | 32.54 32.03 | 32.5		(1) 39.8 | 42.6 44.54 | 46.8		(2) 41.65 | 40.32 43.39 | 38.53	
		(3) 41.64 | 39.94 42.33 | 40.56		(4) 46.2 | 38.8 57.23 | 60.17	
Average Sprinkler Flow Rate, ml/s:	Average 184	(1) 209	(2) 202	(3) 185	(4) 178
Pressure: 18 psi 36.0 | 35.4 35.0 | 36.2		(1) 36.2 | 42.26 37.51 | 42.0		(2) 43.2 | 44.77 47.06 | 43.20	
		(3) 45.47 | 45.0 47.39 | 44.0		(4) 63.48 | 59.68 77.83 | 83.39	
Average Sprinkler Flow Rate ml/s:	Average 180	(1) 185	(2) 191	(3) 181	(4) 176
Pressure: 15 psi 42.85 | 43.48 42.49 | 43.36		(1) 47.92 | 46.99 49.08 | 50.08		(2) 57.02 | 53.85 56.54 | 50.83	
		(3) 54.90 | 52.80 55.45 | 54.27		(4) 69.05 | 58.0 73.0 | 60.76	
Average Sprinkler Flow Rate ml/s:	Average 153	(1) 160	(2) 159	(3) 158	(4) 150

Table 4 Coefficient of uniformity (C_u) and distribution uniformity (D_u) values of the system

Pressure (psi)	Wind speed (km/h)	Wind direction	Cofficient of uniformity	Distribution uniformity
20	2.7	S.E.	67.5	49
20	3.5	N	62	45
20	6.0	E to S.E.	74	60
20	5.2	S	76	63
18	2.5	N.E. to E.	66	45
18	2.5	S.E.	64	41
18	10.5	N to N.N.E.	69	50
15	2.3	S.E.	48	30
15	5.2	S.W.	60	33
15	6.2	N.E.	55	26
15	6.2	S.E.	53	32

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Application of Sprinkler Irrigation in the Sudan



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Abstract

Experimental work was conducted to investigate the application of sprinkler irrigation in the local hot and dry climate of the Sudan. Field tests and field-confined plant tests were done to study the effects of irrigation intervals and required sprinkled water on the yield of lucerne. Both higher yields accompanied by higher water use efficiency were achieved through light and frequent applications. As an innovation to the practiced surface irrigation extensively used in the Sudan, sprinkler irrigation has shown to be promising when applied on heavy - cracking clay soils.

Introduction

The impact of irrigation is well known throughout the history of mankind. Intensive utilization of both land and water resources constitute problems of major concern to many countries. In the Sudan the alloted share of the Nile's water would be able to irrigate only about 20 million acres (1) whereas about 200 million acres is the area of the potentially productive land. Thus, in the near future water and hot land would constitute a limiting factor in agriculture expansion in the country.

Innovation in irrigation practices other than the recent surface gravity methods are highly required, specially if competitive water use efficiency and higher yields are achieved. Limited field experiments and confined field tests were irrigated by sprinkler system (6) to investigate the effects of the total quantity of water and sprinkling intervals on the yield of lucerne growing on cracking soil of the hot dry climates (7) of the Sudan.

Land Potentialities

Irrigated agriculture is considered as the backbone of the Sudan's national economy. Although the country is endowed with vast cultivable lands, water for irrigation constitutes a major limiting factor. Mechanized agriculture in irrigated fields require methods of irrigation that facilitate machine manoeuvrability which is often obstructed by land excessive segmentation resulting from recent applications of small basins or segmentation and ridging as applied in the Angaia system (units of 3 000 m^2). Sprinkler irrigation method, because of its efficient control of water appears to be promising to support a great deal of vegetable and fodder-crops acreage, along the Niles bank (Gerf), islands and whenever reliable water resources exists. Vadja (3) (1966) reported that ground water does exist in many areas, such as the sand stone in Kordofan as well as in the beds of (Wadies) and khors and other natural depressions, hence pumping of this water for irrigation purpose would reason the bias selection of sprinkler or drip installations. The presence of topographic and soil type hindrances in the form of undulating lands, shallow soils, sandy or highly permeable soils, limit the surface irrigation of field crops. Nevertheless sprinklers irrigation system with its flexibility, suitability to different soil types and efficient control of water application, promises to be an important factor in the development of vast irrigated agriculture.

In hot, dry climates, the microclimate around the plants is highly improved by sprinkled water.

Water Infiltration in Heavy Cracking-clay Soils

Heavy cracking-clay soils predominates in the Sudan. Soil cracks have improved the possibility of increasing the water application rate.

Usually a clay soil has a low water intake rate of about 7.5 mm/h and moisture holding capacity of about 2 mm/cm soil depth (8).

The water intake rate of the soil is an important parameter on deciding on the sprinkler application rate. In order to achieve a fair uniformity of distribution with low water application rate, small nozzles and high water pressure have to be used to generate small droplets. Sprinkling with small water droplets would be accompanied by high evaporation losses (5). Both soils with low infiltration rate and hot, dry climate appear to discourage the use of sprinkler irrigation system in the Sudan, where the usual mean maximum monthly temperature is between 29 and 41°C, mean minimum monthly is between 12-26°C, and the mean monthly relative humidity is between 15 and 69%.

The cracks in heavy clay soils in the country encourage a higher water application rate which would decrease the evaporation losses and lead to an efficient use of the sprinkler system.

The presence of cracks in clay soils presents a special interest in the application of sprinkler irrigation. Where surface irrigation method is applied, water either percolates deep through these cracks out of the reach of plant roots or due to the velocity of water flow on the soil surface. Eroded soil particles fill the cracks which result in the reduction of the quantity of water preserved. However, when the sprinkler irrigation is applied, only gentle flow of accumulated drops find their way in the cracks to moisten the inner walls.

In the following experiments a higher water application rate of 12.5 mm/h was adopted, where no water bonding has been observed during the short sprinkling periods.

Table 1 Sprinkled lucerne: dry and fresh yield

(1 acre = 4 200 m²)

Cut (every 23 days)	Total water/ cut/acre	Confined Plants		Actual field dry yield	Correction factor	Confined plants (corrected yield
		Fresh yield	Dry yield			
	m³	(tons/acre)		(tons/acre)	%	tons/acre)
First	314	1,18	0,78	–		0,790
Sprinkling						
3 days	523	4,13	1,22	–		1,240
interval	732	4,39	1,31	1,330	101,5	1,330
Second	314	2,41	0,75	–		0.790
6 days	523	2,77	0,85	–		0,890
	732	3,36	1,07	1,120	104,6	1,120
Third	314	2,43	0,72	–		0,960
12 days	523	2,48	0,75	–		1,000
	732	2,51	0,79	1,050	132,9	1,050
Fourth						
3,	418	3,45	0,98			
6 and	418	3,00	0,82			
12 days	418	2,52	0,73	–	–	–
intervals						
Fifth	942	3,88	1,07			1,590
3 days	1 151	3,74	1,07			1,580
	1 360	3,10	0,80	1,180	1,475	1,180

Apparatus and Experimental Methods

A portable aluminum pipe sprinkler irrigation system with pump driven from the tractor p.t.o was used. Preliminary observational tests were conducted in the laboratory and field in a period of 2 years before the experiments.

The area of the actual experimental field was 340 m² (18.4 x 18.4 m), coefficient of uniformity of water distribution was 65%, size of nozzles used was 4.4 mm and the pump water pressure was 3.16 kg/cm². The difference between the highest and lowest field spots within the experimental area was 7 cm.

Three, 6- and 12-day watering intervals and varying quantities of applied water per cut were compared as indicated in **Table 1**.

As for the field - confined plants tests, 18 metal tins of 25 x 25 x 35 cm, with both ends opened were set at upright position and buried 10 cm in the soil.

Varying quantities of sprinkled water were achieved during the non-stop sprinkling on the whole plot by covering the tins with plastic covers, which were removed soon after the whole irrigation time terminated.

Plants in test tins were of equal population-density. Lucerne (*Medicago sativa* L.) (2) of the local cultivar Higazi were sown by hand at a rate of 18 kg/acre (4 200 m²).

After the crop-establishment period terminated in 50 days, watering treatments were carried out, where manual cutting was done every 24 days from the date of the first watering.

Samples of the field plot were taken at random by using a square sampling frame. All plants in the test tin were cut, with 5 replications in order to determine the yield of a specific treatment.

A correction factor has been established to indicate the yield correlation as computed from plants in the actual field plot and those collected from confined tests subjected to equal treatment.

Results

The actual sprinkled plot and effects of sprinkling intervals are shown in **Table 1** and **Fig. 1**. The yield of lucerne in the sprinkled plot was computed under a constant quantity of water of 732 m³/acre/cut sprinkled at 3-, 6- and 12-day intervals on three successive cuts. (9). The shortest sprinkling interval yielded the maximum fresh and dry weights.

The results of field-confined test and effects of sprinkling

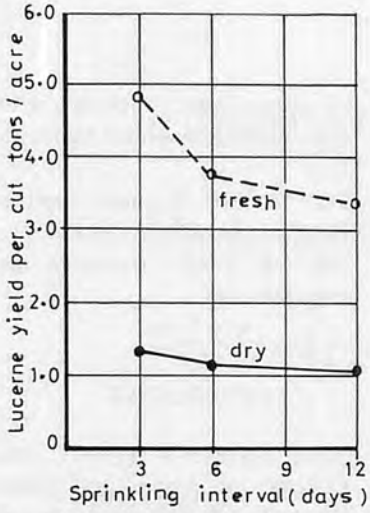


Fig. 1 Effects of sprinkling intervals on yield of lucerne on field plots

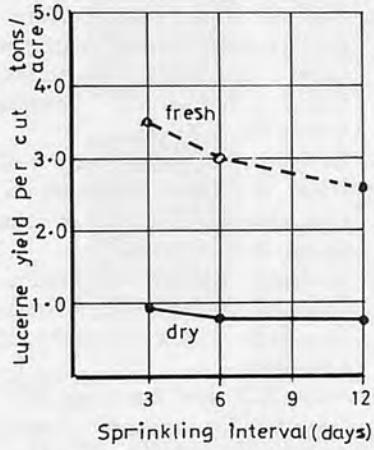


Fig. 2 Effects of sprinkling intervals on yield of lucerne, field confined test

intervals are shown in Table 1 and Fig. 2. The yield of lucerne in the field-confined test was computed, under a constant quantity of water of 418 m^3/acre/cut sprinkled at 3-, 6- and 12-day intervals during the same cut. The shortest sprinkling interval yielded the maximum fresh and dry weight.

For the field tests the results of the different sprinkling intervals and quantities of sprinkled waters are shown in Fig. 3. The volumes of sprinkled water of 314, 573 and 732 m^3/cut/acre were distributed according to the program of 3, 6 and 12 intervals, each on separate cuts. The shortest sprinkling intervals of 3 days resulted in the highest yield with the three levels of volume of sprinkled water.

The water use efficiency of the

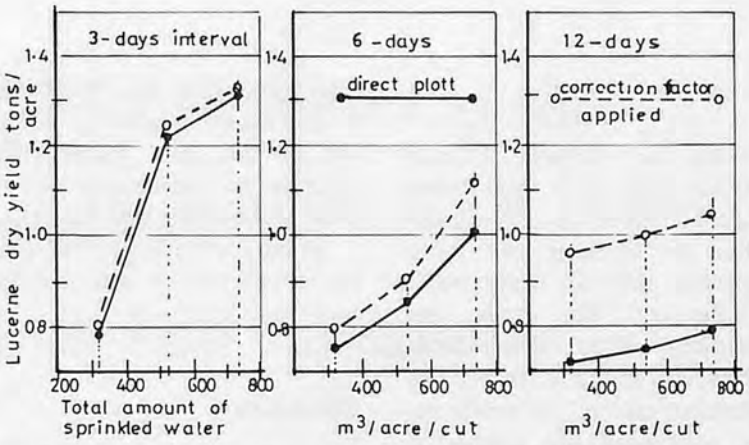


Fig. 3 Effects of varying quantities of sprinkled water and sprinkling intervals on yield of lucerne, field tests

Table 2 Water use efficiency and dry matter weight per unit water volume kg/m^3

Cut and month	Sprinkling interval	Total water/ cut/acre (m^3)	Equivalent Dry matter: water head/day (mm/day)	Equivalent Dry matter: yield/acre (kg)	Dry matter per unit water volume (kg/m^3)
(A) Confined plant test					
First	3 days	314	3,10	780	2 484
April		523	5,25	1 220	2 333
		732	7,25	1 310	1 790
Second	6 days	314	3,10	750	2 389
May/June		523	5,20	850	1 625
		732	7,25	1 070	1 462
Third	12 days	314	3,10	720	2 293
June/July		523	5,20	750	1 434
		732	7,25	790	1 079
Fourth	3 days	418	4,15	980	2 345
July/Aug.	6 days	418	4,15	820	1 962
	12 days	418	4,15	730	1 746
Fifth	3 days	942	9,35	1 080	1 146
Aug./Sept.		1 151	11,41	1 070	0 930
		1 360	13,50	800	0 588
(B) Actual field plot yield					
First	3 days	732	7,25	1 330	1 817
Second	6 days	732	7,25	1 120	1 530
Third	12 days	732	7,25	1 050	1 434
Fifth	3 days	1 360	13,50	1,180	0,868

actual field test and field - confined plants tests shows that the efficiency of water use indicates the weight of dry matter of lucerne which could be produced by the unit volume of sprinkled water (Table 2).

The short interval light watering method was most efficient where the maximum efficiency achieved was 2,484 kg dry lucerne for each cubic meter of water used.

Observations

1. Sprinkled drops wet the bare clay clods very smoothly with some disintegration of its structure.

2. Powder-like soil tilth when sprinkled has the tendency to form soil crusts (10) which impede seed germination. To encourage seed germination, short interval sprinkling is required.

3. Cracks in heavy clay soils were observed to accept higher water application rates of 12.5 mm/h in comparison to 7.5 mm/h as recommended for clay soils without cracks.

4. After sprinkling, the soil under crop remains fluffy after drying with excessive fine cracks and minimum wide cracks, unlike irrigated soils which show crusts on the top and soil compaction under the surface.

Discussion

With the available limited sprinkler apparatus, trials were conducted based on the possibilities of increasing the water application rates for heavy cracking clay-soils. The study was undertaken after observational trials which indicated that a low application rate of 7.5 mm/h applied with small size nozzles of 2.3 mm is inadequate to support the crop under test. It was found that a water application rate of 12.5 mm/h is more favourable for sprinkling on heavy clay cracking soil, under the existing hot and dry conditions of the tropics.

Frequent sprinkling of 3-day intervals of 7.25 mm/day is associated with the highest yield of lucerne fodder. The best computed yield of 4.4 tons/acre/cut is comparable to 3.5 tons/acre/cut achieved by El Amin (4), in the same locality and season, but with surface irrigation methods applied at 7-day intervals.

However, when the sprinkling interval was increased from 3 to 6 to 12 days, the yield of lucerne was drastically reduced to about 50% dry matter.

The yields of lucerne irrigated by the sprinkling method of the high river flood (July/August/ September) were appreciablly low. These findings are comparable with the work of El Amin (1976) who found that low yields obtained during the season June/ September is a known seasonal trend during humid months (rainy season) in this part of the tropics.

Soil crusting due to sprinkling on bare soils represents a real problem, specially for the germination of dicotleydonous plants. Crusting problems after sowing and during germination are overcome by preparing a relatively rough soil structure with minimum powder particles. The adoption of short irrigation intervals during crop germination was found also to be effective against the formation of soil crust, which would facilitate the penetration of the plant embryos through the crust.

An optimum efficiency of water use is achieved by light but frequent irrigations.

Conclusions

1. There is a wide scope for using the sprinkler irrigation as a main or supplementary method to grow different crops in the Sudan.
2. Field trials and field-confined plants tests have produced competitive yields of lucerne when compared by the traditional methods prevailing locally.
3. Although adopting sprinkler irrigation practices require high initial capital investment, accompanied by high running costs, it is still considered as a new approach which would allow further mechanized farm operations, specially for harvesting, where the problem of labour scarcity is being felt.
4. Cracking clay soils are efficiently irrigated with the sprinkler method at the rate of 1.25 cm/h.
5. Light frequent sprinkler applications after sowing and during germination limit soil crust formation.
6. Irrigations of 732 m^3/acre/ 24 days cut, applied by the sprinkler system at intervals of 3 days between irrigations gave the best yields.
7. Short irrigation intervals of 3 days with the heaviest amount of water/acre/cut of 942, 115 and 1 360 m^3 was associated with depressed yields.
8. The longest irrigation interval of 12 days was associated with about 50% reduction in yields.
9. The highest efficiency of water use (dry weight of material produced by one cubic meter of water) was obtained with light irrigations applied frequently.
10. Due to light frequent applications of sprinkler irrigation, the soil was found friable in the irrigated crop.

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Influence of Selected Seedling Mat Parameters and Planting Speed on Performance of Rice Transplanter



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Abstract

A rice transplanter using the mat-type of seedlings was evaluated in the laboratory to optimise the seedling mat parameters and planting speeds in respect of power and mat area requirements, number of seedlings per hill and of missing hills. In the study, a rotary circular soil bin was developed and the transplanting unit mounted over it. The tests were conducted at 4 levels of seedling age, 4 levels of mat moisture, and 3 levels of planting speed for two soil types.

The maximum variation in net power requirement for cutting the seedling mats, mat area requirement and plants per hill were .008 to 0.109 HP, 275 to 450 cm^2/100 strokes and 5.6 to 9.1, respectively. The effect of different parameters on missing of hills was not significant. Rice seedlings up to 30 days old grown in any of the two soils used in the study of moisture varying from 10 to 15% could be used to reduce the mat consumption and number of seedlings/hill.

Introduction

The importance of paddy cultivation in Punjab as well as in India has considerably increased with the introduction of high yielding varieties. The area planted paddy in Punjab in 1979 increased to 0.857 million ha from 0.4 million ha in 1971 and is expected to increase further. In India, the transplanting of this crop completely depends on manual labour which is most tiresome and labour consuming. Therefore, the need for paddy transplanters is being increasingly felt for convenient, timely and better quality of transplanting. An efficient paddy transplanter, however, is yet to be introduced in India.

In Japan, the transplanters using mat type seedlings have completely replaced transplanters using washed root seedlings due to their better performance and lesser labour requirements (5, 6, 7). Tests conducted on a manual paddy transplanter using washed root seedlings, have also indicated similar results (1). Field trials on tractor-mounted paddy transplanter using mat type seedlings show that the mat condition affects its performance to a great extent (2, 9). Seedlings above 25 cm height posed problems in the working of the machine and also sustained damage at the time of transplanting. Seedling height of 25 cm which could be achieved in 20-30 days was found to be most suitable. Moisture content was also reported to be a very critical factor affecting the performance of a transplanter. Higher moisture of seedling mats caused higher mat consumption and greater number of plants/hill. A dry mat, on the other hand, poses considerable resistance while being cut/picked by the fingers causing mechanical failures. No optimum moisture content was,

however, reported.

Similar problems were observed with these type of transplanters in Malaysia (3). Missing hills increased from 11.5% to 17.1% corresponding to increase in speed from 1.08 to 1.44 km/h. This might have been due to increased planting speeds at higher forward speeds. Mat density of 2 seedlings/cm^2 was recommended in the same study. It was also reported that seedling mats with 50% soil at the top layer and 50% carbonized husk at the bottom layer gave the best transplanter performance.

The above mentioned problems are not encountered in Japan because artificial soil is used for raising seedling mats under controlled conditions. Moreover, the technique for raising seedling mats has also been fully mechanized to achieve uniform plant density (8). Adequate information on the optimum seedling mat conditions for natural paddy soil is not available. This information is important to design the transmission system, jaw clutch and for achieving better transplanting performance. Therefore, the present study was conducted with the following specific objectives:

1. To study the effect of seedling mat parameters like moisture content, soil type and seedling age and planting speed on the performance of a paddy transplanting mechanism using mat type seedlings.

2. To determine the optimum seedling mat conditions for efficient field operation of the transplanter on the basis of the results achieved under objective in item 1 above.

Materials and Methods

Description of experimental set up

The single transplanting unit for mat type seedling used in the study is shown in **Fig. 1**. It consists of a planting mechanism, trays, tray moving arrangement and mat pusher

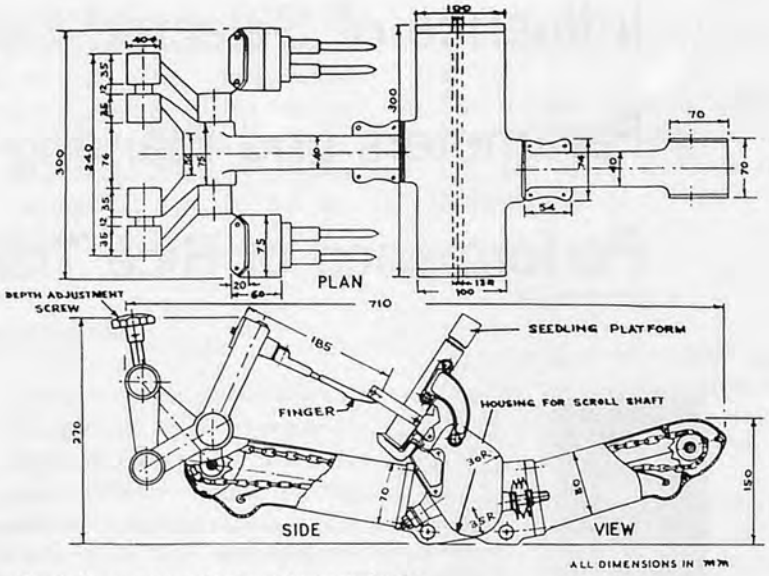
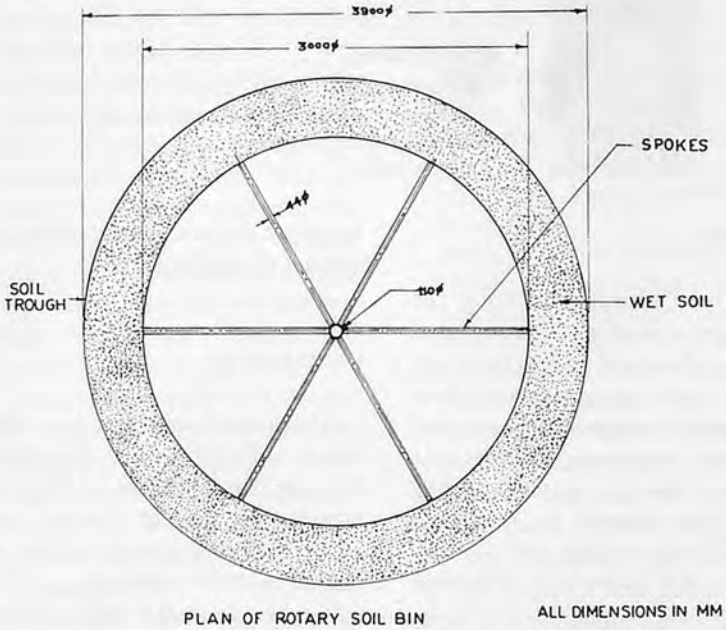


Fig. 1 Perspective of the paddy transplanter



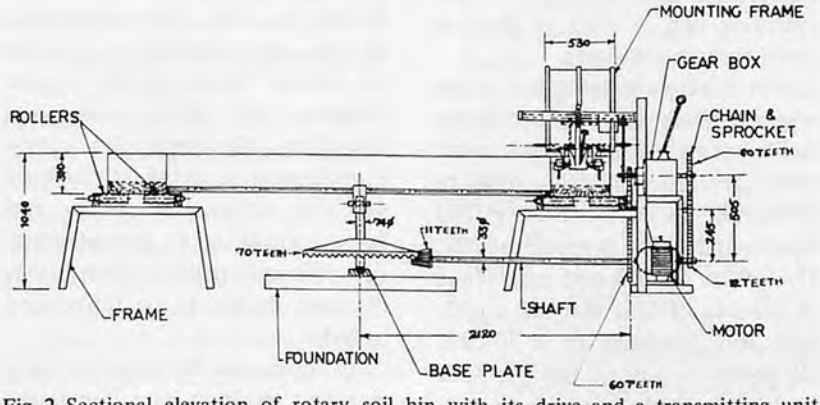


Fig. 2 Sectional elevation of rotary soil bin with its drive and a transmitting unit mounted on it.

mechanism. A pair of fingers are fitted on each planting arm and activated by the rotary motion of the crank shaft through cam, push rod and pair of spring loaded pinions. The finger tips follow an elliptical path during one revolution of the crank shaft. The fingers come closer just before hitting the mat and get a part at the lower most point thus releasing the seedlings in the puddled soil. The process of planting is continuous as the seedling tray moves to and fro over rail by the scroll shaft. The lateral movement of the tray is 1.5 cm per planting cycle. A mat pusher pushes the mat downward at the beginning of each stroke of the seedling platform. The tray angle was fixed at 60° w.r.t. horizontal for smooth downward flow of the mat. The stroke of the planting arms was fixed at mimimum in order to detach a minimum number of plants per hill.

As the study was conducted in the laboratory, a rotary circular soil bin was developed to simulate the field conditions. A view of the circular soil bin with a transplanting unit mounted on it is shown in Figs. 2 and 3. This was done to determine the power requirement of the transplanter, seedling mat area requirement, average number of seedlings per hill and missing hills. The linear peripheral speed at the centre of the bin trough can be varied from 0.96 to 3.85 km/h with the help of a gear box. The soil bin as intended could not be used due to the whirl motion of water at high speeds causing disturbance to the planted hills. Only puddled soil without any standing water was kept in the bin below the lowest point of the fingers to avoid any sticking of the soil with the fingers in the absence of water. A torque transducer of 5 kg/m was mounted on the shaft of the transplanter to measure its power requirements under idle operating conditions and during transplanting operations. The



Fig. 3 Transplanting unit mounted on the soil bin.

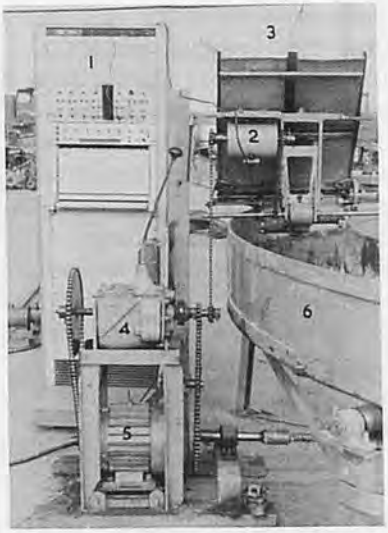


Fig. 4 Measurement technique of power requirements: 1 – 8-channel recorder; 2 – Torque transducer; 3 – Transplanting unit; 4 – Gear box; 5 – Motor; 6 – Soil bin.

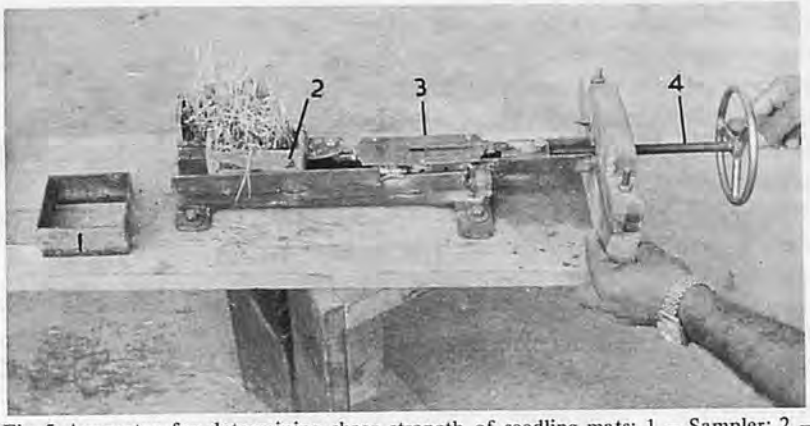


Fig. 5 Apparatus for determining shear strength of seedling mats: 1 – Sampler; 2 – Shear box; 3 – Spring balance; 4 – Nut and screw arrangement.

power requirements were recorded on a 8-channel recorder as shown in Fig. 4. An attempt was made to characterise the mat strength by various indices like cone index, modulus of rupture, tensile strength and shear strength. Cone index, modulus of rupture and tensile strength was not suitable because of limited thickness of the mat. In order to determine the shear strength, an open box of 7 × 7 × 2 cm cut into two halves from the middle was made, one half of which was fixed and the other moved with the help of a nut and screw arrangement through a spring balance of 35 kg as shown in Fig. 5.

Preparation of seedling mats

Two common types of paddy soils in Punjab were used for growing the seedling mats: sandy loam and sandy clay (4). Pre-germinated seeds 100 g of the IR-8 rice variety were used for each tray of 600 cm × 225 m × 20 mm for achieving a minimum plant density of 2 plants/cm^2. The seedlings between the age of 20-40 days and a mat moisture content range of 10-25% on dry basis were used. The seedlings below 20 days were not fully developed while seedlings above 40 days wrapped around the planting arms. Mats below 10% moisture content broke into pieces during

transport while those with more than 25% moisture buckled and fell on the trays (2, 9). The desired mat moistures for the studies were obtained by saturating the mats with water followed by different periods of sun drying. Mat moisture contents at regular intervals were measured with infrared quick-moisture meter to assess the mat drying rates and to achieve desired moisture content level.

Evaluation procedure

The study was planned with a split design with seedling age (A) as main factor, mat moisture (M) as subfactor and planting speed (N) as sub-subfactor for two soil types S_1 and S_2. Each experiment had two replications. Two mats, each one type of the soil were placed over the transplanting unit at one level of moisture content according to the design of the experiment. The gear was then put at the required position and the motor was started. After 2-3 minutes, the clutch of the transplanter and the 8-channel recorder connected with the torque transducer were put into operation. Performance tests for determining the mat area requirements, number of plants per hill and missing hills were conducted by 45 planting strokes, since full width of the mats was sheared off in this duration when the tests were started from one end of the seedling mat. The mat area requirements were determined by marking the position of the top of the mat on the platform before and after the test duration. The number of plants per hill were counted in every seventh hill during the test duration and the average taken. Maximum torque at no load and load, seedling mat area consumed, number of seedlings/hill and missing hills were recorded simultaneously by the methods already explained at different planting speeds. Moisture content above 25% caused problems like buckling while at less than 10% the mats crumbled during transport.

Results and Discussion

Table 1 indicates the effect of the variables on net-power requirement, mat area requirement, number of seedlings/hill, missing hills and mat strength at 5% level of significance.

Power requirements

In general, the net power requirements increased with an increase in seedling age, planting speed and with a decrease in moisture content of seedling mats for both soils S_1 and S_2 as shown in **Fig. 6**. The effect of seedling age is more predominant in soil S_2 than in soil S_1 at higher moisture contents and at higher planting speeds. The maximum variation in power requirements

Table 1 Statistical significance of the studied parameters

Source	Power requirement		Mat area requirement		Average no. of seedlings/hill		Missing hills		Mat strength	
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
A	*	*	–	–	*	–	–	–	*	*
M	*	*	*	*	*	*	–	–	*	*
N	*	*	*	*	*	*	–	–	–	–
A x M	–	–	–	–	–	*	–	–	*	–
A x N	–	*	–	–	–	–	–	–	–	–
M x N	*	*	–	–	–	–	–	–	–	–
A x M x N	–	–	–	–	–	–	–	–	–	–

* Significance at 5% level

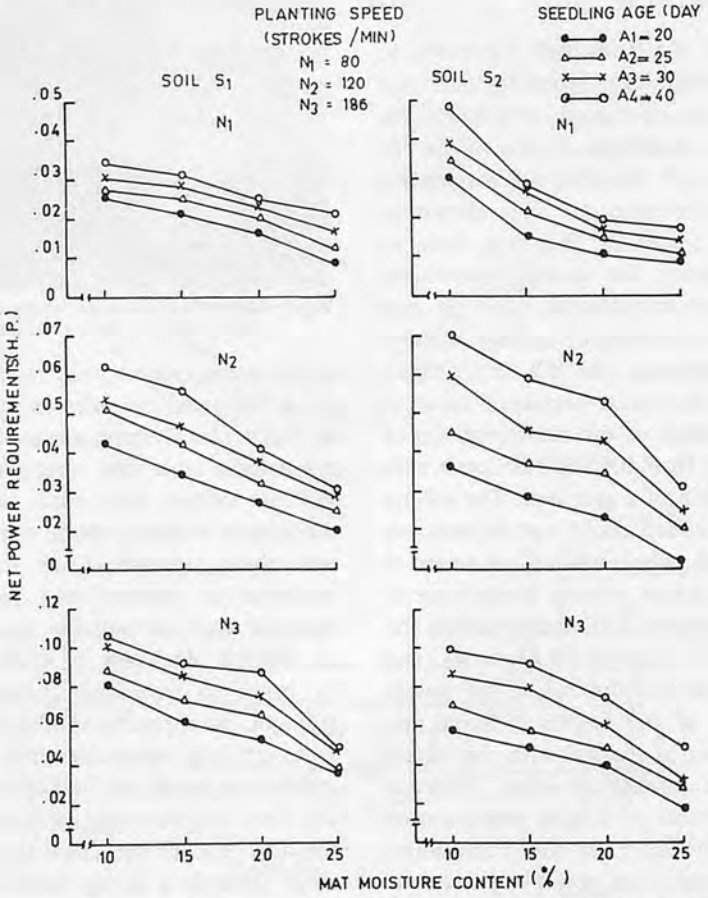


Fig. 6 Effect of mat moisture content on net power requirements of transplanter at different seedling age and planting speeds.

due to seedling age was from .052 to .087 HP for soil S_1 at 186 strokes/min and 20% moisture content. The variation for soil S_2 was from .057 to .109 HP at 186 planting strokes/min and 10% moisture content. The increase in power requirements due to seedling age might be due to the development and entangling of the roots. The power requirements at 25% moisture content is for soil S_2 than S_1 but increases with the decrease in moisture content and is predominantly more than in soil S_1 at 10% level. The reason for this may be that the mat strength variations due to moisture content level were more for soil S_2 than in soil S_1 which was sandy loam. The maximum increase in power requirements due to moisture content was from 0.048 to .106 HP for S_1 and .048 to .109 HP for S_2 for 40-day old seedlings at 186 planting strokes/min. The variation is due to the fact that with an increase in moisture content the strength of the mat decreases.

The effect of planting speed on power requirements was negligible for the two soil types. The maximum variation in power requirements due to the effect of planting speed was from .034 to .106 HP for soil S_1 and .048 to .109 HP for soil S_2 at 10% moisture content for the 40-day old seedlings. The increase in power requirements with planting speed can be attributed to the increase in the cutting torque.

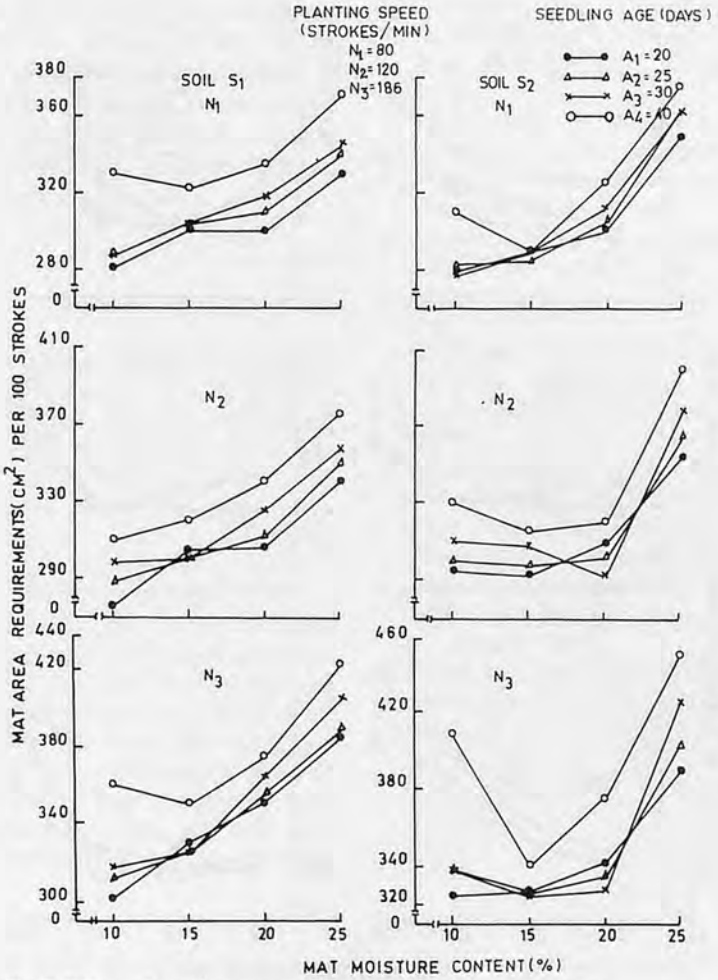


Fig. 7 Effect of seedling mat moisture on mat area requirements at different seedling age and planting speeds.

Seedling mat area requirements

The effect of seedling age on mat area requirement was not significant at 5% level for both soils S_1 and S_2. This might be due to a similarly non-significant variation in the mat condition where the increase in moisture content (except for the 40-day old seedlings) of 10-15% tended to decrease (Fig. 7). This decrease was more predominant for soil S_2 and at planting speed of 186 strokes/min. The maximum increases in mat area requirement due to mat moisture variation were from 317.5 to 405 cm^2 for soil S_1 and 337.5 to 425 cm^2 for soil S_2 for 30-day old seedlings and at planting speed of 186 strokes/min. The mat area requirements were greater in soil S_2 than soil S_1. The former has less frictional resistances to the sliding of mats which contain large amounts of clay. The increase in mat area requirement at high moisture content was due to faster sliding of the mats on platform. On the other hand, the increase in mat area at low moisture contents was due to the mat crumbling and non-uniform cutting of the seedling mats.

The mat area requirements increase in planting speed for the two soil types except for a minor decrease up to a planting speed of 120 strokes/min. The variation in mat area requirement was greater at high planting speeds and more so in soils S_2 using 40-day old seedlings at 10% moisture content. The maximum variation in mat area requirements due to planting speed was from 375 to 450 cm^2 for soil S_1 and 370 to 422.5 cm^2 for soil S_2 at 25% moisture content using 40-day old seedlings. This is because greater vibrations at higher speeds tend to increase the downward movement of the mats.

Density of seedlings per hill

The number of seedlings per hill increased with an increase in seedling age, mat moisture and planting

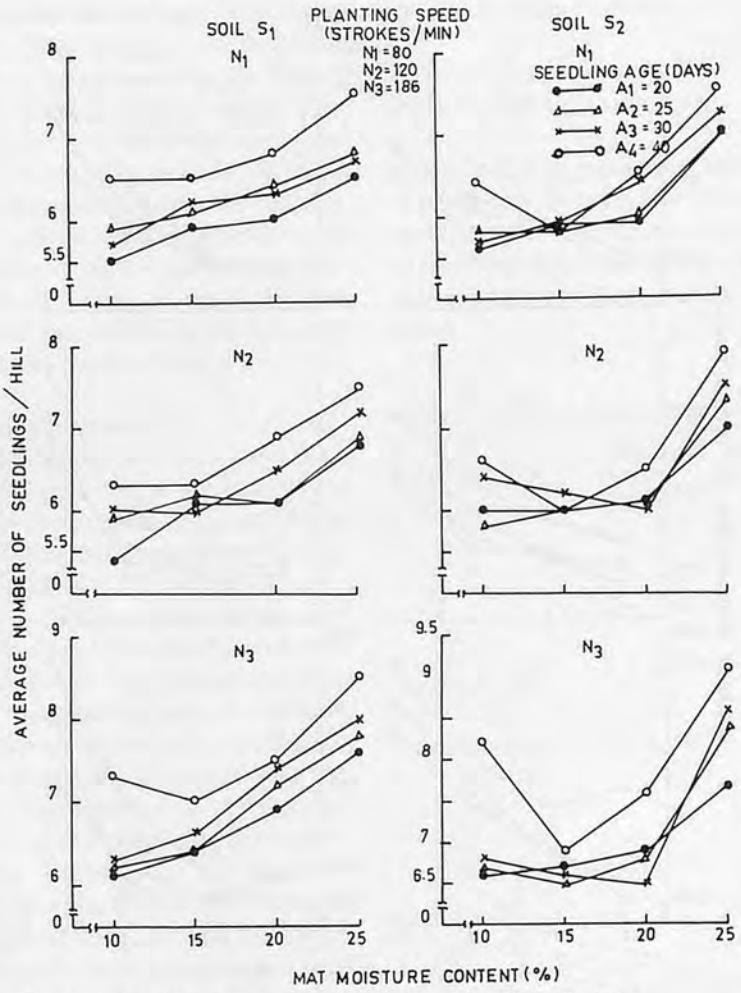


Fig. 8 Effect of moisture content on average number of seedlings/hill at different seedling age and planting speeds.

speed for both the soils S_1 and S_2 (Fig. 8) except the non-significant effect of seedling age on soil S_2. The maximum variation in seedlings/hill due to variation in seedling age was 6.1 to 7.3 at higher moisture content of 25% and at 186 strokes/min. The variations in the number of seedlings per hill due to variation in mat moisture and planting speed were also low, because of the variations in seedling density in the mats and greater entanglement of the roots.

Missing hills

The independent parameters were insignificant at 5% level on the missing hills. This was due to the fact that the plant density of 2 plants per cm^2 was achieved for the seedling mats.

Correlation of mat strength and power requirements

The power requirements increased linearly with the mat strength. The correlation coefficient were 0.82, 0.90 and 0.84 at planting speeds of 80, 120 and 186 strokes/min. The increase in power requirements was greater at higher planting speeds, corresponding to the same range of mat strength due to the increase in cutting torque resulting from the increase in speed (Fig. 9).

Conclusions

1. The maximum net power

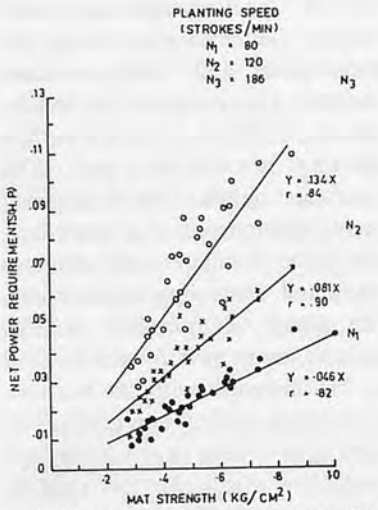


Fig. 9 Mat strength vs net power requirements at different planting speeds.

requirements of the transplanter were .106 HP and .109 HP for soils S_1 and S_2, respectively, which were quite low. Any of the treatment combinations could be used without substantial increase in the total power requirements. Therefore, the breakage of finger chains and gears etc. observed during field testing of transplanters (5) were not due to any variation in the mat conditions but due to obstructions to the planting fingers in the seedling mat or in the field.

2. The net power requirements increased linearly with shear strength of the seedling mats which was taken as an index of mat strength at planting speeds of 80, 120 and 186 strokes/min. However, the linear relationship was more predominant for a planting speed of 120 strokes/min.

3. The variation of mat area requirements from 275 to 405 cm^2/100 strokes for soil S_1 and 280 to 450 cm^2/100 strokes for soil S_2 for different treatment combinations is quite high. Hence, seedlings up to 30 days old at mat moisture varying from 10 to 15% should be used to reduce the variation in seedling mat area requirements and average number of seedlings/hill. Although the mat area requirements and average number of seedlings/hill are less at lower planting speeds these

advantages, however, are offset by the increase in field capacity at higher speeds. Hence, planting speeds of 120 to 186 strokes/min are recommended. The forward speeds corresponding to 80, 120 and 186 strokes/min are 0.72, 1.08 and 1.7 km/h, respectively, at a plant-to-plant distance of 15 cm. The minimum number of 600 mats/ha and minimum number of 5.4 seedlings/hill obtained in these studies are quite high in comparison to the recommended 2-3 seedlings/hill. The reduction in number of seedlings/hill to the desired limit will reduce the nursery requirements to about 300 mats/ha. This can be done by reducing the maximum height of the sheared mat by providing additional slot in the shaking arms of the transplanter. The side movement of the seedling platform should also be reduced from 1.5 to 1.0 cm per planting stroke.

4. The effect of seedling age, mat moisture and planting speed with the ranges studied on the missing hills was not significant. Therefore, missing hills are mainly due to jaw clutch slippage as reported earlier (5). Hence, proper care at the time of sowing to achieve uniform density of 2 seedlings per hill is most important.

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(Continued from page 13)

Performance of a Tractor-Mounted Oscillating Soil Working Tool

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Performance of a Simple Tractor-Mounted Deep-Hole Digger



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Introduction

Hole digging for forest plantation and fencing posts around the roadside and forest area are done either manually or screw-type auger which require a tremendous number of man-hours and cost even for a small area. In the Tarai regions planting the seedlings of poplar and other trees require more water for the proper growth and development, hence deeper holes. Generally, the depth of planting varies from 1.0 to 1.5 m. Manual labour only can conveniently make holes up to 50-60 cm. The mechanical diggers are manually operated blade-type. The screw type augers available in the market are not suitable for deep-hole digging. Thus, the demand of reforestation work requires a tractor operated deep hole digger which was developed at the Department of Agricultural Engineering at Pantnagar University. The testing and evaulation of this digger was done with the following main objectives:

1) To compare the test results of tractor-operated deep hole digger with manual tool "khanti", blade type auger and screw type auger.

2) To study the economy of this digger in comparison to other three types of manually-operated tools.

Constructional Details

The tractor-mounted, deep-hole digger consists of a double flight auger, speed reduction unit, three point linkage and telescopic PTO attachment. The auger is made of 2 m long steel 15 cm diameter. The double flights were welded on the circular shaft of 4 cm diameter to form the auger. The main part of the digger is speed reduction unit which reduces the PTO speed from 550 to 200 rpm. The detailed drawing of the digger is shown in **Fig. 1**. The complete unit is supported on a frame and is attached to the

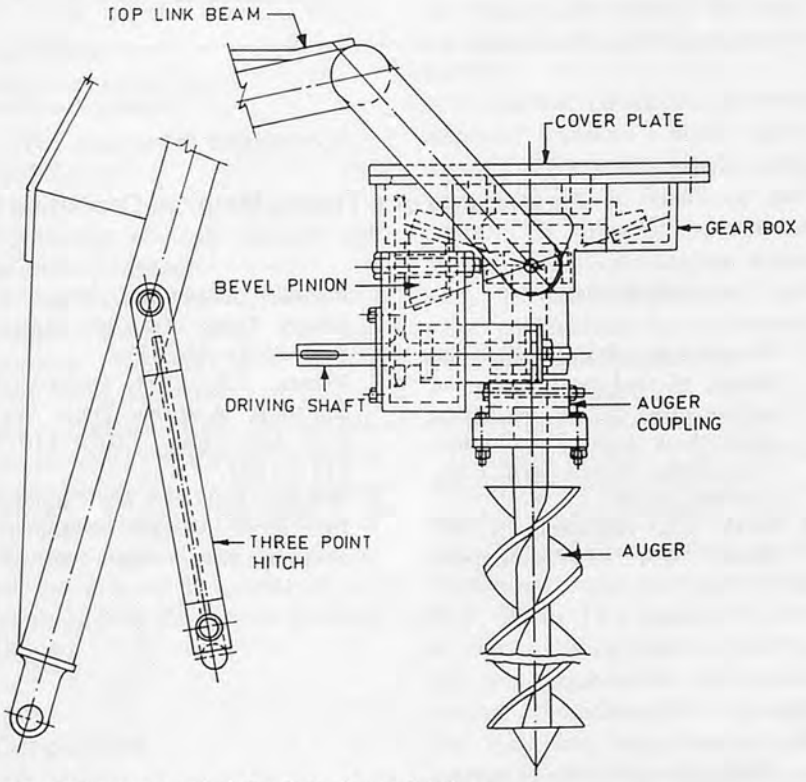


Fig. 1 Tractor-operated deep-hole digger, details

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Fig. 2 Manually operated digging tools, three different types



Fig. 3 Tractor-operated deep-hole digger, final setting prior to digging a hole



Fig. 4 Tractor-operated deep-hole digger before starting the job



Fig. 5 Tractor-operated digger in operation at 75 cm depth



Fig. 6 Tractor-operated digger digs 125 cm depth hole



Fig. 7 Manual digging by "Khanti"

tractor with a three point linkage system. The other three types of manually operated digger are shown in Fig. 2. The local tool "khanti" is made of high carbon steel with wooden handle whereas the augers are made of high carbon steel blade with mild steel pipe handles. The overall length of the "khanti" is 112 cm with 6 cm wide blade end and 4 cm diameter wooden handle. The blade type auger can be used for making holes up to 2 m depth using an extension whereas the screw type auger can be used only up to 1 m deep digging.

Materials and Methods

The testing of the tractor-operated, deep-hole digger was done to compare it with manually operated local tool, screw type and blade type augers in the Tanda forest of Kumaon range near the University Campus. A plot of 1 ha was selected for the study and the demarcation was done in the whole area at the spacing of 5 m x 5 m. Three replications of 10 holes each were done for each method and the average time was recorded for operation, transportation and adjustment. The testing was done at 50, 75, 100, 125 and 150 cm depths. The digger was operated with an International B 275 tractor (Figs. 3 to 6), but it can be operated with 20 to 35 hp tractor of any make. When the machine was in operation the rpm at load and no-load was measured. For 50 cm deep hole the digging was done in one pass whereas for 75 to 150 cm deep hole it was done in two - three passes. Beyond the depth of 1 m only the tractor-operated digger and blade type auger was used.

The three manually-operated equipments were tested in the same plot to maintain the same soil conditions for each test (Figs. 7 to 9). The efficiency of labour was considered as 75% in all the three methods. The manually-operated local tool was used only for 50 cm deep hole as the hole has to be cleared by hand and it can not be done beyond this depth. The screw type auger was operated up to 150 cm depth. In this case the hole was cleared by taking out the digger in a number of passes, while in operation and then put to further depth. In the tractor-mounted digger the efficiency was considered as 100% because of the time for digging, transportation and adjustment. Samples were also collected for soil testing. The soil was silty-clay-loam. The water table in the test region was found from 75 to 150 cm at the time of testing of these equipments. The speed of the tractor-operated, deep-hole digger was recorded as 150 to 175 rpm at load and 200 rpm at no load. The number of holes per hectare at the spacing of 5 m x 5 m square were



Fig. 8 Manually-operated screw type auger in operation



Fig. 9 Manually-operated blade type auger in operation



Fig. 10 Poplar plantation after digging hole by tractor-operated deep-hole digger



Fig. 11 Fixing wooden post in a hole dug by tractor-operated digger

considered as 400 for all the methods of digging. Figs. 10 and 11 show the poplar plantation and fixing fencing posts in the dug hole by the tractor-operated digger.

Results and Discussion

The test results for the actual time requirement for digging 10 holes are given in Table 1. It is evident that the minimum time requirement was in the tractor-operated digger (3 min 16 sec) and the maximum (200 min) for the manually-operated local tool "khanti" at 50 cm depth. Generally, the poplar plantation is dug at a depth of 1 m or more and this is only possible with blade type auger and tractor-operated digger. The screw type auger can be used only up to 1 m depth and requires 192 min for digging 10 holes whereas the tractor operated and blade type auger requires 8 min 6 sec and 242 min, respectively, for the same depth. The number of holes per hour, number of holes per day and days required per hectare were calculated and recorded in Table 2 for each method at different depths. The number of holes per hour were maximum at 184 and minimum 2.25 at 50 cm depth in tractor-operated digger and manually-operated local tool, respectively. Fig. 12 shows the relationship between the number of holes per hour and depth of holes for all the methods of digging. In manually-operated augers the relationship was linear whereas in the tractor-operated digger it was curvilinear. This is because after 1 m depth the auger requires less time for making the hole in comparison to 1 m and less depth. The time requirement is less because the water table is high in this region and the soil is loose. Also, the weight of the digger has an additional impact for penetration to further depths. In the blade type auger the time requirement was greater for clearing the holes in the lower surface than the upper surface whereas the time for digging was less resulting in almost similar pattern.

The values were also calculated for the number of hours required to make holes in 1 ha plot considering 400 holes at 5 m x 5 m square spacing (Table 3). At 50 cm depth a maximum of 177.80 h/ha was required for the manually operated local tool and a minimum of 2.20 h/ha for the tractor-mounted digger. The values are plotted in Fig. 13. There is increase in hours as the depth of holes increased for all the methods. For the 1.5 m holes the maximum value of 341.90 h/ha was for the blade type auger and minimum 10 h/ha for the tractor-operated deep-hole digger.

The fuel consumption of the tractor is shown in Table 4, which was maximum at 76 mℓ/hole and minimum at 17 mℓ/hole at 150 cm and 50 cm depth, respectively. The variation in fuel consumption mℓ/hole with respect to depth of hole can be seen in Fig. 14. The relationship is curvilinear because at the depth of 5 cm to 75 cm the soil has a hard layer and requires more load resulting in more fuel consumption. After 75 cm depth of digging the load decreases due to high moisture content and loose soil strata, in addition to the weight of the digger. The fuel comsumption ℓ/h was almost equal for each depths of digging. The relationship between depth of hole and fuel consumption ℓ/ha is plotted in Fig. 15, showing curvilinear relation. The maximum fuel consumption (30.40 ℓ/ha) was at the depth of 150 cm and minimum

Table 1 Test data for different digging equipments for 10 holes

Unit: min-s ('-'')

Depth of hole	Tractor-operated deep hole digger				Screw type auger				Manually-operated blade type auger				Manually operated local tool (Khanti)			
	R1	R2	R3	Aver-age	R1	R2	R3	Aver-age	R1	R2	R3	Aver-age	R1	R2	R3	Aver-age
50 cm	3'-0''	3'-28''	3'-20''	3'-16''	84'	85'	83'	84'	144'	141'	138'	141'	200'	220'	180'	200'
75	3-33	4-36	4-30	4-33	137	138	136	137	204	198	201	201	–	–	–	–
100	8-6	8-2	8-10	8-6	192	191	193	192	246	241	239	242	–	–	–	–
125	11-32	22-37	11-27	11-32	–	–	–	–	320	323	325	326	–	–	–	–
150	14-48	14-51	15-0	14-53	–	–	–	–	390	382	380	384	–	–	–	–

Table 2 Test results of different digging equipments

Depth	Tractor operated deep hole digger			Manually operated screw auger			Manually operated blade type auger			Manually operated local tool (Khanti)		
	No. of holes per h	No. of holes per day	Days per ha	No. of holes per h	No. of holes per day	Days per ha	No. of holes per h	No. of holes per day	Days per ha	No. of holes per h	No. of holes per day	Days per ha
50 cm	184	1 472	0.27	5.36	42.88	9.33	3.19	25.52	15.67	2.25	18	22.22
75	131	1 048	0.38	3.30	26.40	15.15	2.25	18.0	22.22	–	–	–
100	74	592	0.68	2.35	18.80	21.28	1.85	14.88	26.88	–	–	–
125	52	416	0.96	–	–	–	1.38	11.04	36.23	–	–	–
150	40	320	1.25	–	–	–	1.17	9.36	42.74	–	–	–

Table 3 Comparative performance of different hole digging equipments

Unit: h/ha

Depth (cm)	Time for digging, transportation, adjustment etc	Time for screw type auger in digging etc	Time for blade type auger in digging etc	Khanti type tool
50	2.2	74.6	125.4	177.8
75	3.1	120.0	177.8	–
100	5.4	170.2	215.1	–
125	7.7	–	289.9	–
150	10.0	–	341.9	–

Table 4 Fuel consumption on different depths for tractor-operated deep-hole digger

Depth	Fuel consumption		
	(mℓ/hole)	(ℓ/h)	(ℓ/ha)
50 cm	17.0	3.13	6.79
75	23.0	3.01	9.18
100	39.5	2.93	15.80
125	59.0	3.00	23.60
150	76.0	3.04	30.40

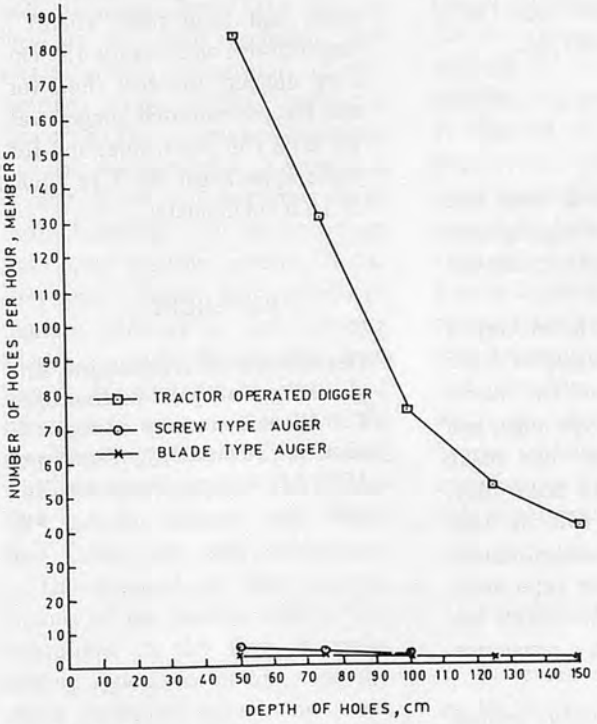


Fig. 12 Performance curve of various hole digging equipments

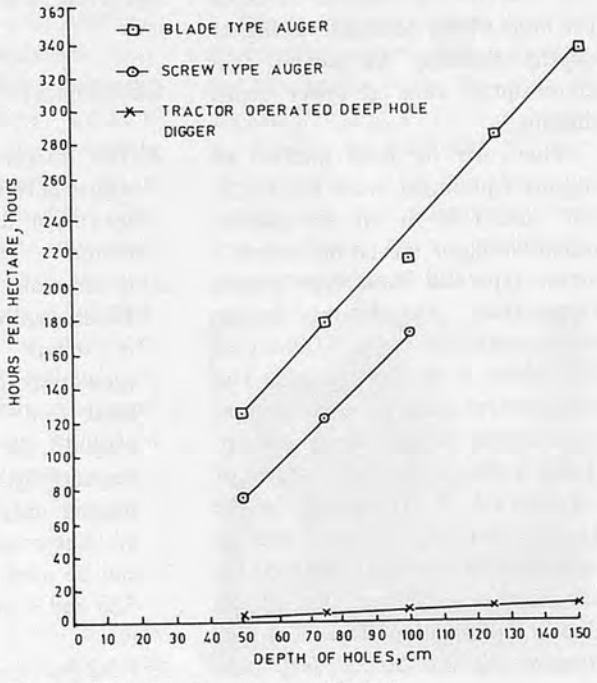


Fig. 13 Variation in number of holes/ha, by depth of holes

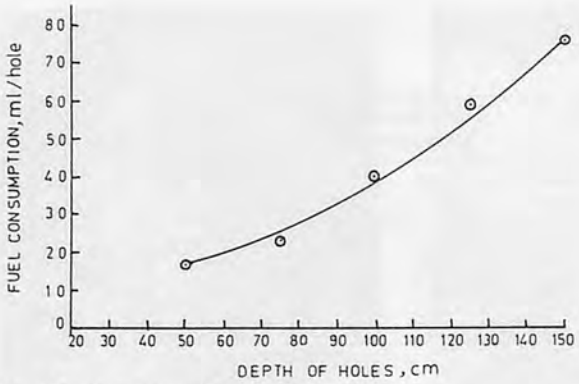


Fig. 14 Variation of fuel consumption by depth of holes

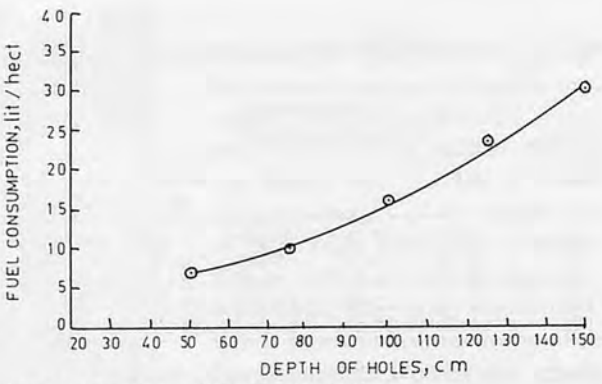


Fig. 15 Variation of fuel consumption by depth of holes

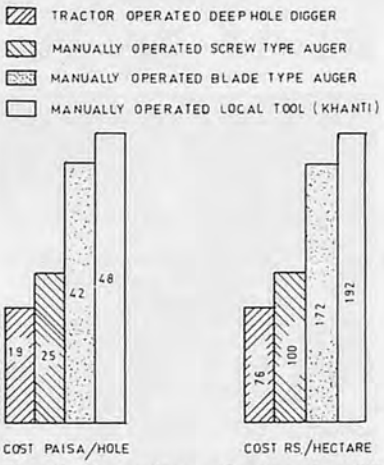


Fig. 16 Comparison of costs for different methods of digging at 50 cm depth

(6.79 ℓ/ha) at 50 cm depth. This was due to the number of holes per hour which decreased at higher depths resulting in greater fuel consumption than at lower depth digging.

The costs for each method of digging equipment were Rs. 35.26, 1.07 and 1.36 /h for the tractor-mounted digger, local tool "khanti", screw type and blade type augers, respectively. The labour charges were considered as Rs. 8.00/day of 8 h which is locally charged. The comparative costs for each method at different depths are shown in **Table 5** showing a minimum cost of 19 paisa (Rs. 0.19) per hole for the tractor-mounted digger and a maximum of 48 paisa (Rs. 0.48) for the local tool "khanti" at 50 cm depth of digging. The cost per hectare for the 50 cm deep hole was maximum at Rs. 192 and minimum at Rs. 76 for the local tool and tractor-mounted digger, respectively (Fig. 16). As for the depth of 150 cm the tractor-mounted and blade type auger were only used, the cost being Rs 352 and Rs 464 /ha. Thus a saving of Rs. 112 /ha was observed in the use of the tractor-mounted digger, or a net saving of Rs. 241.90 /ha.

Table 5 Comparative cost of digging with different types of equipments

Unit: Rupee

Depth	Tractor operated deep hole digger		Screw type auger		Blade type auger (Manually operated)		Local tool (Khanti)	
	Cost/ hole	Cost/ha	Cost/ hole	Cost/ha	Cost/ hole	Cost/ha	Cost/ hole	Cost/ha
50 cm	0.19	76	0.25	100	0.43	172	0.48	192
75	0.27	108	0.41	164	0.60	240	–	–
100	0.48	192	0.58	232	0.73	292	–	–
125	0.68	272	–	–	0.99	396	–	–
150	0.88	352	–	–	1.16	464	–	–

Conclusion

1. The tractor-mounted deep hole digger is capable of digging holes up to 2 m depth and 15 cm diameter.
2. It can make 1 472 holes /day of 50 cm depth at spacing of 5 x 5 m square whereas the screw type auger, blade type auger and local tool "khanti" can make only 43, 26 and 18 holes /day, respectively. For 150 cm deep digging only the tractor-mounted digger and blade type auger can be used and the output was 320 and 9 holes /day, respectively.
3. Fuel consumption in the tractor-operated digger was almost similar for each depth of digging but the fuel consumption in mℓ/hole was different for different depths of digging.
4. The costs /hole of 50 cm depth were 19, 25, 43 and 48 paisa for the tractor-mounted digger, screw type auger, blade type auger and local tool "khanti", respectively, whereas for 150 cm deep digging, the cost /hole for the tractor-mounted digger was Rs. 0.88 (88 paisa/hole) and for blade type auger Rs. 1.16 /hole of 15.0 cm diameter.

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Development and Testing of a Manually-Operated Dung Cleaner



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Introduction

The basic purpose of removal of dung, vegetable waste, liquid excreta and other waste farm products is to provide an efficient and economical method of collection and disposing them. The end in view is to avoid pollution and retain a high proportion of the nutrient value of the waste for recycling. The system is also healthful for the livestock. Maintaining a neat, clean and attractive dairy farm buildings and surroundings have very positive results. House flies and stable flies breed in manure piles or in moist rotting silage or grain found near feed bunks. If sanitation is poor and many such areas are available for fly breeding, the fly population will increase rapidly. The house fly spreads diseases and stable flies cause low milk production.

The disposal of farm manure is one of the hardest and dirtiest operations in the farm in maintaining good sanitation, in the warm weather when the cow-dung, etc. should not be allowed to pile up for any great length of time, since it is an excellent breeding place for flies.

The disposal of dung, vegetative waste, etc. needs continuous efforts and poses problems in large, organized farms. It is commonly observed that in case of labour shortage there is a tendency for dairymen to concentrate on milking the herd and to overlook equally important activities such as disposal of manure. Labourer requirement is greater for the loose housing system where animals are allowed to move freely in an extended area (paddocks). This system is being followed to provide better comfort to animals and also less personal attention is needed. But cleaning of these paddocks with the help of "belcha" or broom stick is difficult as a larger area has to be cleaned compared to a closed housing system.

The Case Study

There are about 1 400 animals at the Indian Veterinary Research Institute, Izatnagar under the All India Coordinated Research Project on Cattle. The daily farms have occupied approximately 25 000 m^2 of housing area for animals and about 15 000 m^2 area for roads, pavement and surroundings. Even in large dairy farms, the methods employed for the disposal of dung, plant residues etc., are more or less conventional.

The traditional method used for the cleaning of paddocks is collecting the wastes with the help of "belcha" in **Fig. 1**. Further cleaning may be achieved with the help of broomstick. This is a time-consuming and labourious method but is in use due to the non-availability of other suitable methods.



Fig. 1 Dung cleaning with the help of "belcha"

Another method is the use of a tractor. With the help of a multi-purpose blade terracer which is basically an equipment for land levelling. The farm waste is collected very fast but with following disadvantages:

i) The multi-purpose blade terracer is a rear-mounted implement. Therefore, during the collection of animal waste, etc. the tractor has to move over the uncleaned surface or over the accumulated waste. The corrosive nature of the dung affects the bearings of the front wheels of the tractor adversely.

ii) The use of the tractor power can be economically justified only if there is sufficient quantity of waste to collect in the paddocks. Otherwise much of the tractor power will be unutilized, hence waste of energy and money.

iii) In small paddocks, the operation of a tractor with a multi-purpose blade terracer is difficult. Moreover, a large percentage of time is wasted in turning operations, hence expensive, too. At the same time, corners of the paddock are left uncleaned.

Design and development – In view of the above, efforts have been made to design and develop a suitable dung cleaner with the following objectives:

1) To develop a low-cost dung cleaner which could be operated manually.

2) The cleaner should be able to collect dung of dried to wet consistency as may result in rainy season.

3) To reduce the drudgery of dung collection and in turn increase the output and quality of work.

Two types of dung cleaners were developed: one without wheels and the other, with wheels.

Dung-cleaner without wheels – This dung cleaner is very simple in construction: made of mild steel plate of 45 x 100 cm which is attached to a wooden handle (Fig. 2). The steel plate with two iron rings scrapes the dung while being pulled by a labourer. Another labourer holds the handle controls which provides proper angles of the plate and pushes the cleaner and it contacts with the ground surface for proper cleaning (Fig. 3).

Dung-cleaner with wheels – This is a simple, manually-operated wheel type dung cleaner (Fig. 4). It has a square frame of 50 x 50 cm fabricated from 5 x 5 cm angle iron. Two wheels of 30 cm diameter are attached to the frame with the help of an axle of 2.5 cm diameter. These two wheels provide perfect balance while in operation.

In front of the frame is a mild steel plate of 60 x 12.5 x 0.3 cm attached to the frame through three bolts of 2.5 x 1.2 cm diameter. This plate scrapes the waste from the surface of the paddock. The dung cleaner is pushed forward with the help of the handles attached to its frame by one operater in a forward motion with the help of front plate. In this process, the waste is collected in heaps.

Testing Details

All the four types of dung cleaners were tested: "belcha", multi-purpose blade terracer, dung-cleaner without wheels and dung cleaner with wheels. Testing was conducted on dry as well as on wet-dung (fresh) conditions. Four readings were observed for each condition on a paddock of 4 000 m^2. These paddocks have brick lining on the floor.

For the "belcha", a single person was required to opeate it. Further cleaning was achieved with the use of a broom stick.

On the other hand multi-purpose blade terracer was mounted behind a tractor. The blade size was 180 x 40 cm and operated by a 45 hp Ford-3000 tractor. During the testing, the wheel slippage frequently occured under wet floor conditions. The cleaning operation using the multi-purpose blade terracer is shown in Fig. 5. The operation of the dung-cleaner without wheels is shown in Fig. 3. Two persons



Fig. 2 Dung cleaner without wheels



Fig. 3 Dung cleaner without wheels in operation



Fig. 4 Wheel type dung cleaner, Size: 6 x 130 cm (W x L), Weight: 20 kg



Fig. 5 Multi-purpose blade terracer in operation

were required to operate it. The total time required corresponds to the cumulative man-hours of both operators.

Observations on the use of the wheel type dung-cleaner were discontinued because it proved very difficult and exhaustive for a single person to operate. But it has a posibility for efficient use if further studies on its operation can be done.

Results and Discussion

The time required under wet dung condition was more than that required under dry dung condition. This is because the wet dung is cohesive and sticks to the floor, hence greater power is required to detach it from the surface. Moreover, for complete cleaning more than one operation may be required.

The average time taken for cleaning the paddocks with the use of the "belcha" both under wet and dry dung conditions were 18.87 man-h and 22.0 man-h, respectively. In the use of the dung-cleaner without wheels, 12.81 man-h were required in dry condition and 15.62 man-h in wet condition or a time saving of 32.40% and 20%, respectively.

The average time taken by the tractor-operated multi-purpose balde terracer to clean the dung in the above area was only 1.15 tractor-h when the dung was in dry condition and 1.37 tractor-h when the dung was in wet condition. In addition, it was necessary to clean the corners by using manual labourer since the multi-purpose blade terracer could not cover the corners of the paddocks. The total man-hours needed in addition to tractor-hours was 4.46 man-h and 4.87 man-h for dry and wet dung respectively, including the time of the tractor driver.

Table 1 Comparative time and cost of operation of various dung cleaning equipment

System of dung cleaning	Condition of dung	Average man-h	Time required for 4 000 m² tractor-h	Average cost of operation in Rs/ha			
				Labour cost	Machine cost	Power cost	Total
Belcha	Dry	18.87	–	88.45	–	–	88.45
	Wet	22.00	–	103.13	–	–	103.13
Dung cleaner (without wheels)	Dry	12.81	–	60.05	–	–	50.05
	Wet	15.62	–	73.26	–	–	73.26
Tractor and multipurse blade terracer	Dry	4.46	1.15	22.50	4.00	96.83	123.33
	Wet	4.87	1.37	35.55	4.80	116.80	157.15

Note: The cost of "belcha" and dung cleaner was considered negligible.

Table 1 compares the time taken and cost of use of the three methods of dung-cleaning. The dung-cleaner without wheels was more effective than the "belcha" both in terms of time taken and cost of operation. The use of the multi-purpose blade terracer was the costliest. Between the "belcha" and tractor and terracer there was a saving 14.41 man-h.

The cost of operating the blade terracer varied from Rs. 123.23 to Rs. 157.15 for dry to wet dung condition which is 1.3-1.5 times the cost of operation with a "belcha."

A similar comparison made between the dung-cleaner without wheels and the terracer shows a saving of 8.35 man-h in the latter.

The dung cleaner without wheels can stand further improvements.

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A Comparative Study of Conventional and Mechanized Farming Relative to Energy Use and Cost



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Abstract

This paper reports the findings of a case study evaluating the energy and cost required for performing various farm operations for paddy and wheat production. The energy and cost inputs were higher for the mechanized farm operations than the conventional ones, and yet the increase in crop-yield and the timeliness of farm operations advocate the use of farm machinery. The case study also found that crop-yield is directly proportional to the energy input.

Introduction

Agricultural productivity cannot hope to increase unless adequate inputs such as power, improved seeds, fertilizers and irrigation water are available timely and applied judiciously. Agriculture in India is labour-intensive and yet the current growth trend of the agricultural labour force is about 2-3% annually against the target % 3-5%. The optimum amounts of energy and costs for growing the two leading food grains (rice and wheat) differ by farming methods, by country and within a country for which reason the present study was undertaken. The objectives were:

1 To measure the energy and input costs per unit area and per unit yield for various farm operations involved in paddy and wheat crop production.

2 To compare the performance of conventional type of farming with the mechanized one using the above parameters.

3 To determine the magnitude of substitution of one source of energy to another.

Review of Literature

The total geographical area of India is about 326 million hectares and the net cultivated area is less than half (133 million ha). The gross area sown is 162 million ha (3). The availability per head of cultivable land is about 0.33 ha as against 0.16 in the U.K., 0.17 in Germany and in 0.07 in Japan (4).

Roy (6) reports that through the use of efficient, modern animal-drawn equipment, the preparation of seedbed and operation up to sowing time would require 25.8 to 36.8 kWh per ha as against 125 to 184 kWh/ha with indigenous equipments. Assuming an average of two intercultural operations, approximately 9.2 kWh/ha would be required using a bullock-drawn cultivator compared with 122 kWh/ha using Khurpies tractor. To harvest a crop of paddy or wheat, the average requirement using a bullock-drawn mower is approximately 2.84 kWh/ha against 36.8 kWh for the conventional sickle. Thus in all field operations with improved bullock-drawn implements and machines already developed and in use within the country would require an average 55.4 kWh/ha compared with 351 kWh/ha by conventional methods.

McKolly (7) found that on the average, 1 000 man-h/ha are expended in paddy production with the use of animal power. In Taiwan and in Japan this figure is about 1 300 while in countries where broadcasting, less inter-cultivation and less tillage are practised the

Table 1 Energy required to produce selected crops

Crop	Man-days	Bullock-days
Paddy	150	50
Wheat	75	75
Jowar	40	40
Cotton	40	20
Sugarcane	90	20

Table 2 Average energy and cost requirement for various operations in paddy cultivation in Treatment A.

Farm Operation	Average Energy supplied by		Total Energy	Average Cost
	Man (kWh/ha)	Animal (kWh/ha)	(kWh/ha)	(Rs/ha)
Seedbed preparation	3	35	38	48
Drilling	5	27	33	52
Weeding	23	–	23	130
Harvesting	14	–	14	81
Threshing	7	–	7	85
Miscellaneous	12	–	12	69
Total	64	62	127	425

Table 3 Average energy requirement for miscellaneous farm operations

Farm operations	Implements & machinery used	Energy required. (kWh/ha)	(Man-hr/ha)
Broadcasting fertilizer	Manual	0.895	(12.0)
Corner edge preparation	Spade	0.358	(4.8)
Bunding	Spade	5.080	(68.0)
Pesticide	Knapsack sprayer	1.960	(26.2)
Transportation	Manual	4.480	(60.0)

figure is about 700.

Farm management studies (8) conducted by India's Ministry of Food and Agriculture indicate energy requirements for raising some of the major crops (Table 1).

In a study (10) conducted in South East Asia it was observed that 7 man-h were needed to produce 20 kg rice while in Japan only 7 man-min were required to produce the same quantity. In U.S.A. it took 30 man-h to grow an acre of wheat in 1850 and 3 man-h in 1950. To date it takes about 30 man-days and 30 bullock-days to grow an acre of wheat in India.

Experimental Design

The experiments were carried out in the experimental farm of the Indian Institute of Technology, Kharagpur. The farm is some 115 km from the eastern sea coast and has an average elevation of about 48 m sea level. The average rainfall in the area is 1 400 mm approximately. The different treatments followed for conducting the experiment were as follows. Paddy crop I.R.8(68) was cultivated with five treatments:

A–Upland paddy farming using bullock and human energy.

B_1–Paddy farming applying local method of transplanting and using human and animal energy.

B_2–Paddy farming applying improved method of transplanting using human and animal energy.

C_1–Paddy farming applying improved method of transplanting using human and animal energy.

C_2–Similar to C_1 but applying improved method of transplanting.

Field operations and quantity of inputs applied were similar in all the operations.

On the other hand, the wheat (Kalyan Sona) crop was grown under two treatments: B–Using animal, human and mechanical energy or C–Using human, mechanical and electrical energy.

The quantity of inputs were likewise similar for both treatments in wheat cultivation. The quantity of inputs and the operation were suggested by the an agronomist who was consulted for the study.

The computation of energy and cost requirement were made on the following assumptions.

1. One normal human labourer generally supplies 0.0746 kW.
2. One average pair of bullocks supplies 0.746 kW.
3. Energy supplied through mechanical energy was computed by the following equation

$$E = 10.645X/Y$$

where

E = Energy in kWh, X = the fuel consumed to cc, Y = time taken for fuel consumption.

4. One human labourer was available @ Rs. 0.44/h*
5. One pair of bullocks without driver was available @ Rs. 0.62/h*

* The present cost is twice the assumptions made in the early seventies.

Results and Discussion

The observations were analysed and tabulated as discussed here.

Energy and cost for paddy cultivation

Treatment A – This treatment deals with upland dry farming. Results obtained are given in Table 2.

The energy consumption for seedbed preparation and seed drilling operation was 71 kWh/ha while the total consumption for crop production was 128 kWh/ha. This high value of energy consumption per hectare may be attributed to the fact that energy supplied per unit time by animal power is more than that by human beings. However, other operations consumed considerably less energy. Weeding required the most human energy (23 kWh/ha) as compared to other operations. The variation in the human energy input for weeding operation ranged between 18 and 28 kWh/ha are attributable to the personal interest of the worker and prevailing operating conditions.

For example, a labourer does the same work very efficiently in the morning than in the afternoon. Also these variations may be due to unequal quantities of weeds in different plots.

In harvesting, the stage of growth of the crop was mainly responsible for the variation in the energy and cost requirements.

Threshing was done by beating the straw with grains on planks. The average output of different

Table 4 Average energy and cost requirements for treatments B_1 and B_2 in paddy cultivation

Farm Operations	Treatment B_1				Treatment B_2			
	Energy supplied by		Total energy	Cost of operation	Energy supplied by		Total energy	Cost of operation
	Human (kWh/ha)	Animal (kWh/ha)	(kWh/ha)	(Rs/ha)	Human (kWh/ha)	Animal (kWh/ha)	(kWh/ha)	(Rs/ha)
Production of seedlings	27	–	27	153	28	–	28	156
Puddling	11	109	120	151	11	111	122	156
Transplanting	32	–	32	181	78	–	79	458
Weeding	26	–	26	147	16	–	16	89
Harvesting	15	–	15	83	13	–	13	75
Threshing	9	–	9	51	12	–	12	70
Miscellaneous	13	–	13	71	13	–	13	72
Total	133	109	242	837	181	111	292	1 075

Table 5 Energy and cost requirement for treatments C_1 and C_2 paddy cultivation

Farm Operation	Treatment C_1						Treatment C_2					
	Human energy (kWh/ha)	Animal energy (kWh/ha)	Mechanical energy (kWh/ha)	Electrical energy (kWh/ha)	Total energy (kWh/ha)	Cost of operation (Rs/ha)	Human energy (kWh/ha)	Animal enrgy (kWh/ha)	Mechanical energy (kWh/ha)	Electrical energy (kWh/ha)	Total energy (kWh/ha)	Cost of operation (Rs/ha)
Production of seedling	26	–	–	–	26	147	25	–	–	–	25	142
Puddling	8	69	88	–	165	220	8	74	76	–	158	231
Transplanting	27	–	–	–	27	155	79	–	–	–	79	448
Weeding	22	–	–	–	22	126	12	–	–	–	12	67
Harvesting	17	–	–	–	17	93	19	–	–	–	19	106
Threshing	6	–	–	17	23	39	7	–	–	28	35	48
Miscellaneous	9	–	54	–	63	138	10	–	72	–	82	178
Total	115	69	142	17	343	918	160	74	148	28	410	1 220

labourers was 20 kg/h having 2:1 ratio of stalk and grain at 18% to 20% m.c. (wet basis). The variation of energy for threshing operation ranged 6 and 7 kWh/ha due mainly to the different yields in different plots.

The data for sub-operations under miscellaneous items are given in Table 3.

The consumption of energy and the cost requirement for various miscellaneous operations were mainly dependent upon the interest and supervision of the work.

Treatments B_1 and B_2 – In these treatments the paddy was transplanted in plots by local and improved methods, respectively, as given in Table 4. Seedling production in both cases and also in treatments C_1 and C_2 consumed nearly 27 and 28 kWh/ha. The other operations consumed an energy more or less similar quantities as in Treatment A.

The costs incurred in various operations in B_1 and B_2 are also recorded in Table 4 and the variation of the cost in different operations was influenced by the nature of work as it is apparent from the Table 4.

Observations for various farm operations under Treatment C_1 and C_2 are given in Table 5. The higher energy consumption in some of the operations such as in the puddling (165 kWh/ha) was due to the higher energy consumption per unit time. The rate of field coverage had less effect on the energy consumption per hectare. Nevertheless these treatments achieved timeliness of the operations which is quite an important factor affecting the yield of the crop. Threshing operation was performed by a Kubota power thresher which consumed nearly 1.25 kWh per quintal of paddy grain with grain and stalk ratio of 1:2 at 18-20% moisture content on wet basis.

The average energy and cost requirement for various treatments for paddy cultivation are shown in Fig. 1.

The study shows that energy consumption per hectare increases with increases in intensity in mechanization, while energy consumption per quintal does not show much variations. This is due to the fact that higher energy consumption for mechanised treatments was also accompanied by increased yields. Also, total operating cost is higher for treatments involving improved method of transplanting. The higher operating cost was accompanied by an increase in yield which, in turn, resulted in low total cost of production per unit of crop produced.

For treatment C_2 where the operating cost was maximum, the total cost of production per unit of yield were minimum, i.e., operating cost was Rs. 1 290/ha and the cost of production was Rs. 53 per quintal only.

Hence, treatment C_2 gave the best results which favours mechanization.

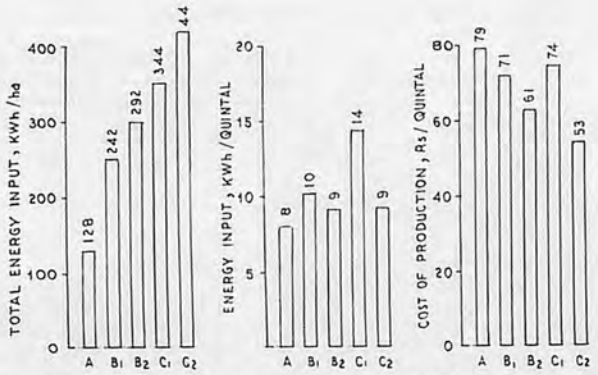


Fig. 1 Energy and cost required for paddy (IR8 (68) (0)) cultivation: A – Upland paddy farming using human and bullock energy; B_1 – Using human and bullock energy with conventional way of transplanting; B_2 – Using human and bullock energy with improved way of transplanting; C_1 – Using human, bullock, mechanical and electrical energy with conventional way of transplanting; C_2 – Using energy same as C_1 with improved way of transplanting

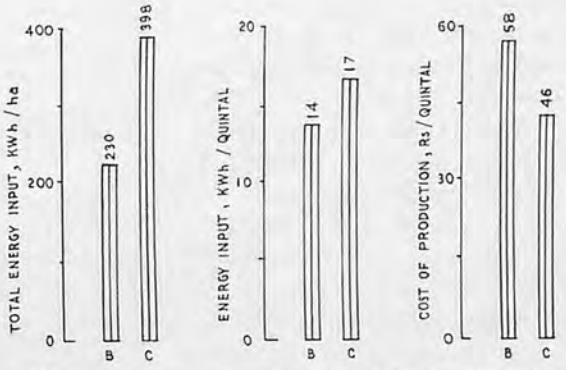


Fig. 2 Energy and cost required for wheat (Kalyansona) cultivation: B – Using human, animal and mechanical energy; C – Using human, animal, mechanical and electrical energy

Energy and cost for wheat cultivation

Treatment B – Various operations under this treatment were performed by human and animal power except irrigation for which power was used. From **Table 6** it is evident that seedbed preparation and seed drilling consumed nearly half of the total energy required for wheat cultivation (122 kWh/ha out of 230 kWh/ha). It is interesting to note that harvesting operation required the maximum human energy which is a peak demand to be substituted by implements and machines.

Threshing was done by beating the cut stalks in bundles on planks manually. It was found that normally, a labourer can thresh 15 kg grain per hour when the moisture content of the crop was 14 to 16% on wet basis and grain to stalk ratio on weight basis was 1:1.75. Other operations consumed energy proportionately as in the treatments for paddy cultivation.

Treatment C – The observations given in **Table 7** indicate a similar trend in the energy and cost consumption in Treatment C compared to Treatment B. Threshing in this treatment was done by a Kubota thresher and its consumption was 14 kWh/ha. Variation in costs and energy used in miscellaneous operations reveal the same rise and fall as in the previous treatment.

Comparison of all treatments – Wheat cultivation (**Fig. 2**) shows that the total energy and cost requirement per hectare were higher in the case of treatment C than treatment B while the total cost of production per quintal followed a reverse trend due to higher yield for treatment C than others.

Test of Significance

The observations were statistically verified. A students' t-test and F- test emphasised that there was a significant effect of the human energy on the crop yield. The value of t was 5.356 and the value of F was 11.325 with 4 degrees of freedom, the overall effect of energy on the crop yield was highly significant.

Summary

The study was conducted to investigate the conventional and the mechanized type of farming. The criterion of comparison was

Table 6 Energy and cost requirement for treatment B, wheat cultivation

Operation	Energy supplied by			Total energy (kWh/ha)	Cost of operation (Rs/ha)
	Human (kWh/ha)	Animal (kWh/ha)	Machine (kWh/ha)		
Seedbed preparation	9	89	–	99	128
Drilling	4	20	–	24	40
Irrigation	2	–	66	68	78
Interculture	12	–	–	12	70
Harvesting	14	–	–	14	80
Threshing	8	–	–	8	51
Miscellaneous	5	–	–	5	31
Total	54	109	66	230	478

Table 7 Energy requirement and costs for treatment C, wheat cultivation

Farm Operation	Energy supplied by			Total energy (kWh/ha)	Cost of operation (Rs/ha)
	Human (kWh/ha)	Animal (kWh/ha)	Machine (kWh/ha)		
Seedbed preparation	1	118	–	119	181
Drilling	0.45	58	–	59	78
Irrigation	2	78	–	80	86
Interculture	13	–	–	13	76
Harvesting	2	51	–	53	75
Threshing	9	–	5	14	87
Miscellaneous	3	56	–	60	92
Total	30	361	5	398	575

on the basis of energy and cost measurement. The results as given in Table 8 could be concluded as follows:

1. Mechanised type of farming with improved system of cultivation proved economical.
2. In general, seedbed preparation consumed nearly one-third of the total energy demanded by both paddy and wheat crops.
3. In paddy cultivation transplanting operation consumed maximum energy: about a third to one-half of the total energy required.
4. In wheat cultivation maximum human energy was required for intercultural operations, 12-13 kWh/ha.
5. The yield was higher in the machanized type of farming than the conventional one.
6. There are chances of cutting down the peak labour-demand by substituting the power-driven equipment for human labour. This substitution not only solves the labour-shortage problem but also the farm operation more economically and effectively.

Table 8 Comparative cost and energy expended for wheat cultivation

Treatment	Average yield (qtl/ha)	Cost of inputs (Rs/ha)	Total operating cost (Rs/ha)	Total cost of production (Rs/ha)	Total energy required (kWh/ha)	Energy required per quintal (kWh)	Total cost of production per quintal (Rs)
B	17	506	479	985	230	14	58
C	31	506	576	1 082	398	17	46

Table 9 Energy and cost required for paddy and wheat cultivation

Crop	Treatment	Energy consumed (kWh/ha)	Energy consumed (kWh/quintal)	Operating cost (Rs/ha)	Cost of production (Rs/qtl)
Paddy	A	128	8	426	79
	B_1	242	10	637	71
	B_2	292	9	1 076	61
	C_1	344	14	918	74
	C_2	411	10	1 219	53
Wheat	B	230	14	479	58
	C	398	17	576	46

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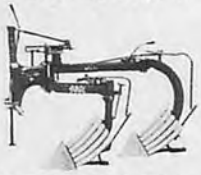
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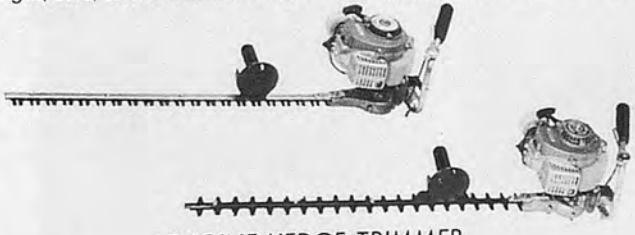
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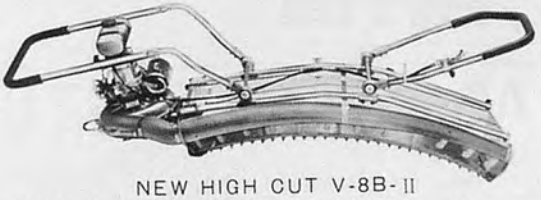
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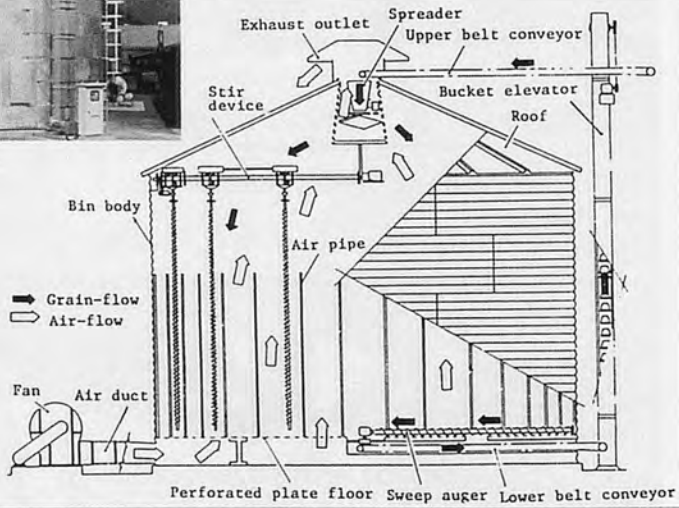
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Max. loading level		m (ft)	3.5(11.5)		
Floor area		m²(ft²)	24.4(262.6)	49.8(536.1)	84.1(905.3)
Max. volume		m³(ft³)	83.3(2943.5)	166.7(5890.5)	277.8(9816.3)
Max. holding capacity	Paddy	t	50	100	180
	Wheat	t	60	120	200
Fan	Type		L.L.F.4½ ≠	L.L.F.5½ ≠	L.L.F.7 ≠
	Power req.	KW(HP)	5.5(7.4)	11(14.8)	15(20.1)
Drying rate per hour		%	0.015 (at normal temperature)		
Fuel consumption		ℓ /Mgol/h)	2~3.5(0.5~0.9)	3~7(0.8~1.8)	5~12(1.3~3.2)
Max. loading capacity		t/h	20		
Max. unloading capacity		t/h	10		
Total power required		KW(HP)	14.23(19.1)	19.73(26.5)	24.73(33.2)



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Tillage Machines Combined with Moldboard Plow



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Introduction

Crop production systems are changing. Reduced tillage systems utilizing moldboard plow combined with tillage machines save fuel and labor inputs because combinations require once-over operation of plowing and refining the seedbed. The moldboard plow is preferred because it is the most important tillage machine. Plowing loosens, crumbles, aerates and warms the soil. The improved soil physical properties enhance the decomposition of crop residue. Soil crumbling and loosening favours availability of soil moisture, better soil aeration and soil temperature, improved soil structure and supply of soil nutrients.

If proper shattering of the soil takes place as the furrow slice follows the operation of any secondary tillage implement combined with the moldboard plow for single pass seedbed preparation, there may be no need for other operations for refining the seedbed. Russel (4) suggests that the deeper the plowing and more accurately the furrow slice is entirely turned and inverted, the more difficult it will be for the weeds to grow and more likely they will be decomposed by the soil microorganisms. Glerum (3) summarizes the qualities of a good seedbed: the soil must be loosened equally, soil crumbling must be sufficient, field must be levelled and the wheel tracks must not be visible. Bukhari *et al* (1) found that the seedbed refining implements combined with moldboard plow greatly improved the physical properties in black soil. The effect of soil loosening and crumbling by moldboard plow at a speed of 8.65 km/h was the best. Feuerlein (2) conducted tillage implements experiment to investigate the loosening, crumbling, inverting, transporting effects on sandy loam, clay and humus soils. The loosening effect in plowed plots was more durable. The plowing at a speed of 5.04 km/h produced the best crumbling results in sandy loam than in clay soil.

Moldboard plowing also offers the best means of improving the quality of poorly drained soils. Once-over plowing operation reduces the cost of seedbed preparation and soil compaction. These tillage implements combined with the moldboard plow for once-over seedbed preparation are described in this paper.

Acknowledgement: The authors wish to express their gratitude to all the manufacturers who cooperated in allowing the use of their brochures and pamphlets on moldboard plow combinations.

Passive (Unpowered) Tillage Machines Combined with Plow

CH-clod buster

The clod buster is manufactured in Hungary. The star wheels (rotors) are made of cast iron and the bearings are provided for two gangs of star wheels, fitted in a rectangular frame. The clod buster combination with moldboard plow is shown in Fig. 1. It is 1.15 m wide with a rotor diameter of 32 cm and with 20 teeth in the rotor.

The implement follows the moldboard plow, pulverizes and crumbles the soil in one trip. The crank axle of the clod buster is used to raise



Fig. 1 CH-clod buster and moldboard plow operating in the field.



Fig. 2 IH-coil tine harrow and plow operating in the field.



Fig. 3 IH-coil tine harrow combined with 9-bottom moldboard plow.

the rotors for transport. The buster is an efficient treader to trail behind the plow. It is light and very effective in pulverizing big lumps and clods of freshly plowed soil.

IH-coil tine harrow

The coil tine harrow is made in USA. The work width, coil tine slant angle and the load on the implement are adjustable and fits with the 4-, 6-, and 9-bottom moldboard plows. The smaller units are easy to raise or lower with the plow attached. The mounted type IH-coil tine harrow for the 5- and 9-bottom plows are shown in **Figs. 2 and 3**. The implement is folded onto the plow frame for transport.

Broy hill tilling tool

The Broy Hill tilling tool combined with moldboard plow is shown in **Fig. 4**. The implement is made in USA. The harrow tines are round and three rows of coil tines are rigidly bolted to the steel pipes. The width is adjustable from 0.7 to 2.1 m, the straight tine is 27 cm long and the coiled part of the tine is 30 cm long. The coil tine harrow is also available in two or three sections. The tine slant is adjusted by threaded rod for deep or shallow penetration. The implement is also made with rigid or curved tines. The Broy Hill tilling tool is available for the 2-, 3-, 4-, 5-, and 6-bottom plows.

PLH-20 coil tine harrow

The PLH-coil tine harrow shown in **Fig. 5** is manufactured in USA. The harrow is attached to the moldboard plow frame members by pipe consoles. The harrow tine slant is adjustable. The implement has three rows of coiled tines bolted to the pipes. The bigger plows of 5-bottom size need two sections of coil tine harrows. Each unit of harrow pulverizes, crumbles 1 m of plowed land. The harrow units are attached in tandem to the plow. The coil tine harrow is lifted when the plow is lifted in the field and for transport. The pipe console is adjustable in order to reduce the total width of the harrow during transport.

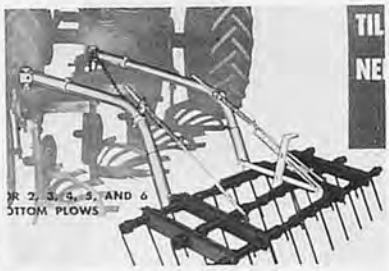


Fig. 4 Broy Hill tillage tool and moldboard plow.



Fig. 5 PLH-20 coil tine harrow and moldboard plow.

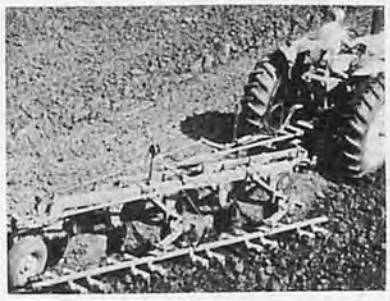


Fig. 6 Pressure-matic harrow and plow operating in the field.

Pressure-matic harrow

The pressure-matic harrow has a single, rugged main frame attached to the moldboard plow by an adjustable lift arm as shown in **Fig. 6**. According to the manufacturer, the implement is more economical than many other complex plow-mulcher combinations. The implement provides three field adjustments for proper soil tilth conditions. Heavy duty coiled tines provide the required pressure and the lift arms provide proper depth of tine penetration in the soil. The tine angle is also adjustable.

Combining plowing and mulching for single pass operation, the pressure-matic harrow eliminates any other secondary tillage implement behind the plow. The unit is complete with a winch which is used for folding the implement for transport or compact storage. The winch has a load control brake which automatically holds the implement load when the winch lever is released for its operation position.

The pressure-matic harrow is available with spring tooth or spike tooth bars in sizes suitable for most of 4-, 5-, 6-, 7-, and 8-bottom plows.

Spike tooth harrow

The spike tooth harrow is made in USSR. The implement is 1.75 m wide and is attached to the semi-mounted moldboard plow by chains



Fig. 7 Spike tooth harrow and plow.

and square beams which are bolted to the plow frame. The depth is adjusted by shortening or enlarging the chain length. The implement combined to the plow is shown in **Fig. 7**.

For transport, the spike tooth harrow is folded on the square beams in such a way that the spike tooth harrow does not touch the ground.

Tilling machines

The mounted tilling machine combination with the plow is manufactured in Hungary. The tilling machine combination attached to the moldboard plow consists of sub-surface packer followed by a rod crumbler. The implements combined with the plow produce a fine tilth and desirable soil packing. The depth of tillage implements attached to the plow is adjusted through the spring provided on the implement. The once-over combination with the plow prepares a suitable seedbed. The implement combined with moldboard plow is shown in **Fig. 8**.

B-452, 454, 456 tilling tools

These tilling tools are made in East Germany. Each section of the tilling tool is composed of one row of sprocket-like sub-surface-packer wheels and two rows of clod buster star wheels. The sub-surface packer works deep enough, packs the sub-surface of the soil and the clod buster star wheels break the clods and level the surface. The depth is adjusted by screwing the threaded bar. The combination prepares a suitable seedbed in a single pass of the tractor. For transport, the width of the combination is reduced by attaching and trailing the implements one after another. The wheels of the implement are rolled down to raise the tilling parts of the combination. The combination of two units of tilling tools in tandem with the moldboard plow in operation is shown in **Fig. 9**.

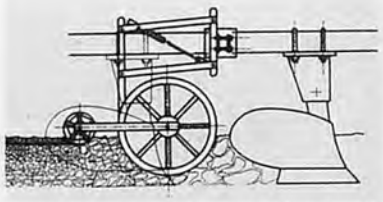


Fig. 8 Tilling machine combined with plow.



Fig. 9 Two tilling tools and plow operating in the field.

Becker crumbler for plow

The Becker crumbler is 1.6 m wide. It is attached to the moldboard plow and consists of a square frame of angle iron bars in which three units of the crumbler are fitted. The diameter of the central crumbler is bigger than the front and rear crumblers. The desired soil packing is achieved by adjusting the screws of the central crumbler which produces a friable and mellow seedbed. The tires of the crumbler are rolled down to raise the crumblers for transport purpose. The Becker crumbler combined with a plow is shown in **Fig. 10**.



Fig. 10 Becker crumbler and plow operating in the field.

Kockerling plowing-seeding combination

The West German Kockerling firm manufactures the plowing-seeding combination for 2- to 6-bottom plows. The combination is economical in the sense that it plows and prepares the seedbed, drills grain, applies fertilizer, covers and packs the seeds slightly. All operations are performed by one man in a single trip.

The experimental results show that the combination operates effectively and produces good quality of work in medium and light soils. The once-over combination consists of moldboard plow, crumbler sub-surface-packer, seed fertilizer (combined) drill, sub-surface-packer and crumbler. The Kockerling implements combination is shown in **Figs. 11 and 12**.



Fig. 11 Kockering plowing-seeding machine.

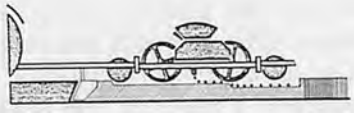


Fig. 12 Sketch diagram of Kockering plowing-seeding machine.

Power Tillage Combined with Moldboard Plow: Low Powered Tillage Machine Combinations

Vibrating harrow and plow

The vibrating harrow is made in West Germany. This implement is operated by tractors with power take off. The moldboard plow and vibrating harrow operation are



Fig. 13 Vibrating harrow combined with moldboard plow operating in the field.

shown in **Fig. 13**. The vibrating harrow combined with the moldboard plow for single pass seedbed preparation could effectively and efficiently be used in dry clay soils. The harrow produces a mellow and friable structure of the plowed land.

If the crumbler is hitched behind the vibrating harrow, the quality of the work is improved and a desirable soil compaction is produced to conserve soil moisture. The depth of penetration of the harrow is adjusted through its trailing wheels.

Rotavator and plow

The West Germany-manufactured rotavator is attached in front of the rear wheels of the tractor. The rotating blades of the implement break the clods into small particles and produce a very fine tilth in clay soils with moldboard plow combination. The single pass moldboard plow and rotavator operation is shown in **Fig. 14**. It is an excellent tillage implement combination which produces clean, loose, mellow and very fine tilth.

In transport, the machine can be lifted vertically and tied to the tractor frame.

Rex rotavator and plow

The Rex Rotavator is also manufactured in West Germany. The hydromotor is attached in front of the tractor which operates the rotavator. The Rex rotavator and moldboard plow attachments and seedbed prepared by a single pass of both implements is shown in **Fig. 15**. It produces a fine seedbed free of clods, crop residue and



Fig. 14 Rotavator combined with moldboard plow operating in the field.

weeds and is friable and mellow. If the crumbler is pulled behind the rotavator the desirable packed soil surface could be obtained to conserve soil moisture. The depth of work could be obtained by adjusting the I-bolt provided for the purpose.

The vibrating harrow, rotavator and Rex rotavator combined with moldboard plow for single pass seedbed preparation are the mounted-type and suitable for 3-bottom moldboard plows and medium sized tractors.

High Power Combinations

Vibrating harrow and plow

The German-made vibrating harrow is 2 m wide and has wheels for adjusting the depth of operation. It can be lifted and lowered hydraulically during transport. The tilling machine, in combination with the moldboard plow, produces fine tilth in a once-over operation. The powered vibrating harrow combined with moldboard plow is shown in **Fig. 16**.

Omsel rotavator and plow

The Omsel rotavator (made in Italy) and plow is shown in **Fig. 17**. It produces loose, clean, friable, mellow and unpacked seedbed.

Takakita high-cut rotavator and plow

This mounted-type implement combination is manufactured in



Fig. 15 Rex rotavator combined with moldboard plow operating in the field.



Fig. 16 Vibrating harrow for once-over plowing combination.



Fig. 17 Omsel plow rotavator combination.

Japan. The power-operated rotors are attached to the frame of moldboard plow. The rotors till the soil from 6 to 10 cm deep and rotate at the speed of 680 rpm. The high rotating velocity of the rotors produces fine soil tilth and a levelled and suitable seedbed in a single pass. The tilling machine attached to the moldboard plow is shown in **Fig. 18**.

Vibrating harrow and crumbler

Fig. 19 shows the combination

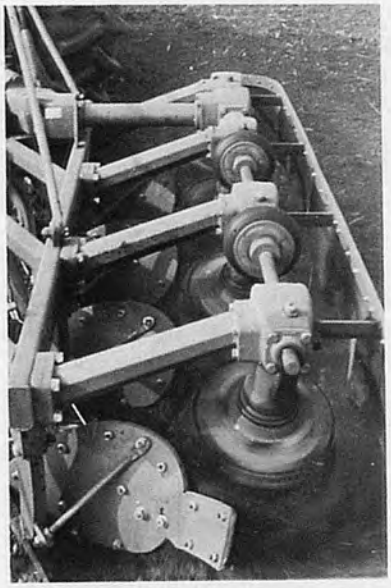


Fig. 18 Takakita high cut rotary plow.

of moldboard plow, vibrating (at 540/min) harrow and crumbler attached to the tractor. The working width of the implement is 1.1 m and the depth of work is 4, 9 and 14 cm. The combined harrow and crumbler can be lifted vertically by a hydraulic system during transport. The vibrating harrow is operated by the side power take off of the tractor and the crumbler is pulled behind the vibrating harrow. The mounted moldboard plow is hitched through a three-point hitch of the tractor.



Fig. 19 Vibrating harrow and crumbler combined with moldboard plow operating in the field.

The combination of moldboard plow, vibrating harrow and crumbler is suitable for once-over seedbed preparation in heavy soils. The depth of operation of the vibrating harrow is adjusted by raising or lowering the crumbler.

Plowing-seeding combination

The machine is manufactured in West Germany **(Fig. 20)**. The rotary tiller is operated by the hydromotor. The horizontal pipe of the broadcaster drops the seeds in the soil which is worked and thrown by the rotary tiller. The seed from the hopper is forced to the pipe by air pressure. The air pressure is maintained by the air pump provided at the bottom of the seed broadcaster. The Farm Machinery Research Institute, Godollo, Hungary conducted experiments and found the combination suitable for single pass plowing-seeding operation.



Fig. 20 Rotary tiller and seed broadcaster combined with moldboard plow operating in the field.

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Performance and Potential of Rubber Rolls in Husking Paddy



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Introduction

Rubber rolls are consumable items used in modern rice mills for dehusking paddy. They are a fast-wearing component and therefore need replacement very often. Rubber rolls are mounted on two horizontal shafts of a paddy dehusker. One shaft has a fixed position whereas the other is adjustable to obtain desired clearance between a pair of rolls, which are driven mechanically in opposite directions with differential speed.

When the paddy kernels are fed between the two rolls, they are caught under pressure by the rolls. Due to the elastic friction created by the differential speed of the rolls the paddy husk is split into halves. Because of the abrasive nature of the husk and the constant friction, the rubber rolls wear out gradually, hence a regular replacement is necessary.

The requirement for rubber rolls is steadily rising due to the replacement of the disc-sheller by rubber roll dehuskers in India and other countries. Most of the developing countries, including India have taken initiative to modernize the conventional rice mills in order to achieve higher productivity and better quality products. In India, the modernisation programme for rice mills started in 1970 and it is estimated that by the end of 1980 nearly 6000-7000 conventional mills will have been modernised. The remaining mills are in the process of effective modernisation.

Status of Rubber Rolls and Their Development

The rubber roll technology for dehusking paddy was started more than two decades ago but gained popularity in India and several developing countries only for the last decade. Initially, rubber rolls were manufactured in Japan, Australia and few other countries and exported to various Asian countries. These rolls were both expensive and less efficient for the Indian paddy due to different climatic conditions and paddy varieties.

During the early 70s, the importance and potential of rubber rolls for paddy dehusking was realised by the Indian rubber manufacturers and technologist. Few rubber industries developed such rolls; initially in black colour. The dehusking capacity of these rolls was hardly 30-50 t of raw paddy. They also left a blackish tinge on the surface of polished rice particularly when the paddy was not well dried before milling. With continuous research and development of technology, the life of rubber rolls increased to 100-150 t during 1975-76. Later, white, cream and non-black rolls were also developed which ultimately eliminated the blackening effect on polished rice.

For the last five years, a number of Indian rubber manufacturers, have produced rubber rolls, and the life of such rolls has been extended to 200-300 t of paddy. However, the cost of rolls increased also. In 1970, the cost of a pair of rubber rolls per ton of raw paddy ranged between Rs. 10 and 12. Due developments in their quality, cost decreased to between Rs. 5 and 8 a pair per ton of paddy in 1975-76 and was further reduced to Rs. 4 to 6 by the end of 1980. A few Indian manufacturers are trying to develop polyurethene rolls which are expected to dehusk about 1000 t of paddy. This may further reduce the dehusking cost and frequent replacement of rolls.

Parameters Affecting the Life of Rolls

It is a common complaint among rice millers that they hardly achieve the rated life span of rolls as advertized by their manufacturers. The life of rolls is not only governed by the quality but also several other factors such as variety and type of paddy (short/long, raw/parboiled);

climatic condition; age of rubber rolls; peripheral speed of rolls; distribution of paddy; moisture content of paddy; dehusking percentage of paddy; clearance between the rolls; cleanness of paddy; cooling arrangement of rolls; roll shaft's eccentricity; and operator's skill. Some of these parameters e.g. variety of paddy and climatic conditions are beyond the control of the rice millers but others can be controlled very well.

Variety of paddy – the size and roughness of husk affects the performance of the rolls. When long grain varieties of paddy are dehusked the contact area of the grain with the rubber is much longer compared to short grain varieties. Consequently, the wear is higher and the life of the roll is considerably reduced. The same quality of roll can dehusk about 200 t of short variety of paddy grown in Japan against only about 100 t of long grain paddy variety in tropical countries (Fig. 1).

When parboiled paddy is milled, the husk gets loosened and thus split easily. Therefore, the same quality of rolls can dehusk about 300 t of parboiled paddy against only 200 t for raw paddy.

Climatic conditions – Climatic conditions, e.g., high temperature and high relative humidity of the air also affects the life of the rubber rolls. Due to high ambient temperature, the rolls are heated and results in softening of the rolls which affects their life.

Age of rolls – Rubber rolls deteriorate gradually as shown in Fig. 2, hence they can be stored only for a limited period and yet it is recommended that they should be utilised between 3 and 6 months after production. Therefore, rice millers should not store rubber rolls beyond one year. Rather a continuous supply should be maintained in order to achieve optimum efficiency.

Peripheral speed of roll – The rolls rotate at different rpms and in opposite directions. Normally, the peripheral speed of the adjustable roll is about 25% slower than the fixed roll. Hence, the former wears slower comparatively even as the rolls are interchangeable in position (Fig. 3). The pheripheral speed of fast rotating roll is about 14 meter/sec.

Distribution of paddy – Quite often the grain distribution device does not function correctly and the roll surface wears out unevenly (Fig. 4). Therefore, the roll surface is corrected by removing the rubber from the sides of the roll. To obtain optimum life of the rolls and efficient dehusking performance, the grain should be evenly distributed.

Moisture content of paddy – Moisture is an important factor affecting the life of rubber roll. Quite often freshly harvested paddy with 17-20% moisture content is milled without drying. At high moisture level the husk is more firmly attached to the kernel and does not easily split. In order to achieve normal dehusking degree, the clearance between the rolls is reduced. This ultimately wears the rolls faster. The high moisture content in the paddy also affects the blackening of rice. If the paddy is properly dried to safe milling moisture content level of 14-15% (w.b.), these problems can be overcome.

Dehusking degree – It is a common practice that rice mills are operated at over capacity for profit reasons. When this is the case, the load on paddy separator is reduced by dehusking paddy upto 95% degree in a rubber roll sheller. Obviously, less clearance between the rolls is maintained which ultimately wears the roll faster. The dehusking degree should not exceed 80-85% in order to achieve optimum life of the rolls and the machine too.

Clearance between rolls – The clearance between the rolls is related to the dehusking degree of paddy.

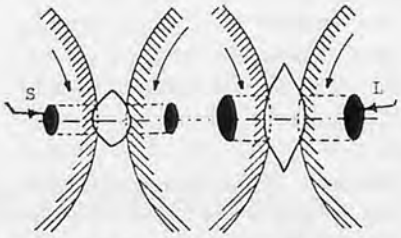


Fig. 1 Relationship between paddy variety and dehusking capacity of rubber rolls: S–Contact area with short grain paddy L–Contact area with long grain paddy.

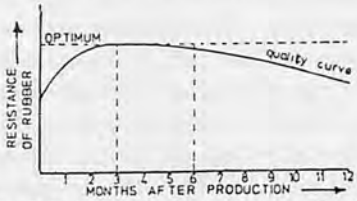


Fig. 2 Relationship between age of rubber roll and durability.

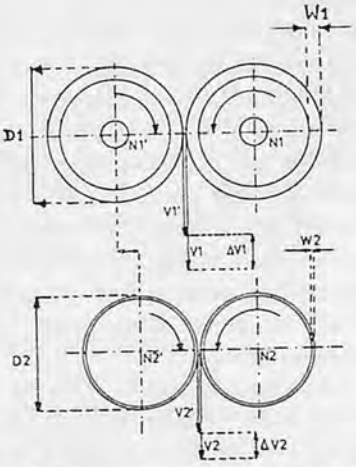


Fig. 3 Relationship between rubber roll diameter and peripheral speed: N1 & N1'–RPM of fixed and adjustable roll, D1 & D2–Roll diameter before and after partial wear, △V1 & △V2–Differential speed of the rolls before and after partial wear.

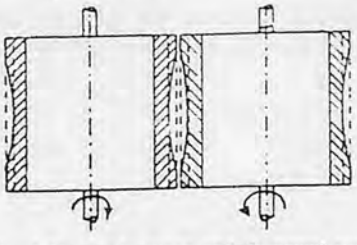


Fig. 4 Unevenly worn and damaged surface of rubber rolls due to unequal distribution of paddy.

If the gap is small, more area of paddy surface will be in contact with rubber rolls, thus creating more frictional resistance on the rolls ultimately affecting faster wear and tear. The recommended clearance is 2/3 to 3/4 of the paddy thickness. The pressure spring must also be tightened gradually to maintain uniform pressure on the rolls.

Cooling arrangements – Due to continuous friction on the rolls caused by the abrasive husk during dehusking operation, the rolls are heated up. If the cooling arrangements for the rolls is inadequate, the roll temperature gradually rises and when it reaches beyond 60°C, they soften and wear faster. In cold countries, however, this problems does not arise but in tropical countries cooling arrangements become necessary. For this purpose, cooling fans/aspirators are incorporated with the paddy dehuskers. Sometimes due to poor maintenance of the machine sufficient air is not available. If the fan belt is properly tightened and the air ducts are cleaned periodically, the temperature of the rolls can be controlled. During hot seasons, half an hour break at every 4-hour run of dehusker is helpful.

Cleanliness of paddy – Presence of impurities in paddy such as dust, stones and metallic substances not only deteriorate the roll but also spoil the machinery. If paddy is not properly cleaned, lot of dust comes in contact of the rolls, reducing the cooling efficiency and also choking the air duct. The stones and metallic impurities scratch the rolls and pits are formed. Therefore, paddy should be cleaned before dehusking by a modern paddy cleaner, consisting of screens, aspirator, destoner and magnetic separation system.

Eccentricity in the shafts – The rubber rolls are fitted over two horizontal shafts and rotate in opposite directions. If there is even a little eccentricity in the shaft or a play in the bearings, the eccentricity will go on increasing as the rolls wear out. If any vibration or noise is noticed, the shafts and bearings should be checked immediately. Proper care should also be taken while fitting the rolls on the mandrel.

Operator's skill – This is the most important factor which governs all the above parameters. If the operator is not properly trained and aware of the above adjustments, the life of the rolls is affected considerably. It is, therefore, essential to provide some basic training to the operator so that he can adjust the clearance between the rolls, dehusking degree of paddy, spring tension and efficient cooling. If these factors are considered properly, they will not only help to increase the life of the rubber rolls but also the smooth operation of paddy dehusker and other machinery.

Potential Demand for Rubber Rolls

The demand for rubber rolls may be projected on the following assumptions:-

The life of a pair of rubber rolls is 200 t on raw paddy and 300 t on parboiled paddy, at a price of Rs. 1000, including all taxes; 50% of paddy produced is milled by rubber roll dehuskers, and 70% of the paddy milled is raw and 30% is parboiled paddy. The production of paddy in 1978 in India was 69 million t, in Asia 320 million t or a world's total of 377 million t. The number of pairs of roll required for India and the value are calculated as follows:

i) Number of pairs required for raw paddy = (69 000 000/2 x 200) x (70/100) = 1,20,750 pairs.

ii) Number of pairs required for parboiled paddy = (69 000 000/2 x 300) x (30/100) = 34,500 pairs.

Total pairs of roll = 155 250 per annum valued at Rs. 155 million.

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Elastic and Visco-elastic Properties of Agricultural Products in Relation to Harvesting and Post-Harvest Processes



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Abstract

The basic concepts of linear elasticity and visco-elasticity, and the instrumentation used in characterizing agricultural products are reviewed. Application of mechanical properties of solid food materials in evaluating food texture and in the design of harvesting machines are discussed. Experimental results from an investigation conducted to relate corn kernel and corn cob mechanical properties to cob break-up and kernel damage in a combine cylinder are briefly presented.

Introduction

Biological materials, including plants, animals and food products are frequently subjected to mechanical forces of different types during production, processing and storage. In all these materials, failure is usually observed in the form of rupture in their internal and external cellular structures. Thus, the mechanical properties of bio-materials under simple stress conditions, such as tension, compression and shear, must be known to facilitate the determination of the maximum allowable stresses prior to rupture. Knowledge of the general stress-strain-time behaviour of the materials is also needed in order to completely characterize their mechanical properties, such as, Young's modulus, shear modulus, complex modulus, and modulus of toughness.

In the study of the mechanical properties of biological materials, it is assumed that the techniques employed in evaluating the behaviour of engineering materials will be applicable (Mohsenin, 1970). Linear elastic theory is assumed, although biological materials, being composed of solids and fluids do not act in a purely elastic manner. Rather, their resistance to applied external load is a combination of elastic, plastic and viscous behaviour.

Basic Concepts

Mechanical propertics may be defined as those having to do with the behaviour of the material under applied forces. Mechanical properties that are time dependent may be considered as rheological.

Elastic Behaviour – A material is called elastic when the deforma-

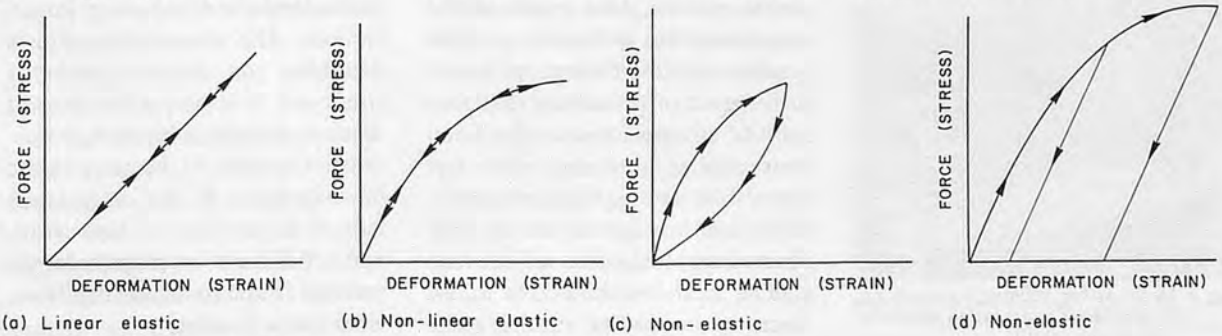


Fig. 1 Elastic and Non-elastic stress-strain diagrams

tion produced in the body is wholly recovered after removal of the forces (Fig. 1). For linearly elastic materials, the relation between stress and the corresponding strain, in the elastic range of the material is linear. According to Hooke's law, the ratio of stress to strain is a constant characteristic of the tested material. This constant of proportionality is termed as Young's modulus, plastic modulus or the modulus of elasticity, E.

The definition of the modulus of elasticity does not require the stress-strain curve to be linear (Moustafa, 1967). If the curve is not linear, the modulus of elasticity should be taken as a secant or tangent elastic modulus, both defined in Fig. 2. A more commonly used term is the apparent elastic modulus which is determined from the linear portion of the non-linear curve.

Linear Elastic Contact Theory – For large deformations as occur in loaded biological materials, the contact areas between the material and the loading device do not remain constant. Therefore, the calculation of stress as force per unit cross-sectional area of the loaded material is not valid. Appropriate theories for calculating the contact stresses have been developed in classical theory of linear elasticity (Timoshenko and Goodier, 1970). Fig. 3 illustrates the solution for the maximum contact stresses developed when two cylindrical elastic bodies are pressed together, based on Hertz elastic contact theory.

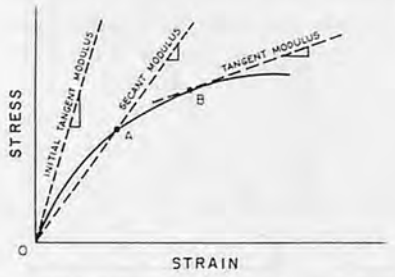


Fig. 2 Methods for defining the modulus in non-linear stress-strain diagrams (Mohsenin, 1970).

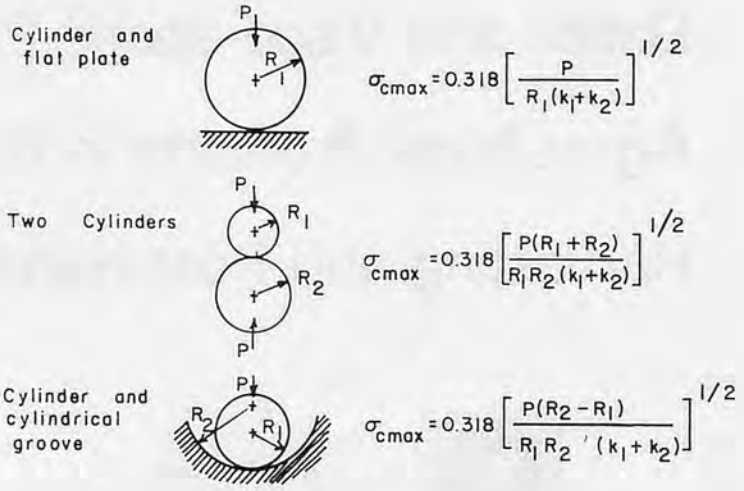


Fig. 3 Calculation of contact stresses based on Hertz linear elastic contact theory.

On the assumption that their response behaviour is essentially that of a linear isotropic material for small deformations, the Hertz elastic contact theory has been applied to biological cylindrical materials under radial compression (Snobar, 1873; Sherif, 1976 and Anazodo, 1980). Applying the simplifying assumptions illustrated in Fig. 4, simple equations for calculating the apparent elastic modulus E and the maximum contact stress or crushing strength, σ_c, were derived by Anazodo (1980, 1981(a), 1981(b)) and used in the study of the mechanical properties of corn cobs (Anazodo and Norris, 1979(a), 1979(b), 1981).

Plastic Behaviour – Many materials when stressed beyond a certain minimum stress show a permanent, nonrecoverable deformation. This is called plastic deformation, which is the result of permanent displacement of atoms and molecules from their original positions after the removal of stress. An ideal plastic body will be represented on the stress-strain diagram as a line parallel to the strain axis at a distance corresponding to the yield stress of the material.

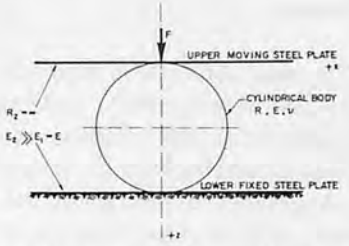


Fig. 4 Simplifying assumptions made in applying Hertz linear elastic contact theory to cylindrical biological materials.

Viscous Behaviour – For perfectly viscous liquids, Newton's law states that stress is always directly proportional to rate of strain but independent of the strain itself. The constant of proportionality is termed viscosity, η.

Visco-elastic Behaviour – Biological materials (and indeed all real materials) do not behave in a perfectly elastic, plastic or viscous manner because of structural imperfections. The stress-strain ratio is dependent on the magnitude of stress and it is also a function of time. A material with such characteristics is said to be visco-elastic in behaviour. If the stress-strain ratio is a function of time alone, and not of the stress magnitude, the material is said to behave in a linear visco-elastic manner.

Mechanical Models – Mechanical

models are physical abstractions which are employed in the mathematical representation of a visco-elastic material as one possessing some of the viscous flow characteristics of a liquid and the rigidity of a solid. The phenomenological theory of linear isothermal visco-elasticity is entirely based on the hypothesis that the microscopic structure of a linear visco-elastic material is mechanically equivalent to a network of linear viscous and elastic elements (Bland, 1960). In this theory, the most satisfactory representation is obtained if the network contains a large number of viscous and elastic elements. Fig. 5 describes the more commonly used models in the visco-elastic characterization of agricultural products.

Mechanical models are not meant to be exact structural models of the biological material being studied. Rather, they should be visualized in this way: if the spring and the dashpot symbolize storage of potential energy and dissipation of energy, respectively, on the molecular scale, the mass stands for storage and exchange of kinetic energy on that scale.

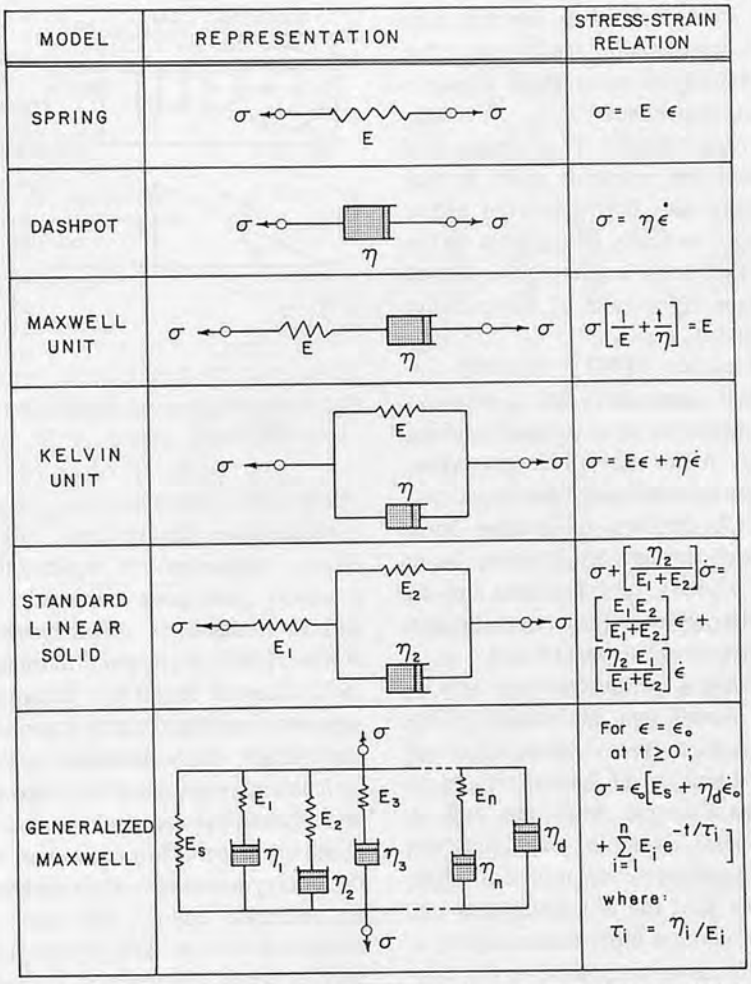


Fig. 5 Simple mechanical models used in the visco-elastic characterization of biological materials.

Instrumentation

Quasi-static Tests – The standard test machine for experimental determination of the mechanical properties of agricultural products under quasi-static loading is the Instron universal testing machine (Fig. 6), described by Bourne *et al.* (1966) and Bourne (1967).

Briefly, the testing machine consists of two parts:

1) the drive mechanism which drives a moving cross-head in a vertical direction by means of twin lead screws at fixed speeds in the range from 0.05 to 50 cm/min; and

2) the load-sensing system which consists of electric bonded-wire strain gauges whose output is fed to a strip-chart recorder. The latter draws a force-distance curve of each test sample performed.

A time axis can also be easily obtained from the chart since the recorder chart and the moving cross-head are synchronously driven from the same power supply.

The Instron universal testing machine can easily be adapted to handle compression, tensile, shear, bending, relaxation and creep tests. It can be equiped with an environmental chamber for control of temperature and humidity during test of the agricultural products.

Simpler, cheaper but less versatile compression and tension devices can also be used to conduct quasi-static tests. However, any device in which the rate of loading cannot be relied upon to be constant once



Fig. 6 Instron Universal Testing Machine (Table Model) used in all laboratory investigations.

the desired speed is selected may give questionable results since the behaviour of agricultural products is rate-dependent.

Impact Tests – The behaviour of agricultural materials under impact loading has been reported either using a vertically falling mass on the product or by impacting the desired surface by means of a pendulum impactor.

Fletcher (1971) describes an impact apparatus which employs the principle of a vertically falling mass, in this case an electromagnetic plunger. Basically, the apparatus, **Fig. 7**, consists of loading component devices to measure force and velocity (a transducer and an accelerometer, respectively) and an instrument to record data.

Using a pendulum type impactor, Jindal and Mohsenin (1976) determined the damage resistant characteristics of fuits expressed in terms of several parameters such as hardness, dynamic yield pressure and dynamic elastic modulus. They argued that the test conditions can be controlled more accurately by a pendulum as compared to the case of a freely falling fruit or an impacting mass.

Dynamic Tests Using Sinusoidal Force – The use of dynamic testing to determine the dynamic viscoelastic properties of agricultural products has been reported by several researchers (Finney and Norris, 1968; Wen and Mohsenin, 1970; Rao *et al*, 1976). Compressive, tensile or shear stress is applied sinusoidally on a specimen of the agricultural product at the rate of one cycle per second or more. In this type of deformation part of the energy is stored in the specimen as potential energy and part is dissipated as heat. The periodically varying strain will result in periodically varying stress. The main viscoelastic property determined from this type of test is the complex modulus, E*, which is a function of the frequency of the stress and strain.

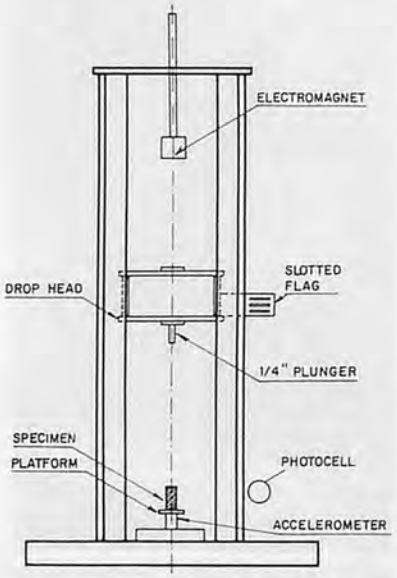


Fig. 7 Impact drop apparatus (Fletcher, 1971).

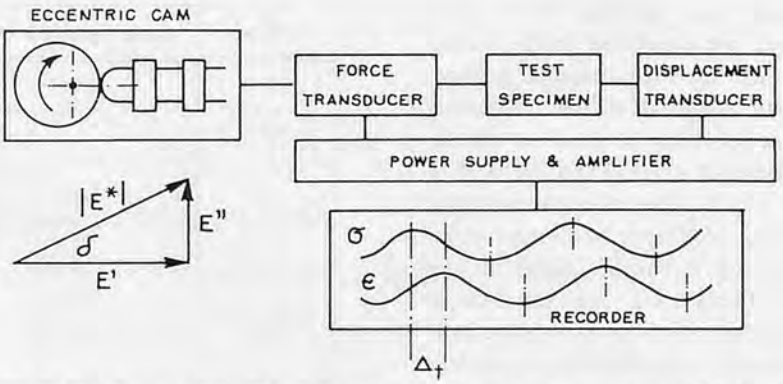


Fig. 8 Block diagram for low-frequency dynamic visco-elastic measurement (Mohsenin, 1970).

The sinusoidal force is frequently provided by an electrodynamic vibration generator. The test specimen is placed between two flat compression surfaces, and the sinusoidal varying force and displacement are recorded using a force transducer and an accelerometer. The signals from the transducer and accelerometer are amplified and fed into an oscilloscope. The resulting lissajous figure in the form of an ellipse which is displayed on the oscilloscope is analyzed to determine the force, acceleration and the phase lag of acceleration. **Fig. 8** describes the essential elements of an instrumentation for dynamic testing of agricultural products.

Applications

To demonstrate the importance of the study of biomaterial physicomechanical properties, three practical examples are briefly presented.

Characterization of Food Texture (Mohsenin, 1970) – One of the most successful applications of the study of the physical and mechanical properties of biological materials is in the design and marketing of instruments for objective evaluation of the textural characteristics of food materials. **Table 1** summarizes the objective parameters which are used. A few of the commercially available instruments for testing the rheological and textural properties of solid food products are listed in **Table 2**. Without such devices an objective assessment of the quality of unprocessed and processed food products cannot be undertaken. Mere sensory evaluation of the quality

Table 1 Elastic and rheological parameters used in textural chracterization of solid food products

Subjective (Textural) Characteristics	Objective (Elastic and Rheological) Parameters
Firmness, Springiness, Hardness	Relaxation time or ratio of viscosity to elasticity
Crispness, Mealiness	Turgor pressure and/or Tissue rigidity
Chewiness	Toughness
Bread quality	Strength and/or toughness

Table 2 List of devices for imitative and empirical tests

Device	Test
Tenderometer	Simulates jaw action
Puncture tester	Resistance to penetration
Maturometer	Shearing resistance
Fibrometer	Cutting strength
Succolumeter	Extractable juice volume
Bloom gelometer	Rigidity of edible gelatin
Kramer shear press	Combination of textural measurements

of such products is not sufficient. This does not, however, rule out the use of test panels in ascertaining the taste of a processed food product. Nor does it eliminate the need for evaluating the nutritional quality of food materials after being subjected to post-harvest treatments.

Design of Stripper Harvester for Rice (Sutton, 1971) – Sutton (1971) determined the average energy required to cause failure for different parts of the rice plants. His results are shown in Table 3. The average energy required to remove each spikelet was then used to estimate the power required to strip off the grains. The expression used by Sutton (1971) is:

$$\text{Power} = \frac{\text{energy}}{\text{spikelet}} \times \frac{\text{spikelets}}{\text{unit area}} \times \frac{\text{area covered}}{\text{unit time}}$$

From such a simple and inexpensive analysis, it was possible to design a stripper harvester for rice with the minimum energy input. The design also minimized damages and loss of rice grains.

Other design applications of mechanical properties of solid food materials are discussed in the proceedings of a workshop organized by Pennsylvania State University (1975).

Table 3 Average energy required to cause failure for different parts of rice plants (Sutton, 1971)

Parts of plant	Energy kg-cm
Spikelet attachment	0.003
Secondary branch and attachment	0.008
Primary branch and attachment	0.039
Tiller	1.270
Plant anchorage	94.100

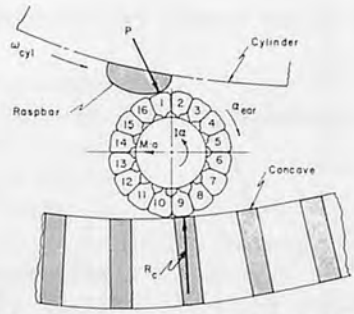
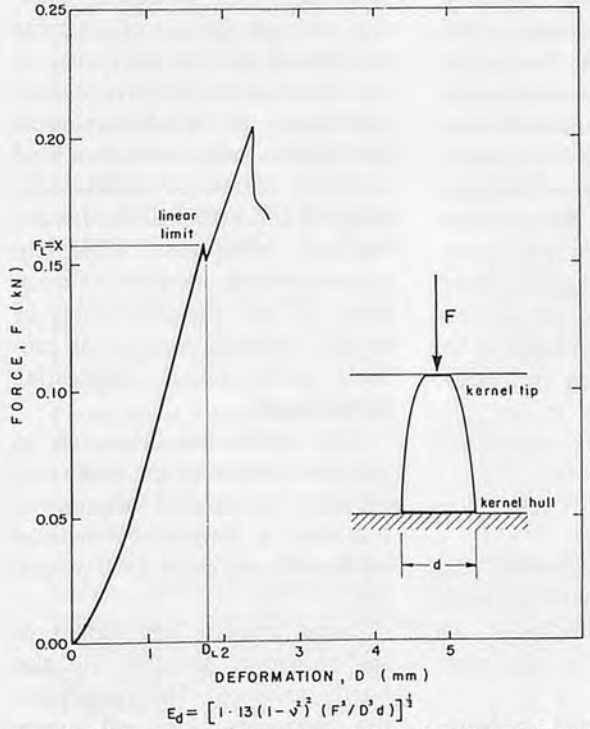


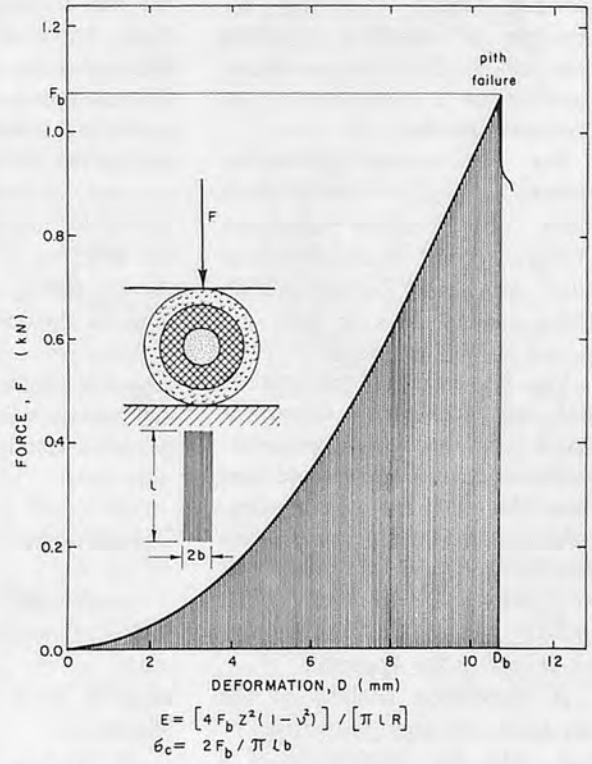
Fig. 9 Corn ear being shelled in a combine cylinder-concave.

Corn Kernel and Cob Physico-Mechanical Properties Related to Combine Cylinder-Concave Performance (Anazodo et al, 1981) – An investigation was conducted to study the relationships of the physical and mechanical properties of corn kernel and corn cob to the performance of a stationary conventional thresher. Damage and loss of corn kernels during shelling in the combine cylinder-concave have been a frequent experience of



$$E_d = \left[1.13\,(1-\nu^2)^2\,(F^3/D^3 d)\right]^{\frac{1}{3}}$$

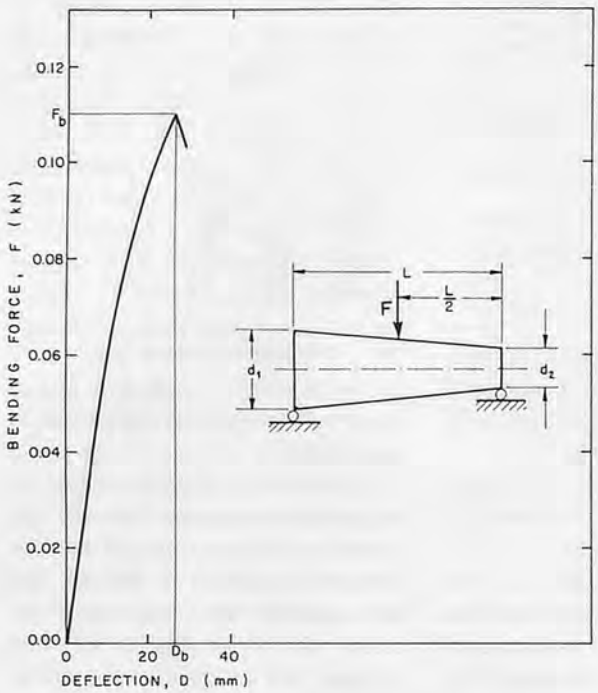
Fig. 10 Typical force-deformation curve of corn kernel under compression (each kernel hull was slightly sanded before compression was applied).



$$E = \left[4\,F_b\,Z^2\,(1-\nu^2)\right] / \left[\pi\,l\,R\right]$$

$$\sigma_c = 2\,F_b / \pi\,l\,b$$

Fig. 11 Force-deformation and cross-sectional view of radially compressed corn cob composite.



$$E_b = 8F_bL^3C/\pi D_e$$

$$\sigma_b = (64\,F_bL)/\left\{\pi(d_1+d_2)^3\left[1-f^4(1-m)\right]\right\}$$

Fig. 12 Force-deflection and schematic diagram of whole length corn cob in simple bending.

Table 4 Correlation of corn physico-mechanical properties with the performance of a laboratory sheller (Anazodo *et al*, 1981)

Physical and Mechanical Properties	Sheller Performance Parameters			
	CBI	CSE	SHE	KDM
Kernel				
Moisture content	0.007	0.695**	0.333	−0.523**
Modulus of deformability	−0.204	−0.246	−0.013	0.128
Linear limit load	−0.290	−0.219	0.102	0.008
Cob				
Moisture content	0.159	0.448*	0.148	−0.388*
Pith diameter	0.352	−0.115	−0.071	0.181
Cob diameter	0.644**	−0.193	−0.228	0.355
Elastic modulus	−0.145	0.243	0.430*	−0.282
Crushing strength	−0.556**	0.529**	0.676**	−0.656**
Toughness	−0.727**	0.322	0.522**	−0.531**
Bending elastic modulus	−0.203	0.752**	0.479*	−0.654**
Bending strength	−0.232	0.705**	0.508**	−0.631**

* Significant at 0.05 level, ** Significant at 0.01 level

farmers using mechanical harvesting methods. Fig. 9 illustrates the principle of threshing (shelling) corn ear in the cylinder-concave assembly of a conventional corn combine harvester.

The performance parameters determined include: Cob Breakup Index (CBI); Concave Separation Efficiency (CSE); Shelling Efficiecy (SHE) and Kernel Damage (KDM). These parameters were fully explained by Wall and Norris (1979).

Figs. 10-12 describe the methods used and experimental curves obtained in measuring the mechanical properties of corn kernels and corn cobs. The equations used in calculating the properties determined are also included in the Figures. They were derived by Anazodo (1980, 1981(a), 1981(b)). All the symbols are defined in the Appendix.

A correlation analysis of the physico-mechanical properties of corn with the performance of a laboratory sheller was undertaken. The results are shown in Table 4. From this it was concluded that the cob crushing strength was the most important crop property influencing the performance of the laboratory corn sheller. The highly significant correlation coefficients further led to the conclusion that the study of the mechanical properties of the corn cob would enhance the selection of corn varieties and also the timing of harvesting operations for the optimum performance of the corn combine. All the cob properties studied were found to be significantly affected by corn variety and harvesting date.

Conclusions

Determining the mechanical properties of biological materials under static or dynamic loading is an essential initial step in any work relating to:

1) Objective textural measurement of unprocessed and processed food materials;

2) The reduction of mechanical damage to agricultural producrs during physical handling, processing and storage; and

3) The design of harvesting and post-harvest systems.

The importance of studying the physico-mechanical properties of agricultural products locally produced cannot be over-emphasized, particularly for developing countries who are desirous of achieving self-reliance and self-sufficiency in agricultural production by judicious application of agro-technological innovations. Indigenous agricultural machines cannot be satisfactorily designed and evaluated nor needed imported equipment effectively adapted without adequate attention given to the characterization of locally produced agricultural products using proper engineering terminologies.

This article has attempted to give an overview of the basic concepts and the standard instrumentation used in studying bio-material mechanical and rheological properties.

Some practical applications of the propertics discussed are also briefly presented. The comprehensive references cited will supply the detailed information that may be required by interested readers.

List of symbols

a	linear acceleration of corn ear (Fig. 9)
b	half width of contact area
C	Correction factor for corn cob tapering
d	defined in Fig. 10
d_1, d_2	average diameters of corn cob at the tip and butt ends
D	total vertical deformation or deflection
De	elastic component of D
E	elastic modulus or apparent elastic modulus of corn cob in radial compression
E*	complex modulus of elasticity
E_b	E for corn cob in simple bending
E_d	modulus of deformability of corn kernel
f	ratio of pith radius to cob radius
F	applied normal load
F_b	applied normal load in simple bending
I	Moment of inetia (Fig. 9)
l	length of cylindrical body or short section of corn cob.
L	Loading span in simple bending
m	ratio of the elastic modulus of pith material to that of the mid-cob material
M	Mass of corn ear (Fig. 9)
P	Threshing Force (Fig. 9)
R	principal radius of curvature or cross-sectional radius of a circular cylinder or cob radius.
R_c	Resultant force due to the threshing concave (Fig. 9)
Z	defined as R/b
α_{ear}	angular acceleration of corn ear (Fig. 9)
μ, ν	Poisson's ratio
σ	contact stress
σ_b	bending strength
σ_c	crushing sttength
ω_{cyl}	angular velocity of threshing cylinder (Fig. 9)
η	viscosity.

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c. "The AMA does not pay for articles published. However, the writers are given collectively 5 free copies (one copy air-mailed and 4 copies sent by surface/sea mail) of the AMA issue wherein their articles are published. In addition, a single writer is given 25 off-prints of the article and plural writers are given 35 off-prints (also sent by surface/sea mail)"

Procedure

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

Format/Style Guidance

a. Whether the article is a technical or popular contribution, lecture, research result, thesis or special report, the format must contain the following features :
   i) a brief and appropriate title ;
   ii) the writer(s) name, designation/title, office/organization ; and mailing address ;
   iii) an abstract following ii) above ;
   iv) body proper (text/discussion) ;
   v) conclusion/recommendation ; and a
   vi) bibliography
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".
c. Tables and figures must be preceded by texts or discussions. Inclusion of such tables and figures not otherwise referred to in the text/discussion must be avoided.
d. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
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.
h. Round off numbers, if possible, to one or two decimal units, e.g., 45.5kg/ha instead of 45.4762kg/ha.
i. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers . . . , or Five tractors . . ." instead of 45 workers . . , or, 5 tractors.

Performance Evaluation of a Modified Fertilizer Applicator



by
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Abstract

Of the three different forms of fertilizer presently available: gas, liquid and dry forms, the dry, granular form is popular among Nigerian farmers. There are problems associated with mechanical application of fertilizer in Nigeria: the difficulty in handling such fertilizer and the fragmented nature of Nigerian small-sized farms.

A four-row Gandy applicator was modified to a two-row applicator aimed at making it either a hand-guided or animal-drawn band applicator. This equipment was evaluated for its flow rate and draft power, respectively. Results show that the equipment is appropriate for draught system.

Introduction

Due to the small size of most Nigerian farms, fertilizer is applied by hand. Small sized farms often mean low incomes for the farms suggesting that the purchase and use of small machines is not bright but a simple and relatively inexpensive fertilizer applicator should help them in applying fertilizer conveniently. Proper design of the metering units requires corrosion-resistant parts (2). Cummings (1) points out that fertilizer greatly accelerates corrosion, hence there is need for coating the hopper units. Lee *et al* (4) confirm that the rate of flow of granular fertilizer depends on the speed of operation and the flow characteristics of the material. They contend that at low speed, the flow is due mainly to gravity.

The main objectives of this study (5) were to modify a fertilizer applicator so as to make it suitable for Nigerian small farms and to ensure that the equipment conforms with the required method and rate of application. A four-row band applicator was modified to a two-row applicator. This equipment was calibrated in the laboratory to establish its rate of application and its performance was investigated in the field.

Material and Methods

The original design was made by the Gandy Manufacturing Company



Fig. 1 Metering units for the applicator

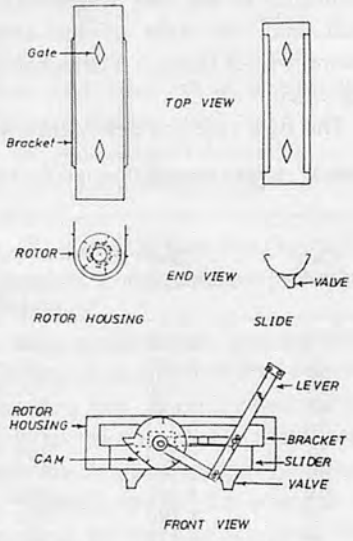


Fig. 2 Rotor for the metering units

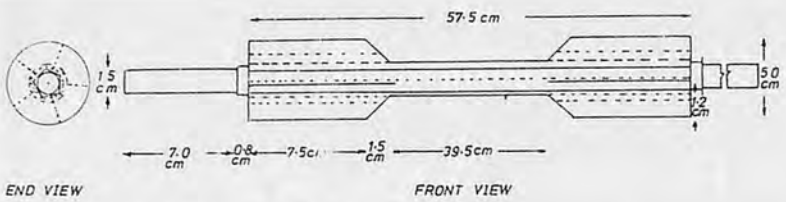


Fig. 3 Field determination of draft power

of U.S.A. The equipment was however modified to achieve the intended purpose.

The hopper unit was designed to hold 11.35 kg of granular fertilizer (Fig. 1). The granular form used in this investigation was urea containing 45% nitrogen. The metering units consist of a rotor housing with four gate openings two of which were blocked, hence reduced it to a two-row applicator. A scaled, lever operated cam mechanism for adjusting the opening of the gates was connected to the rotor housing and the slider as shown in Fig. 2. When the gates are fully opened the diamond-shaped gates in the rotor housing and the slider merge. Inside the rotor housing is the rotor on which are mounted five blades spaced 72° apart. These blades were modified at the blocked gate openings to provide the modified form shown in Fig. 3. The rotor is driven by a sprocket connected to the end of the rotor shaft and the axle of the two ground wheels through a detachable link chain.

The flow rate was determined in the laboratory using a 0.2 kW electric motor which had been geared down to 30 rpm. Different pulley sizes were used on the motor shaft and the rotor shaft to achieve the desired speed of rotation and hence the flow rate. The two pulleys were connected by a V-belt. Timed tests were conducted for the flow rate and power measurements.

Flow Rate Measurement

Three rotational speeds of the rotor were selected: 25, 30 and 35 rpm. Using the 0.2 kW electric motor, the pulley size required by the motor shaft was determined using:

$$N_m/N_r = D_r/D_m$$

where,

N_m = motor shaft rpm

N_r = rotor shaft rpm

D_m = motor shaft pulley diameter

D_r = rotor shaft pulley diameter

There were two sets of test runs: i) the hopper was nearly full before the commencement of the flow rate measurement and ii) the hopper was nearly empty. For the latter, enough material was put into the hopper to just complete the flow measurement. In either case the flow rate was replicated twice for each gate opening setting. The gate settings used were designated as 30, 35, 40, 45, 50, 55, 60, 65, 70, 75 and 80 as indicated on the cam mechanism. The area of opening represented by each gate setting is shown in Table 1.

Power Tests

Draft measurements were achieved using a hydraulic cylinder whose pressure gauge was calibrated using known weights. The power test was performed on the equipment to ascertain if the intended purpose could be achieved. The equipment was operated on a piece of land that had been ploughed and disk-harrowed. The soil was of silt-clay in nature. Prior to the test, the hydraulic cylinder with its pressure gauge was connected to the handle bars. The furrow openers were set at about 3.8 cm depth and the furrow closing devices were set in place (Fig. 1).

The time taken to push the equipment over 30 m was recorded. The average gauge pressure reading was also recorded and using the calibration curve, the draft force was established. The observa-

Table 1 Mean values of flow rate for three speeds at each gate opening and different hopper heads

(Unit: kg/ha)

Gate Setting	Gate Opening (cm^2)	25 rpm		30 rpm		35 rpm	
		Nearly full	Nearly empty	Nearly full	Nearly empty	Nearly full	Nearly empty
30	0.258	44.191	46.485	50.034	49.085	51.174	53.139
35	0.387	66.025	68.648	71.599	70.262	74.896	76.691
40	0.516	87.900	91.281	100.360	100.151	102.687	101.959
45	0.645	116.093	120.471	127.708	128.907	129.580	129.871
50	0.774	156.480	158.628	167.640	164.834	169.829	168.955
55	0.903	194.708	197.984	204.220	207.531	213.975	215.048
60	1.302	239.034	241.178	257.015	256.638	259.474	260.464
65	1.161	292.927	295.647	308.761	305.977	310.248	209.328
70	1.290	362.751	362.094	363.349	362.198	367.119	366.977
75	1.419	420.441	422.317	446.796	443.740	445.200	447.685
80	1.548	429.991	433.196	476.692	476.554	484.598	485.057

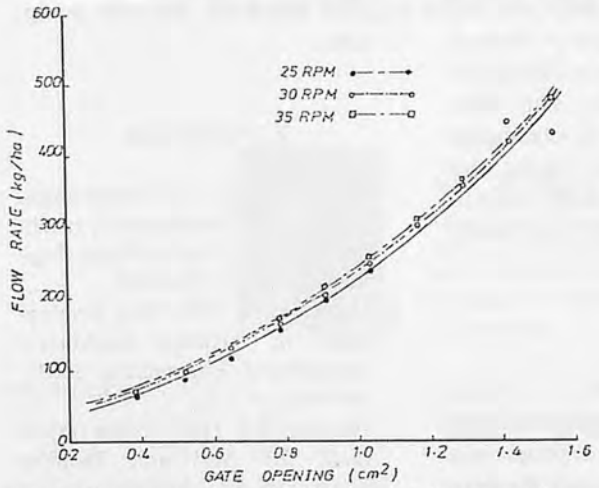


Fig. 4 Flow rate vs gate opening for three different speeds

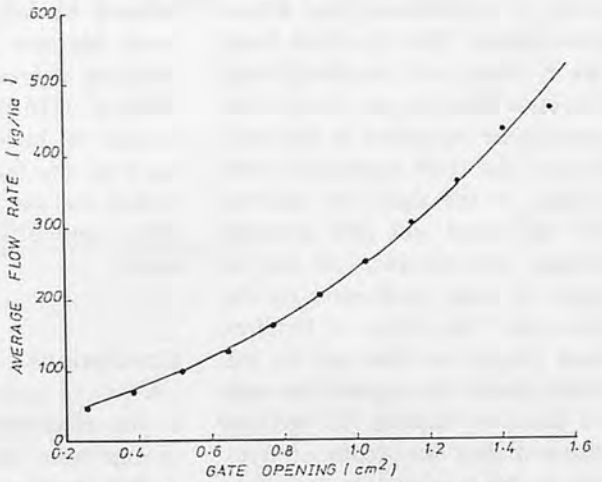


Fig. 5 Average flow rate vs gate opening for all speeds

Table 2 Mean values of flow rate for each gate opening over all speeds and hopper heads

Gate Setting	Gate Opening (cm^2)	Flow Rate (kg/ha)
30	0.258	49.018
35	0.387	71.320
40	0.516	97.390
45	0.645	125.438
50	0.774	164.394
55	0.903	205.578
60	1.032	252.300
65	1.161	303.814
70	1.290	364.082
75	1.419	437.696
80	1.548	464.348

Table 3 Analysis of variance for flow rate showing F values and level of significance

Variation due to	DF	Mean Square	F	Alpha Hat
Speed (S)	2	5 292.426	2 853.483	0.0
Hopper depth (H)	1	29.993	16.171	0.000
Gate opening (G)	10	383 994.875	207 036.000	0.0
S x H	2	43.814	23.623	0.000
S x G	20	338.871	182.707	0.0
H x G	10	4.484	2.417	0.011
S x H x G	20	2.714	1.464	0.105
Error	132	1.855		

Table 4 Average draft and power required to push or pull the fertilizer applicator at full hopper head and opener depth of 3.81 cm

Test No.	Trial	Time for 30 m (s)	Average Draft, No.	Power kW
1	push	33.60	153.00	0.455
2	push	30.90	175.50	0.566
3	push	37.80	207.00	0.545
4	push	36.00	207.00	0.575
5	pull	36.00	261.00	0.705
6	pull	39.00	261.00	0.670
7	pull	37.00	243.00	0.654

tions were for the hopper in nearly full state. This test was to indicate the amount of force required to push the equipment. Again, a calibrated scale was used to pull the equipment over a similar distance and the force required was established.

Results and Discussion

The results of flow rate measurements were analysed and presented in graphical form as shown in **Fig. 4** and the data is presented in **Table 1**. The flow rate in kg/ha was plotted against the gate openings for each of the three speeds used. The plots are curvilinear. The flow rate equation was established by a regression analysis and the curvilinear regression equations which involve second degree polynomials are as shown below.

$$\overline{W}_{25} = 1.10 + 119.75G + 113.21G^2 \quad \ldots\ldots\ldots (1)$$

$$\overline{W}_{30} = 16.82 + 84.28G + 143.32G^2 \quad \ldots\ldots\ldots (2)$$

$$\overline{W}_{35} = 20.36 + 82.64G + 145.11G^2 \quad \ldots\ldots\ldots (3)$$

where:

$\overline{W}$ = flow rate for each selected speed (kg/ha)

G = gate opening (cm^2)

Fig. 5 is a graph of the average flow rate plotted against the gate opening for all speeds and depth of the material in the hopper. The flow rate equation as determined by regression analysis:

$$\overline{W}_a = 12.76 + 95.56G + 133.88G^2$$

where

$\overline{W}_a$ = average flow rate (kg/ha)

The data for this plot is presented in **Table 2**.

Figs. 4 and 5 show that doubling the gate opening more than doubles the flow rate. This may be attributable to the nature of material used and the shape of the gate openings.

Table 3 shows the analysis of variance for the flow rate tests. The table gives the F-values and the

levels of significance used in the investigation. With all effects fixed, the F-values were calculated using the error mean square value of the appropriate parameter as the numerator. The 100% significance level (shown in the alpha hat column) for the speed and gate openings explain the influence of one or both of these parameters on the flow rate. The effect of fertilizer head (depth) on flow rate for the three speeds investigated can also be seen in Table 1. It will be observed that the depth of fertilizer in the hopper does not affect the flow rate.

Power Measurements

Table 4 shows that the power required to push or pull the equipment continuously is reasonably higher than what can be achieved continuously by human efforts. Hopfen (3) claims that a man working continuously can only develop an average draft of one-tenth his own weight. A bullock weighing approximately 700 kg can develop 0.56 kW (3) and since a pair of bullocks is commonly used on the farm in Nigeria, this makes the use of draught animals quite appropriate for this equipment.

Conclusions

1. The rotor speed and gate openings were the two parameters that greatly influenced the flow rate of the material used.
2. Increasing the speed of the rotor increases the flow but at a decreasing rate.
3. The depth of the material in the hopper had no influence on the flow rate as long as there was enough material to be metered during each test run.
4. The high power requirement tended to favour the use of draught animals for continuous operation of the equipment.

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(Continued from page 65)

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Farm Mechanization in Sierra Leone



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Introduction

Sierra Leone is one of the smaller countries of Africa, and its 73 326 sq·km which lie between 6°55′ and 10°N and between 10°16′ and 13°18′W represent just under 0.25% of the African continent.(1) The tropical climate is characterised by a 7-8 months wet season from May to November, with heavy rains from July to September. Although some rain continues to fall during the predominantly dry season from December to April, and the humidity remains relatively high, the drought is sufficiently severe to leave dead vegetation tinder dry, to allow hot bush fires which, both controlled and uncontrolled, are a typical feature of the country's agriculture. The rainfall of about 3 000 mm a year on the coastal plain drops to 2 300 mm a year in the north of the country, where the dominant forest regrowth gives way to some savanna woodland.

The population of the country as of December 1970, projected from results of the 1963 population census at a growth rate of 1.5% is 2 568 705. Of this number, 1 888 125 (73%) make up the farming population. The total number of adults engaged in agriculture is about 866 330 which is about 60% of the total adults of 1 443 883 that make up the population of the country.(2)

There are about 286 137 small agricultural farm holdings in the country, cultivating about 1 286 348 acres of land. In addition, another 18 806 acres are operated by institutional farms and large farms, making a grand total of approximately 1 305 154 acres devoted to the growing of crops. This is about 7.4% of the total area of Sierra Leone, with an overall average farm size of 4.5 acres. A greater portion of the total area consists of land lying idle to rejuvenate (by shifting cultivation).

Mechanization of agriculture in Sierra Leone could be said to have started when the first agricultural tractor, plough and harrow were brought into the country by the Department of Agriculture in 1946.(3) Since then; there has been a gradual importation of tractors and farm machinery into Sierra Leone, with a view to increasing the production of the country's staple food, rice. In 1980, the Sierra Leone Produce Marketing Board (SLPMB) made available to the Ministry of Agriculture and Forestry (MAF) a quantity of agricultural machinery and associated equipment, to form the basis of a Crash Rice Programme, which was formulated by the Ministry early in 1979 with the main objective of reducing the dependence on foreign sources for the supply of the staple food crop of the country.(4)

Several factors such as the land tenure system, types of machinery and equipment, lack of spare parts and servicing facilities influence the mechanization of Sierra Leone Agriculture. Except for a few agricultural development projects and parastatal companies which indirectly promote mechanization, the Government has allowed the progress of mechanization to take its natural course which proceeds at a very slow pace. Indeed, there is a need for a Government programme to promote mechanization in a systematic and workable manner.

If ever a mechanization programme is to be conceived it has to be long-range. It should consider the mistakes of past experiences and the conditions prevailing in the country. The future of mechanization in Sierra Leone will depend upon how its course is charted, how its programme is to be implemented and how the many and

Table 1 Land Use

Type of Land	Acres	Percentage
Under crops by individual farmers	1 286 348	7.2
Under crops by Insititutional farms and large farms	18 806	0.1
Forest Reserves	670 157	3.7
Protected Forest	82 368	0.5
Residual Land	15 815 321	88.5
Total	17 873 000	100.0

varied factors directly or indirectly affecting the programme behave through the years ahead. Thus the objective of this paper is to highlight the present status and problems of farm mechanization in Sierra Leone.

The Present Status of Mechanization in Sierra Leone

An appraisal of the state of mechanization in Sierra Leone would necessarily influde pertinent information on the land, water and power and machinery resources as well as other related data. Such resources and other factors influence the present situation and would affect the future of mechanization in the country.

Number and size of farm holdings – The Agricultural Statistical Survey of 1970/71 in the country indicated that Sierra Leone was basically a country of small farm holdings. The survey showed that there were 286 137 small agricultural holders in the country, cultivating 1 286 348 acres of land, or an average of 4.5 acres per farm.

Land ownership – One of the problems confronting Sierra Leone society is related to the tenancy system. Land tenure refers to the right under which the land is operated and not to ownership as understood in non-tribal societies. Except in the western area, land in Sierra Leone is not individually owned. Use of the word "ownership" is justified only as a matter of convenience. Title to land is implicitly vested in the community as a whole through the paramount chief or certain large family groups acting as custodians. These groups or their members may allow others to occupy and use the land under their control. "Others" include natives who borrow land from land holders in their own chiefdom, town, or villages, and "strangers" from other chiefdoms who take land for settlement and/or cultivation.

Land use – Mixed cropping - defined as the "phenomenon whereby a combination of crops is cultivated within the same field and which crops may or may not be harvested at the same time" - is the rule in Sierra Leone agriculture, with some 70% of the total acreage under cultivation under mixed crops.

Rice is by far the major crop, and is cultivated by most farmers. The total acreage under rice is the largest, occupying over 50% of the total acreage under cultivation and is grown by 81% of all the farmers. About 74% of the total rice acreage is under upland rice and 26% under swamp rice. Compared with the results of the 1965/66 agricultural statistical survey, where about 80% of the rice acreage was under upland rice, there has been a slight shift toward swamp rice cultivation.

Power and machinery resources – Human labour constitute the major source of power in farming in Sierra Leone. Animal power was first used in Sierra Leone in different parts of the northern area in 1928/29.[5] There was a sustained effort by then the Department of Agriculture to help the farmers in using draught power, particularly in the northern sector of the country. While the use of animal power has been shown to be practicable, the potential benefits of using work animals has been realized only to a very limited extent, and nearly all the agricultural energy is supplied by human labour.

Almost all the farmers in the country are illiterate, and although willing to take advantage of modern technology, are poor and do not have the necessary and adequate collaterals with which to secure loans from banks. With the exception of a few small garden tractors privately owned, and a few individuals with wheeled tractors for hire, all mechanical cultivation by wheeled tractors is done by the Ministry of Agriculture and Forestry or co-operative societies. The agencies plough and harrow fields at a set fee per acre.

With the national and local requirements to increase the output of food crops in Sierra Leone, methods of increasing the efficiency of agricultural production are considered vital. A recent FAO report had stressed that draught animal programmes are complementary, and should both be encouraged in appropriate circumstances. In recent years various costly attempts have been made to introduce mechanical cultivation in many areas of Sierra Leone, while comparatively little has been done to develop animal powered farming in the country.

The constraining factors in the development of widespread mechanical cultivation are daunting and include high capital costs involving foreign exchange, increasing costs of imported fuel, and very severe organizational problems involved in adequately servicing and repairing complicated mechanical equipment widely dispersed around the country. The long term national impact of previous mechanical cultivation schemes have been small, for the vast majority of farmers in the country have never had access to the tractor ploughing schemes, and the limited number of farmers who have at one time benefited, have suffered from the short-term nature of the various projects which have generally stopped completely when the tractors broke down and were abandoned after a few years.

What Mechanization should Accomplish

The introduction of mechanization in a developing country like

Sierra Leone should lead towards more productivity and profit for the farmer. Other benefits derived from mechanization are of secondary importance, especially on small farm at the present stage of development.

Mechanization does not necessarily increase the yield per unit area but should increase the overall productivity by enabling the farmer to plant crops on time and hence more crops per year at a lower cost of production. Mechanization, therefore, provides an opportunity for the farmer to intensify his farming. On the other hand, a small farmer needs to intensify his farming to justify mechanization. Therefore, they should be complementary with the result of giving the farmer a better standard of living.

Mechanization should not lead to over-investment such that the farmer can not get back the cost of machinery. In such a case, mechanization does more harm than good because it leads to an economic imbalance for the farmer himself.

In introducting mechanization, the labour force should be absorbed by an industry or industries created relative to mechanization. Since mechanization eases labour for devotion to other activities, such activities could be either wholesomeleisure thereby increasing the standard of living or other productive activities such as cottage industries or other farming enterprises such as poultry and livestock raising. Mechanization, in other words, should not displace labour. On the contrary, its introduction should be such that it should directly and indirectly absorb labour. Therefore, a well-designed and well-planned mechanization programme should be conceived in order to derive benefits and avoid unwholesome consequence.

Problems of Mechanization in Sierra Leone

Historically, the evolution of farming tools and equipment has been slow. The first digging sticks were developed over the years into the plough, which was pulled by the farmer or his wife and, later on, by oxen or other draught animals. In Sierra Leone these indigenous methods are still in use. Similarly, harvesting is carried out by hand and the grain crop threshed by flail.

Cultivation by mechanical means in tropical regions appears to present a problem, perhaps of its own creation, through the introduction of machinery to land where the idea is still novel. Notorious mistakes have been made by introducing implements to countries where the agricultural and social conditions differ greatly from those for which the implements were designed, developed and tested.

In the tropics agricultural science in the fields of agronomy, plant breeding etc., has made considerable progress, but the supporting engineering has lagged behind. One of the main difficulties with mechanization in less-developed areas is the lack of equipment, coupled with the lack of knowledge of existing equipment and its performance under tropical conditions.

Although the government of Sierra Leone desires that its farms be mechanized in order to increase productivity, the mechanization of Sierra Leone farms is hampered by several problems many of which cannot be solved in this decade. Some of these are outlined below:

Expensive mechanical power source and equipment – The capital investment for even a small farm is quite high because most mechanized equipment is imported. The non-availability of foreign exchange, particularly at this time in the development of the country, makes the importation of mechanized equipment impossible. Even where machines are imported the prices of these machines are so high, that on small farms where production is low, it becomes uneconomical to employ the use of such machines.

The high cost of imported machinery has always been a serious, limiting factor in the mechanization of tropical agriculture. Farmers in the developing countries like Sierra Leone pay considerably higher for machines than their counterparts in the industrialized countries, whereas the returns from agriculture are usually much lower in the less developed countries.

Spare parts and service – The non-availability of foreign exchange is also, tied up with the provision of spare parts. The restriction on foreign exchange by the government has made it very difficult for dealers in farm machinery and equipment to bring in spare parts. Also, with the ever changing political atmosphere in Africa, dealers are afraid to tie up their capital in the provision of spare parts. Thus the lack of spare parts for agricultural machinery and equipment is a major problem which greatly affects all mechanization schemes in the country.

Also, service facilities provided by the dealers are limited. Sometimes no after sales service is available. This, with the lack of fairly well equipped workshops in the country makes it very difficult to effectively carry out mechanization programmes.

The cost of fuel and oil – With the high cost of diesel fuel and engine oil, which is a result of the general oil price increases in the world, it is indeed expensive for an average farmer in Sierra Leone to own a tractor. A gallon of diesel fuel costs about Le3.00, (3 leones) and a gallon of engine

oil about Le10.00 (10 leones) depending on the quality. The high cost of fuel and engine oil therefore puts an embargo on the economic use of farm machinery and equipment. Even with the Crash Rice Programme of the Ministry of Agriculture and Forestry, which is heavily subsidised by government, the cost of fuel and oil make up a sizeable part of the operating costs.

Inadequacy in design of available equipment – What makes most imported farm equipment all the more expensive is its inefficiency in working under local conditions. Some modifications and redesigning have to be done to make such machines at least functional. This situation has been the result of a lack of suitable testing and evaluation programme to find out the efficacy of imported equipment.

Low level of technology for mechanical operations – The educational attainment of most farmers in Sierra Leone is very poor. Almost all the farmers in the country are illiterate, and have little experience with mechanical implements. The farmers have little or no exposure to modern machines for the farm and as such are hesitant to even try handling a powered piece of equipment. A programme of farmer education in handling and managing farm machinery is a must in a mechanization programme. The training programmes must therefore be very thorough and well planned in order to convey the essential knowledge.

Lack of trained operators and service men – The need for a core of trained personnel at all levels as a prerequisite for successful mechanization is obvious but this is often neglected. No programme have been instituted to train operators and service men for the various types of machinery and equipment brought into the country. With no special training on how to use tractors in the field, some people are called upon to operate tractors and equipment with the result that much damage is done to both tractor and equipment. The men have not been trained to carry out the necessary routine services on the tractor, or to carry out the necessary adjustments on the implements. Thus the machinery is badly used, which results in major breakdowns, and delays in farming operations.

The land tenure system – Tenural arrangements seem to inhibit agricultural development since communual land is not easily available to many people who want it. In the western area, however, individual ownership of land is practised. The government needs to investigate land inheritance laws for the purpose of finding an alternative to land fragmentation. Small holdings do not lend themselves to mechanization, particularly if they are scattered over large areas, as the cost of transporting machinery to cultivate small plots is far from economical. Pointers which the government may well consider when reviewing natural resources in connection with land utilization are collective farming in areas of individual ownership, cooperative societies, or perhaps a system of group farming.

Technical problems – Many technical problems in machinery operations need to be solved through research. Imported machinery and equipment require trials and modifications to suit the situation in Sierra Leone.

The economic and social aspects of mechanization need to be investigated and research in these areas be undertaken. More extensive research on ago-climatic problems and man-machine relationships are a requirement in mechanization programme.

The formulation of a suitable mechanization programme for the country needs a wealth of technical, economic, social, political, educational and other data.

Problems related to irrigation of farms – Since the early forties, the government was involved in carrying out both drainage and irrigation work in some parts of the country. Even though the inland bolis and some of the riverain grassland areas can be made to yield two crops of rice per year if irrigation techniques are effectively employed, yet the government has not put much emphasis on this aspect of mechanization.

The development of irrigation is beset by problems in financing, problems related to the improvement of irrigation service by the Ministry of Agriculture and Forestry, lack of credit facilities for the farmers, problems pertaining to the improvement of the farms already established and problems in marketing.

Other problems – Other problems of mechanization are related to the economic, social and political developments in the country. For example, the shortage of foreign exchange makes all farm inputs very expensive. In some cases some of these imputs are not available in the country.

Methods of Dealing with These Problems

Co-operatives – A logical answer to one of the many problems of mechanization seems to be the creation of co-operatives, which could institute syndicate farming, machinery pools and joint storage projects. Such arrangements have been successfully introduced in other countries, where previously it was thought difficult to persuade farmers to co-operate. Care should be taken in starting such schemes where there is already an abundance of labour. The use of machinery may lead to a reduced need for labour though this

will be required at a later stage when more work is done on agricultural processing. In the interim period, employment could be created by the local manufacture of improved hand and animal-operated implements needed for regular cultivation operations in the agricultural cycle. This period could also be used for the education of farmers, and those wives who would be released from the need to work on the land. Educational schemes of this kind should properly be organized and financed by government authorities.

Government action and aid – The government should accept the necessity of opening up new areas by bush clearing, surveying for corrective soil conservation measures, and introducing group farming. Such schemes require capital and technical assistance contribution which could be sought from foreign donors and the United Nations' agencies, supplying capital either as gifts or loans on favourable terms.

Such projects may prove highly successful. The clearing of the bush may help to eradicate the black fly that causes river blindness, and consequently improving the health of the people. There would be more permanent settling on the land, and equipment pools could enable farmers to hire machinery for use on their own farms.

However obvious it may seem that machinery is needed, nothing can be done unless the people wish to make use of it. Although there may be initial reluctance to try new tools, great enthusiasm generally evolves once the benefits of mechanization are realised. The use of machinery may, nevertheless, produce its own problems. Where land is traditionally inherited and held by families in small holdings, the use of machinery will be difficult. Law of inheritance and subdivision of land can only be changed by government legislation, and feelings of family and traditional rights must be dealt with cautiously.

Before any major project of mechanization is undertaken, it is essential that the economic factor should be given thought. A large amount of capital would be required for assistance in the initial stages of a land clearance scheme. The heavy equipment necessary for clearing bush would be beyond the reach of a small scale farmer. Once land is cleared, further capital would be necessary to cover its division into settlements - allocating it to group farmers etc. In addition, the farmers would either need loans for buying their initial equuipment or the opportunity of hiring Government or syndicate-owned machines. For efficiency steps would have to be taken to process and store the crops, that is processing machinery and stores would be needed. In addition, effective transport and marketing systems would have to be created.

Planning – The importance of forward planning cannot be overstressed when introducing mechanical methods of cultivation into the agricultural industry and it seems essential to consider the following factors in order to ultimately achieve successful mechanization: the availability of machinery service and maintenance facilities; increasing the acreage of ploughable land at the expense of that previously used for grazing animals; growing cash crops as well as high yielding food crops; observing soil conservation practices; making maximum use of favourable climatic conditions; securing greater output per man per acre; altering the system of land tenure; and establishing training centres for educating farmers in the use and understanding of machinery. The list is long and items are not necessarily given in order of priority.

Many instances can be cited in which countries, eager and enthusiastic to introduce mechanical schemes, have failed through the lack of preparation and planning to make them work, with the result that equipment has prematurely reached the scrap heap.

Capital outlay, overhead costs and organization – Mechanization in its general sense, involves considerable capital outlay. In African countries, labour usually abundant and capital scarce. The government should therefore consider very carefully before embarking on schemes that involve the replacement of abundant labour by scarce capital, eventhough there are certain compensating advantages - in the shape of additional employment at later stages - with the operations of harvesting, marketing and processing, these aspects are usually limited.

The importation of agricultural machinery often constitutes a heavy drain on foreign exchange. Similarly, spare parts, fuel and lubricants are very expensive. The use of foreign exchange for these agricultural purposes may hinder industrialization programmes. Therefore careful planning must be exercised in order to assess priorities and maintain equilibrium within the nation's economy.

In areas where it may be decided to undertake mechanization, planning is essential if the waste of scarce resources is to be avoided. In particular the importance of considering the policy of gradual approach to mechanization should be stressed. In large-scale farming schemes, whether privately or publicly owned, heavy mechanization is necessary if extensive field operations are to be carried out with the minimum cost.

In many cases, there is the tendency to encourage the use of tractors without due consideration of the part that could be

played by draught animals. In small-scale farming efficient use could often be made of animal draught power, though as the farms increase in size the problem of ensuring timely ploughing, cultivating and planting becomes critical.

Machinery pools should be established to serve individual farmers or groups of producers. In this regard, it is necessary to plan administration, supervision and maintenance in such a manner that the overhead costs are kept to a minimum without in any way impairing efficiency. Successful administration is usually the result of accurate survey work in the initial stages which involves investigation into the needs of the producers and careful selection of equipment to meet these needs.

It is essential for maintenance facilities to include adequate base workshops capable of handling major repair work with connecting depots where regular preventive maintenance can be performed with efficiency. Only too often one comes across very expensive machines standing in a state of disrepair for long periods due to lack of service facilities. Operating costs of machinery are also increased by inadequate maintenance and unskilled operators; this aspect, of course, is particularly aggravated where tractor hire services are spread over large areas.

Successful organization and management of machinery pools or large scale mechanical agriculture projects demand a high degree of executive leadership and a sound knowledge of agriculture and agricultural machinery. Management must, in all instances, have built into it a degree of flexibility together with adequate provision for the recording and analysis of technical and economic data on which to base evaluation and necessary changes often resulting from various side effects, such as changes in land tenure or political interferences which were unforseen in the planning stages.

Sometimes, the introduction of a large variety of makes and types of tractors and implements increases the problem of maintenance and also causes unnecessarily large amounts of capital to be tied up in spare parts and servicing tools, coupled with extra training programmes, if they exist at all. Therefore, it is necessary for the Government to set up a machinery testing station, preferably in the University, to test the equipment according to a standard of procedures under local conditions. Government should restrict the import of machines, by not granting import licence to dealers whose machines do not meet the specifications of the standard required. A testing station of this type in the country could contribute to the saving of foreign currency by preventing the entry of machinery which is not suited to the conditions of the country.

The need for research – The need for mechanization in the developing countries of the world is apparent. By the use of machines, improved methods of husbandry can be practised, yields can be increased and operations made more timely. In addition to more food, a better standard of living can be achieved by the farmer and his family. However, the fact must be recognized that some tractor and implement design with conventional equipment is not always ideal for conditions in tropical agriculture and that there is a need for research into adaptation of such equipment to the local conditions that exist in the country. Many technical problems in machinery operations could be solved through research. The formulation of a suitable mechanization programme for the country needs a wealth of technical, economic, social, political, educational and other data.

To conclude, there are a number of factors which contribute to the success or failure of a mechanization scheme. Each must be given due consideration, for lack of attention to a single factor can result in technical or economic failure of the entire scheme. One must never loose sight of the fact that a tool or machine must pay for itself through increased returns or decreased operating costs.

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Forced Aeration: A Technique to Handle High Moisture Paddy under Humid Condition



by
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Abstract

In several states of India, harvesting the matured paddy is inadequate. Warm and dry days are ideal to harvest and thresh paddy but unexpected rains make the problem worse. Paddy starts deteriorating very fast, specially in humid regions. Grains become yellow and activities of micro-organisms reduce the nutritive value of prepared product made from such paddy. Hence, a problem of preserving the paddy exist where the arrival of the monsoon coincides with harvest.

Under the Post-Harvest Technology Scheme (ICAR) a project was undertaken to reduce the high moisture content of paddy. The forced aeration technique was used to keep the paddy for a period of 50 to 60 h under high humidity (rainy) condition. In addition, some traditional methods have also been included in the study.

Introduction

In the eastern part of India where high humidity prevails, the harvesting period of the kharif crop normally coincides with the onset of the monsoon. The frequent and erratic rain makes the condition even worse and increased grain moisture prohibits storage beyond few hours. It is now recommended that paddy should be harvested at a moisture content of about 22% (w.b.) in order to reduce shattering losses. Paddy, being hygroscopic in nature, is very much susceptible to qualitative deterioration, caking, and discolouration. Mechanical drying is one answer to this problem, but this is beyond the capacity of the small farmer and such facilities are not readily available, even on custom-hiring basis. Grain deterioration is a function of the grain respiration resulting in temperature and moisture changes. Freshly harvested paddy gets easily spoiled due to spontaneous heat generation and enhanced activities of micro-organisms. Damage to grain occurs if this type of heat development is allowed to continue for a longer time than desired.

The Paddy Processing Research Centre in Tiruvarur has been advocating that 5 kg of salt and 40 kg of rice husk powder if added to 100 kg of about 30% moist paddy, the moisture goes down to 17.6%, within a period of 24 h. Similarly, sandy soil of equal amount of moist grain when mixed thoroughly with 5 kg salt can reduce the paddy moisture to a level of 16.1%. But, this technique is labour consuming and requires a lot of storage space with efficient separating facilities before the paddy can be put to some use.

Freshly harvested paddy containing 27.5% moisture (w.b.) was subjected to 1.38, 1.67 and 3.2 m^3/min/qtl air flow rate and the samples were milled to determine the condition of the paddy. Other traditional methods were also tried to compare the results in terms of milling yield under the scheme.

Methodology

The following variables were studied.

Independent Variables:

1) Variety – JAYA

2) Time of aeration cum storage – 72 h

3) Air flow rate – 1.38, 1.67 and 3.2 m^3/min/qtl

4) Relative humidity (RH) – It was raised to 90% whenever found less than 90. This was done by a humidifier.

5) Temperature of air – Average ambient temperature was almost 30° C.

6) Initial moisture content – It was initially 27.5% but was reduced

Acknowledgement: The authors are indebted to Dr. T. P. Ojha, Prof. & Head, Post Harvest Technology Centre, I.I.T., Kharagpur for his valuable suggestions and continuous help. Thanks are also due to the employees of Harvest and Post Harvest Technology (ICAR) Scheme of Kharagpur Centre.

to 25% by the time experiment started.

Dependent Variables:

1) Resulting moisture content of the grain.

2) Temperature of the grain.

3) Milling quality.

Experimental Procedure

The complete aeration system consists of a humidifier attached to blower which forced the air to pass through the bin equipped with a series of thermometer.

The moist paddy was filled in the bin having perforated pipe in the centre allowing the air to cross flow through the grain. The temperature and moisture content of the grain were measured at an interval of 6 h. The paddy samples were taken after an aeration period of 12 h and dried in the shade so that the moisture was reduced to 14%. The dry and wet bulb temperatures of the humid air going in the bin were recorded in order to determine the R.H. of the passing air. Air velocity was measured by a micromanometer

Four traditional methods were also tried which farmers generally practise. For this purpose, four equal size (6x6 m) of plots were choosen. The paddy of the first plot was harvested and left in the field for 72 h. In the second, harvested paddy was bundled and stacked on the threshing floor. The paddy of the third plot was harvested, threshed and stored in a gunny bag for 72 h. The fourth was harvested, threshed and immediately dried. All harvests contained high moisture. The samples for milling purposes were taken after 72 h and were dried before the milling qualities were determined. The laboratory facilities of the Post-Harvest Technology Centre, IIT, Kharagpur was used for sample testing.

Table 1 Milling quality of paddy after 72 h

Treatment	Total yield	Head yield	Broken
Paddy harvested and left in the field (P_1)	77.6%	44.8%	32.8%
Paddy harvested, bundled and stacked in threshing yard (P_2)	7.48%	60.8%	14.0%
Paddy harvested, threshed and stored in gunny bag (P_3)	73.2%	64.8%	8.4%
Paddy harvested, threshed and dried immediately (P_4)	77.2%	69.2%	8.0%

Results and Discussion

a) Variation in grain moisture and temperature – The grains' moisture content decreased according to aeration period and was much more prominent in case of 3.2 m^3/min/qtl, air flow rate. It was observed that higher flow rate has a better cooling effect. Minimum grain temperature was observed at 3.2 m^3/min/qtl during 12 h of aeration on the first day of experimentation, lesser variation in grain temperature were observed at lower air flow rates.

b) Variation in head and total yield – The influence of the aeration period and air flow rates on milling quality of paddy is shown in **Fig. 1**. The total yield decreases as the aeration period increases. This decrease was not very fast but gradual in all the three air flow rates. The same trend was also found in case of head yield, but the decline was higher. The air flow rate of 3.2 m^3/min/qtl helped retain the head yield up to 60% even after 72 h of aeration. **Table 1** shows the milling results of the paddy kept in the traditional way.

Among for traditional ways of keeping paddy, the technique in which paddy is immediately dried after harvesting and threshing (P_4) gave maximum head yield with minimum broken percentage. The broken percentage is higher in case of P_2 and P_1 because of the crack formation in the grain due to intermittent heating and cooling.

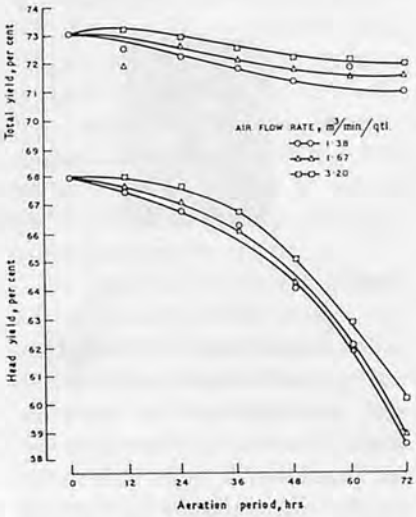


Fig. 1 Effect of aeration period and air flow rate on paddy head yield and total yield

Conclusions

Freshly harvested paddy should be subjected to forced aeration at the rate of 3.2 m^3/min/qtl. This technique not only helps preserve the paddy from deterioration but also maintains better milling yield. It may be mentioned, however, that there is extra cost involvement in this technique.

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SIMA
March 7-14, 1982 Paris/France

The 53rd International Exhibition of Farm Machinery (SIMA) was held in Paris.

With a wide choice of equipment: under 2 300 trademarks originating from 30 countries, almost 20,000 machines and items of equipment are exhibited covering all types of use, all requirements for all countries.

Farmers, technicians, dealers, industrialists, teachers and researchers thus form a universal symposium where the latest progress in agronomy, the latest requirements of users are all discussed.

The exhibition will also include: The 14th international exhibition of mechanised gardening equipment. In 1982 there will be many novelties amongst the 3 000 items of equipment for activities ranging from gardening and horticulture to the creation of green spaces and the maintenance of the landscape.

This year's medal-winning machines (three gold, six silver and fourteen noteworthy) selected by the Committee to Encourage Technical Research are introduced on New Products corner of this issue.

FIMA/82
March 27 - April 4, 1982, Zaragoza/Spain

During the nine days of FIMA/82 and as in no other place, the Agriculture has its main appointment in Zaragoza.

The Fair shows a wide view of the present advances of the Technique applied to agricultural machinery and equipment.

The importance of FIMA may be estimated by the high number of exhibitor firms and machines shown, as well as by the number of visitors coming from every country of the world. The Fair will hold several events, amongst which the following deserve special attention:

14th International Conference on Agricultural Mechanization March 31 - April 4, 1982 during FIMA/82.

General Subject: Microcomputers in agricultural mechanization.

Report 1 – Tillage and harvesting equipment by S.W.R. Cox.

Report 2 – Livestock housing equipment by G. Postma.

Report 3 – Agro-Food industries by D. Manuel A. Page.

Report 4 – Organization and Management by D. Jose Ruis de Miguel Arenal.

Closing Lecture: Prospects of informatics applied to agriculture by D. Fernando de Elizaburu Marquez.

The DLG Show
May 20-26, 1982, Munich/West Germany

The exhibition programme covers all investment and technical requirements for agriculture:

Farm machinery, tractors, other machinery and implements – animal husbandry (all breeds and races in competition, International Animal Show, livestock management, machinery and equipment for intensive production), farming requirements such as seeds and plants, fertilisers, plant protection products, feeding stuffs, farm buildings – vegetables – fruit and market garden – forestry – conservation – information and special displays, advice.

More than 1 200 exhibitors and additional representative firms will show a comprehensive range of goods and equipment from 28 countries.

Daily Programme: Presentation of DLG Award Winning Machinery with agricultural/techanical innovations – Demonstration of machines and equipment for gardens, landscaping and public parks. Presentation of international livestock breeds. Parade of prize winning German livestock with outstanding show results.

The Exhibition is open daily from 9 a.m. to 6 p.m.

International DLG Symposium: The fourth DLG International Symposium entitled, "Multifarm use of agricultural machinery in the Middle East and North Africa", will be held in Munich from May 17th to 20th, immediately prior to the Exhibition. The Symposium, organised in collaboration with the FAO, the EEC, the Agency for technical co-operation (GTZ) and the German Foundation for International Development (DSE), is for project leaders, technicians, and senior Civil Servants.

EIMA 1982
Nov.10–14, 1982, Bologna/Italy

In November will be opened in Bologna (Italy) the 13th edition of EIMA.

EIMA – which stands for International Exhibition of Farm Machinery Industry – has been organized in order to foster the interests of agricultural machinery manufactures all over the world and it is promoted by UNACOMA, the Italian national association of agricultural machines manufactures. It represents the ideal platform for the presentation of the world's new machinery and equipment, developed to facilitate and rationalize farm work and to accelerate the restructuring of agricultural activi-

ties by raising productivity.

As it has been confirmed by all previous editions, EIMA, by virtue of the choice of its timing, represents the ideal meeting point for distributors, users and machinery manufacturers, enabling them to formulate their production programmes on the basis of the requirements which emerge from contacts with representatives of all interested categories.

In addition, 13 separate production sectors and absence of any form of advertising facilitate the comparison of technical characteristics and the choice of the machine which meets more closely farmer's needs and the ecological conditions in which it has to operate.

Bologna's exhibition quarter has an overall surface of 500,000 square metres of which 70,000 square metres composed by covered and heated stands. Motorway intersections at 500 m, railway and city centre at 2 km and the international airport at 6 km enable rapid access to EIMA.

Conference rooms of various sizes, logistics and interpreter services provide the exhibitor with the opportunity of arranging, within the EIMA framework, meetings with distributors and customers.

Swaminathan named as New IRRI Director General



Los Baños, Philippines – The International Rice Research Institute (IRRI) announced the appointment of Dr. M.S. Swaminathan, 56, as director general on Friday 18 December, 1981.

Dr. Swaminathan, a plant breeder and geneticist, is known as an "architect of modern Indian agriculture." He assumes duties in mid-April 1982, replacing Dr. Nyle C. Brady, senior assistant administrator, U.S. Agency for International Development, who served as IRRI director general for 8 years.

Dr. Swaminathan has served as vice chairman of the Technical Advisory Committee of the Consultative Group on International Agricultural Research (CGIAR), a group of donor agencies dedicated to the improvement of agriculture in developing nations.

IRRI, which was established in 1960 by the Ford and Rockefeller Foundations in cooperation with the Philippine Government, is now funded through the CGIAR. The 2 000 IRRI employees include about 60 international scientists from a dozen nations.

IRRI works with national rice improvement programs to increase the productivity of rice lands by developing and testing improved varieties, production technologies, and rice-based cropping systems. The Institute, about 60 km south of Manila, is best known for its development of improved semidwarf rice varieties that spearheaded the *green revolution* – a term coined to describe the phenomenal increases in rice and wheat production in developing nations since the mid-1960s. Today about 30% of the rice in the tropics is planted to IRRI varieties or to their progeny.

Dr. Swaminathan's early recognition of the potential of semidwarf varieties of wheat and rice contributed to their wide-scale adoption by Indian farmers. Dr. Swaminathan was born in 1925 in Tamil Nadu, India. The Swaminathans have three children.

3rd All India Conference on Desert Technology

Nov. 11-13, 1982
Bhavnagar, Gujarat, India

Complete papers not exceeding about 10 typed pages (A-4 size) are invited by the Indian Society of Desert Technology for the 3rd All India Conference on Desert Technology to be held on November 11-13, 1982 at the Central Salt & Marine Chemicals Research Institute, Bhavnagar, Gujarat (India.). The papers may relate to any of the following themes of the Conference.

A Plant Sciences
1 Dry land agriculture
2 Production of pulses and oil seeds
3 Afforestation, pasture development and economic plants

B Animal Sciences
1 Dairy development with emphasis on milch cattle
2 Wool production and sheep breeding

C Engineering Sciences
1 Development of energy sources-solar, wind and bio-mass
2 De-salination
3 Engineering behaviour and application of desert soils
4 Water resources development

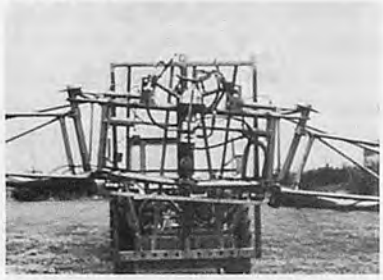
D Any other topic of relevance to integrated desert development.

The papers may please be sent by Reoistered Airmail before the dates of Conference to Dr. Alam Singh, General Secretary, ISDT, Faculty of Engineering, University of Jodhpur, Jodhpur, India. ■■

NEW PRODUCTS

Medal-Winning Machines at 53rd SIMA

No.1 GOLD MEDAL
Dynamic Stabilization of a Spraying Boom



The main purpose of this system of hydraulic stabilization of very wide spraying booms is to maintain them at a constant distance from the surface of the soil.

Two or more ultrasonic transponders situated at the ends of the boom continuously measure the distance between the soil and the boom.

The data so provided are integrated by a microprocessor which controls the servo-valves supplying the actuators that correct the parallelism of the booms, by connexion to the hydraulic pump of the sprayer or the tractor.

This "active" device makes it possible to obtain the correct position at any moment and very rapidly with adding to the weight of the equipment. It can be applied to any type of boom.

No.2 GOLD MEDAL
Compact Self-Regulating Drop-By-Drop Irrigator



To make drop-by-drop irrigation economically possible in every sort of open field cultivation, arboriculture, and market gardening, these droppers have been designed to be self-regulating, simple, and inexpensive. They consist essentially of an internal membrane, which deforms under the effect of pressure and maintains a constant flow.

Its small size makes it possible to insert it in the irrigation piping, so permitting the mechanization of the annual laying and lifting of the drop-by-drop irrigation networks. They reduce the time and the laboriousness of the operation.

No.3 GOLD MEDAL
Threshing Machine for African Millet and Maize



A fixed knife mounted at the edge of an opening first of all cuts the long ears of millet. The threshing rotor and an opposed part, that partly perforated and partly covered with a rough material.

The multiplicity of employment is achieved by changing the opposed part designed for millet, to another designed for maize or sorghum, by a sliding action.

The equipment is suitable for throughputs of some 350 kg per hour of millet or some 1 500 kg per hour of maize.

No.4 SILVER MEDAL
Self-Tracking Axle for Trailers



To reduce side-slips in reverse as well as when going forward, a self-tracking axle has been designed for mounting on two-axle or three-axle bogie on a trailer. This axle consists of two pivots set in bearings, which cause the inclination of the axis of the direction of the wheels in a vertical plane parallel to the movement to vary. According to the direction of movement of the trailer, this variation may take place towards the front or the rear. The wheels put themselves into a position suitable for the turning movement of the trailer.

Manoeuvres with multi-axle trailers are thus simplified. The turning circle is reduced. Wear on the tyres is also reduced. The traction force required when turning is less. The ground is less cut up.

No.5 SILVER MEDAL
Screw-Operated Proportional Distribution Boom for Powdered Fertilizers



For the spreading of fertilizers, the screw-operated boom is pierced with holes, more or less blocked, according to the desired output of fertilizer, by a movable slide.

This slide is controlled by an actuator which takes up its position according to the quantity of fertilizer arriving in the boom.

The slide only opens the holes when the ramp is full. A good regularity across the length of the boom is obtained by the use of a progressively varied pitch for the screw thread.

No.6 SILVER MEDAL

Combine Harvester with Cylindrical Separators



The usual vibrators are replaced by 8 transverse cylinders with adjustable speed of rotation, consisting of drums with toothed bars placed above casing in perforated sheet metal.

The spacing between the drums and the casings is adjustable by changing the position of the two support rails on which they are mounted.

The separation is obtained by rubbing during the forced passage through this space and by breaking the sheaves between each cylinder.

The bulk of the type of high power combine harvester, for which this system is designed, is noticeably reduced.

No.7 SILVER MEDAL

High Density Press



The VICON HP 1600 pick-up baler is intented for ensilage, hay, and straw. It produces bales of rectangular section (1.60 x 1.20 x 0.70 meters) at very high density (weight: 400 to 900 kg), whose dimensions and shape make for easy handling and distribution by conventional equipment.

This tractor-drawn machine carries out the pressing continuously. The pick-up and the primary conveyor feed the precompression chamber. A secondary conveyor sends the crop into the compression chamber. The shaping of the bale is carried out by seven strokes of the piston. The binding with four iron wires is done by a twisting device.

As soon as the pressure level has been reached, the bale is ejected. A microprocessor checks and controls all the operations.

The many uses of this equipment ensure its rapid amortization.

No.8 SILVER MEDAL

Pneumatic Clipper with Built on Sprayer "Felco Matic P"



A spray nozzle is mounted on the body of a pneumatic clipper. The air escaping from the clipper during its return to the open position is used to draw up and spray a disinfectant liquid and to direct it to the blade and the pruning wound.

The reserve of liquid is contained in a plastics bottle carried by the operator, joined to the clippers by a suction tube. A non-return valve avoids the unprimings of the suction.

Thus, the pruning and the localized spraying are carried out simultaneously, avoiding the propagation of different diseases by the pruning wounds.

No.9 SILVER MEDAL

Multidiameter Grape Stalk Remover



The casing of the destalker consists of two successive parts of different diameters so as to improve the operations of destalking and drying, which require two different circumferential speeds.

– The destalking zone properly so called ensures the separation of the berries. A cover with a slide modifies the amplitude of the destalking or suppresses it. This zone has the largest holes and the smaller casing diameter.

– The draining zone has a greater diameter to increase its efficiency. It has medium sized holes followed by small ones.

The quality of the berries produced and the proportion of

stems or fragments of stems remaining amongst the grapes is changed.

The rotating assembly is preceded by leader blades which, like the hopper have been designed for direct filling of the equipment. A washer nozzle boom is built in.

No.10 COMMENDED
Swath Layer



Fitted to a "TAARUP 307" mowing machine, this swath layer makes it possible to lay forage with a width of mowing of 5. 40 m in swaths.

A rubber conveyor belt, with bars, makes it possible to move the cut forage either to the right for the first pass, or to the left for the second to arrange the hay in one swath. The hydraulic control of the belt is provided by a hydraulic motor from the tractor's auxiliary circuit.

This simple solution makes it possible to reduce the cost of crop harvesting using self propelled vehicles of high power for the pick-up, so reducing the compacting of the soil, by reducing the number of passes.

No.11 COMMENDED
"Hydroporteur" Self-Propelled Vehicle

Having a wide variety of uses, this equipment carries out equally well operations of loading, lifting, distribution, or transport, in agri-



cultural working.

The HYDROPORTEUR is in fact a self-propelled vehicle, with hydrostatic transmission, having a high degree of stability and good handling qualities, the driving position itself being reversible.

More productive than a classic tractor, it can carry out work usually done by specialized equipment (loader, dumper, hoist).

No.12 COMMENDED
Device for Easing Beet Lifting



To reduce wastage during beet lifting, two driven disks with flexible rubber fingers are placed in each row above the liftings blades. These disks break up the earth adhering to the beetroots, and lift them clear of the ground to send them into the cleaning turbines.

This rotary device makes it possible to place the turbines of the beetlifter higher up and gives them an increased efficiency. At the same time the help given to the work of the blades reduces the breakage at the end of the pivotes.

No.13 COMMENDED
"BI-MA300" tractor

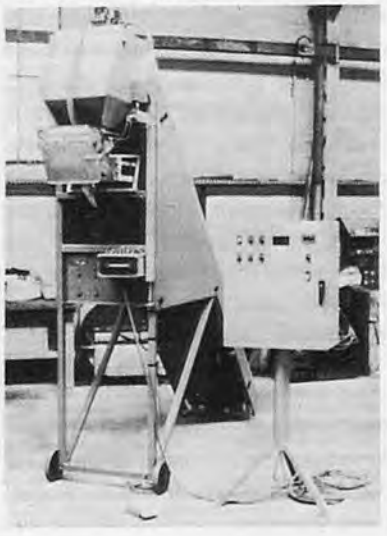


This tractor, of a new type of design, brings together several agricultural functions simultaneously at the front and at the rear, so improving the organization of agricultural work by reducing the number of passes, and reducing the required man power.

The "BI-MA300" is a tool mounting, self-propelled, articulated, 300 hp tractor, with hydrostatic transmission electronically servored to the movable cab and the auxiliary transmission devices (front and rear hydraulic lifting and power take-off devices).

Its modular design makes custom-built construction possible and simplifies the technical maintenance operations.

No.14 COMMENDED
Electronic Weighing Packer



NEW PRODUCTS

This weighing packer for products in relatively large individual pieces, used most frequently for potatoes, indicates the weight instantaneously and makes it possible to increase the sacking-up rates.

The weighing sacker associated with elevator is filled with an electronic assembly including a strain gauge. The weighing head, through this sensor, affects the rate of delivery during the weighing according to the instructions set up on the preselector devive.

This simple and accurate equipment, furthermore, needs only a limited degree of maintenance.

No.15 COMMENDED

"Paraplow" Soil Surface Loosener



To loosen the soil to the depth of the arable layer, without turning the surface over, the "PARAPLOW" has a series of parts suitable for this task. Each part includes a laterally oblique blade, fitted at the front with wear protectors and the rear with adjustable fins.

These parts, preceded by a circular coulter are mounted at regular intervals along an oblique beam, as are those of a plough. As they pass, the earth tends to be fissured more or less vertically, without the earth's being displaced.

No.16 COMMENDED

Front Axle with Inclined Universal Joint Pivot Shaft for Four-Wheel-Drive Tractors



To simplify turns, a castor angle of 13° has been given to the pivot shaft of the front axle universal joints on four-wheel-drive tractors. When turning, the front wheels whose turn would be limited by rubbing against the sides of the tractor, tilt, and pass below them. The turning angle of the wheels is thus increased by about 10°.

Thus, four-wheel-drive tractors have been given a manoeuvrability analogous to that of two-wheel drive machines, without recourse to steering by braking. They can be fitted with larger tyres.

No.17 COMMENDED

"FC300" Mowing Machine



The 3 metre cutter bar, with six oval disks, is attached by a floating method to the chassis. Two shafts pass through the end disks, carrying the cutter bar, one acting as the drive. The outer disks are each topped by a separator cone.

The lower surface of the housing includes a special anti-wear plate.

The bearings of the disks can be individually dismantled, even in the fields.

The swath laying by means of articulated fingers and a rake is adjustable. The swath width can be varied by means of adjustable deflectors.

This machine can be fitted equally well to 540 rpm and 1 000 rpm power take-off.

No.18 COMMENDED

Liquid Marure Tank with Remotely Controlled Filling and Spreading



This liquid manure tank is provided with accessories that make it possible to load and to spread the manure without the driver's having to get out of his cab. The rotary spreader is situated at the front, at the end of the mixer screw. For filling, the turbine installed at the rear is mechanically driven by the power take-off, through the screw. It can pump vertically or obliquely. It folds back on the tank hydraulically.

Apart from the interest in being able to work without coming into contact with the product, the simply constructed equipment has the advantage of being able to be used on buried out-of-doors cess pits which are coming into use by some stock raisers.

No.19 COMMENDED

Liquid Manure Trailer

This liquid manure trailer makes it possible to carry out the operations of filling, stirring, transport, and spreading from the tractor's



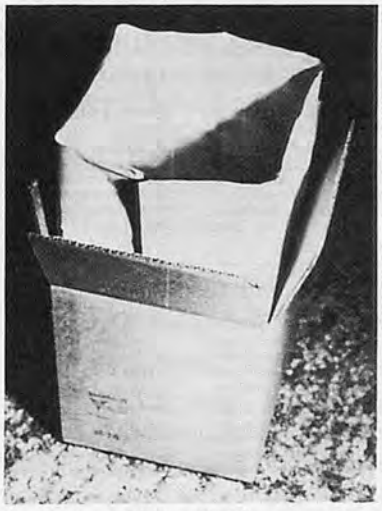
driving position.

A jointed arm is fixed to the drawbar of the trailer and has at its end a hydraulic pump to ensure the loading of the liquid manure from the cess pit. Spreading is carried out from the rear of the tank by a turbine.

In addition to its ease of use, the equipment makes an economy of the working time and the power needed for these operations possible, and this in very desirable conditions of cleanliness.

No.20 COMMENDED

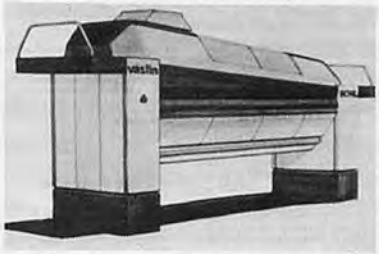
"Open Neck" Filler for Plastics Wine Containers



The "EMBAVIN" container, made up of a cardboard box and a semi-rigid complex bag, makes "open neck" filling, with complete automation of the line, and especially of the filling (preservation under vacuum or nitrogen) possible.

No.21 COMMENDED

Pressing and Draining Equipment with Rotary Inclined Casing



The inclination of the casing of a horizontal press makes it possible to fill it through an annular cover placed at one of its ends. The emptying takes place in rotation by the lower cover. The pressure level is taken at on of these plates. At the same time, an electronic check makes it possible to make the measurement of the juice extracted, without contact with it.

The rotation of the casing assists in the complete filling, and in the efficient draining with the recovery of a considerable quantity of high quality juice. The pressure is automatically increased by progressive oscillating levels, each level being followed by a breaking down of the mass.

The circles and chains, intended to ensure a more efficient breaking-down can be omitted in the case of a "Crémant" type of pressing.

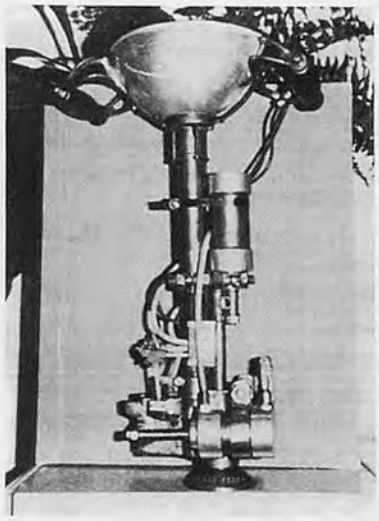
No.22 COMMENDED

Machine for Putting Corks into Bottles

This automatic portable corker makes it possible to put real corks into bottles without handling or effort.

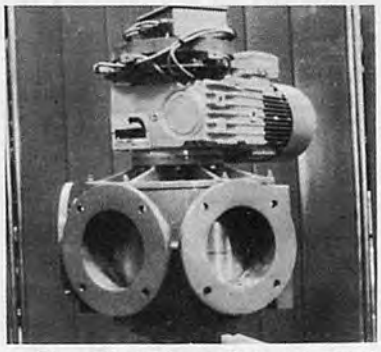
The use of a pneumatic circuit ensures the operation of several actuators.

Taking all types of corks, this equipment makes it possible to work at a rate of 1 000 bottles per hour.



No.23 COMMENDED

Electrically Controlled Rotary Valve with Integral Passage-Ways



Six selectable outlets are possible in this valve with integral passage-ways, the body of which is made in an anti-corrosion alignmentary quality aluminium alloy. The electric motor that controls it makes it possible to pass from one phase to the next very rapidly. Contactors ensure the coincidence of the selection outlet and the pre-selected outlet orifice. The motor-reducing gear is fitted to the end of the valve shaft. The control can be carried out remotely. An electrical cabinet makes it possible to display the selection position by signals on a control board. ■■

BOOK REVIEW

Post Harvest Technology of Cereals and Pulses

(India)

by A. Chakraverty and D. S. De
PHTC, IIT, Kharagpur, India

This book deals with principles, processes, operations, designs and other aspects of drying, parboiling, milling and by-product utilization of common cereals and pulses. Different types of machinery used in rice and other grain milling have been dealt with in detail. Special emphasis is placed on specifictions, designs and testing procedures of modern grain dryers, husk fired furnaces and data on physico-thermal and physico-chemical properties of cereal grains.

The book will prove to be a comprehensive text and reference book for post graduate and under graduate students of agricultural engineering, food technology and allied subjects. It will also be useful for the research workers, designers and other professionals.

Contents: Grain drying and dryers; Parboiling; Milling; Utilization of by-products for energy, food and feed; Appendix.

335pp., Price: Rs. 36.00.

Published by Oxford & IBH Publishing Co. 66, Janpath, New Delhi-110001.

Mechanization of Small-Sacle Farming in Japan

(Japan)

by Osamu Kitani

This paper was presented at the Seminar on Mechanization of Small-Scale Peasant Farming held in Hokkaido, Japan, 1980.

It deals with the subject in three parts: Development of small farm machinery in Japan; Present status of farm mechanization in Japan; Energy problems in farm mechanization. Contains statistical tables.

N.B. The reprint will be available upon request as long as the stock remains.

Size: 27 x 21cm, 31 pages.

Published by Department of Agriculture, Faculty of Agriculture, The University of Tokyo, Yayoi 1-1-1, Bunkyo-ku, Tokyo 113.

No Need for Hunger

(U.S.A.)

by Robert R. Spitzer

The "have not" world of the developing nations is almost unknown to the average American and to citizens of other advanced nations as well. Except for the all but forgotten depression of the 30's, only a fraction of the U.S. population has ever experienced hunger.

Yet hunger is there, across the border and beyond the sea. Between 500 million and 1 billion people in the world are malnourished and go hungry from day to day.

World hunger and poverty result in large part from the cumulative decisions and administrative practices of national governments abroad and, in turn, industries within nations.

The key questions are: (1) Will national governments endorse more free market conditions wherein the people may secure daily food directly as farmers, or may have enough income from other jobs (usually agriculture-related) to buy food? (2) Will our American agribusiness help lead the way? and (3) Will U.S. technical assistance bring these parties together to tackle the job?

International groups, including the Food and Agriculture Organization of the United Nations and the World Food Council, and U.S. groups, including many volunteer agencies and business groups such as the Conference Board and the Agribusiness Council, are concluding that self-help and economic development are the only long-range answers.

The priorities and modus operandi of the Reagan administration and the Agency for International Development should be restructured to provide leadership abroad, while agribusiness, the land grant universities and technical colleges, American farmers and thousands of experienced volunteers join forces to get the job done. The new look in business- and systems-oriented technical assistance and development programs can cost less, accomplish more and directly serve U.S. national interests.

No Need for Hunger offers hope and optimism through specific plans for nations and for individuals for eliminating world hunger and poverty.

Size: 23.5cm x 16cm, 356pp.

Hard cover, Price $11.95

Published by the Interstate Printers and Publishers, Inc. Jackson at Van Buren, Danville Il. 61832, U.S.A.

Farm Tractors 1950-1975
American Society of Agricultural Engineers

(U.S.A.)

ASAE has published the encyclopedic "Farm Tractors 1950-1975," a book on the tractors introduced by manufacturers during that 25-year period.

The book is a sequel to "The Agricultural Tractor. 1855-1950" by the late R.B. Gray, a top seller for the ASAE since its latest edition was published in 1975, said ASAE spokesman Susan Getman.

The history was written by Lester Larsen, head of the Nebraska Tractor Testing Laboratory at the University of Nebraska at Lincoln from 1946 until 1975.

Larsen wrote that he was assisted in compiling information for the book by over 100 experts in the field, including Carlton Zink, his predecessor at the laboratory.

The book includes over 400 photos and specifications of all the important models produced by U.S. and foreign manufacturers during the 25-year period.

Larsen outlined many of the changes in the design of tractors during those years, including increased horsepower, the change from L-head to I-head engines, the replacement of other types of fuels by diesel, increased travel speeds, the introduction of dry-type air cleaners, and steel pan seats that grew very uncomfortable after several hours of work.

Size: 28cm x 21.5cm, 192pp.

Soft cover, Price: $14.95

Published by American Society of Agricultural Engineers, P.O.Box 410, St. Joseph, Michigan 49085, U.S.A.

Bibliography:
Drip/Trickle Irrigation

(U.S.A)

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by Megh Raj Goyal

At a time when much of the world is becoming increasingly aware of water scarcity and the competing demands for available water, a new technology has developed that will greatly increase the efficiency of water usage for food production. This is known as drip/trickle irrigation. Practiced extensively in arid and semi arid regions of the world, this system of irrigation is also proving practical in many humid regions as an efficient method of supplemental irrigation.

In an area of rapidly developing technology such as this, it is important that all parties involved whether they be manufacturers, researchers, extension workers, or growers, have available references on this subject. This bibliography was prepared to provide a major source of information for all who have an interest in drip/trickle irrigation.

This is the third in a series of Technical Bulletins published by the National Agricultural Plastics Association. Inquiries regarding the association or publications available should be addressed to it at Rt. 5, Salisbury, Maryland 21801.

Price $10.00, 92pp.

Published by National Agricultural Plastics Association, Vegetable Research Farm (c/o Dr. F. Schales), Route 5, Salisbury, Md. 21801, U.S.A.

Survey of Irrigation in Eight Asian Nations

(U.S.A.)

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by William R. Gasser

Most good land in the eight Asian nations surveyed is cropped, so large production increases will likely come from more intensive cultivation made possible by irrigation. Extension of irrigated areas and better water management could double production in some areas of India, Pakistan, Indonesia, Thailand, Bangladesh, South Korea, Philippines, and Sri Lanka. But, large investments will be required.

This report reviews the current state of irrigation, plus prospects and plans, in these countries. Surface water will continue as the major irrigation source, although groundwater in India and Pakistan is gaining in importance.

Size: 27.5cm x 21cm, 120pp.

Published by Economics and Statistics Service, U.S. Department of Agriculture, Washington, D.C. 20250, U.S.A.

The World Bank
Accelerated Development in Sub-Saharan Africa – An Agenda for Action

(U.S.A.)

The central theme of the report is that more efficient use of scare resources–human and capital, managerial and technical, domestic and foreign–is essential for improving economic conditions in most African countries. From this flow a number of suggestions for the improvement of incentives and institutional support for production, particularly in agriculture. The public sector will have to meet the extensive needs for infrastructure, education, health, and other services. The efficient provision of these services will place enormous demands on administrative and managerial capacity–the scarcest resource in all countries. It is in this context that the report suggests that African governments should not only examine ways in which the public sector organizations can be operated more efficiently, but should also examine the possibility of placing greater reliance on the private sector.

Size: 26.5cm x 20.5cm, 206pp.

Published by The World Bank 1818 H Street, N.W., Washington, D.C. 20433, U.S.A. ■■

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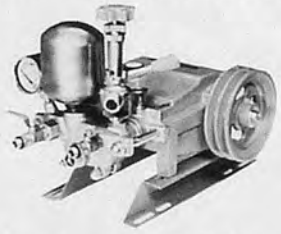
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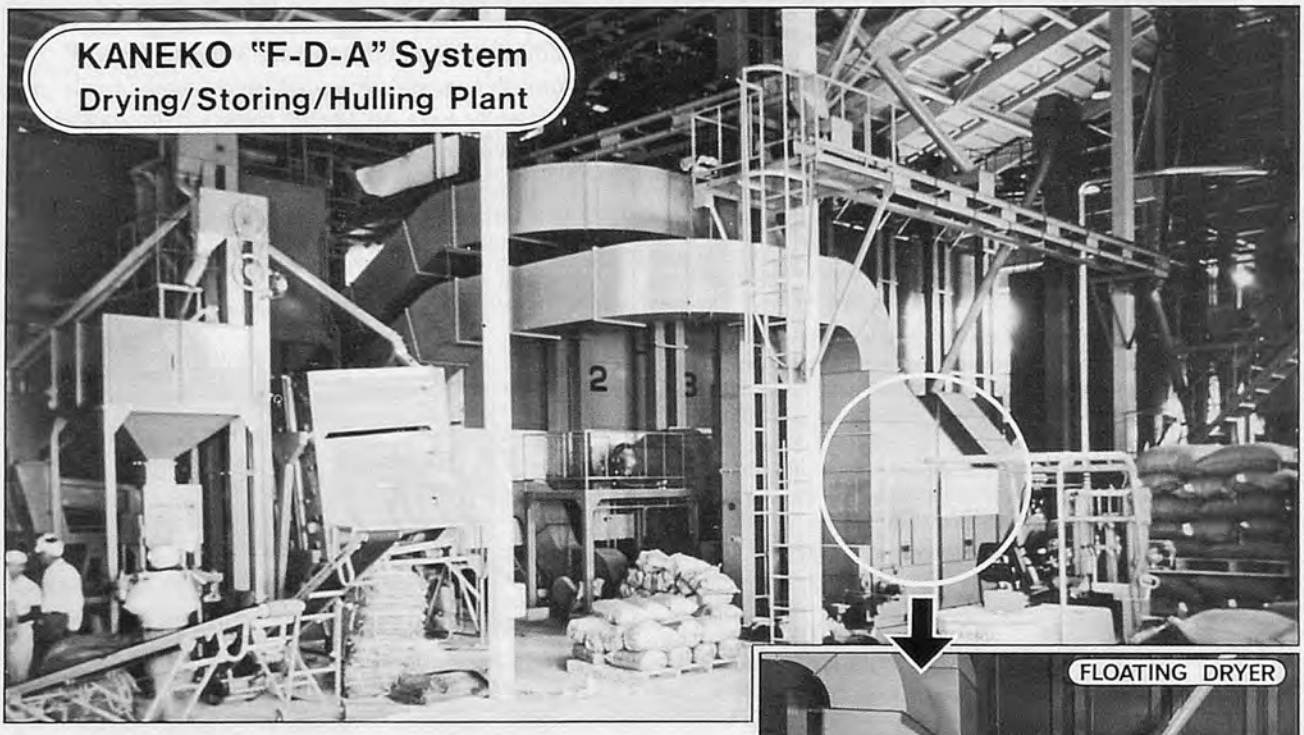
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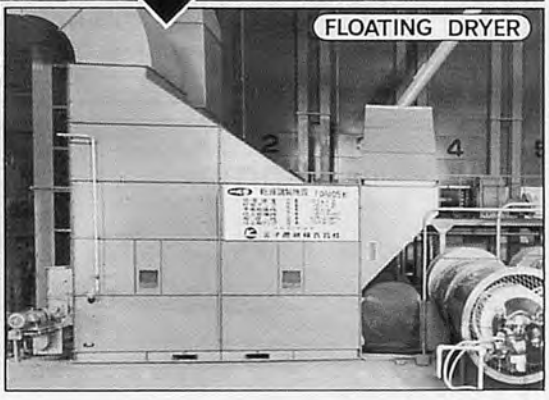
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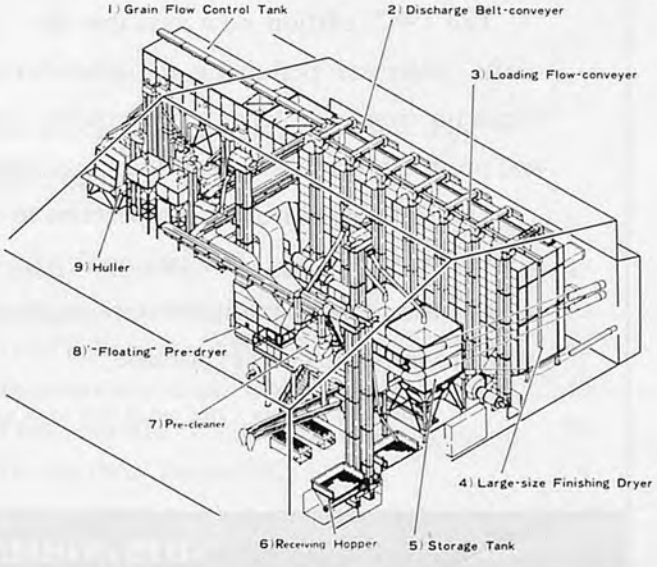
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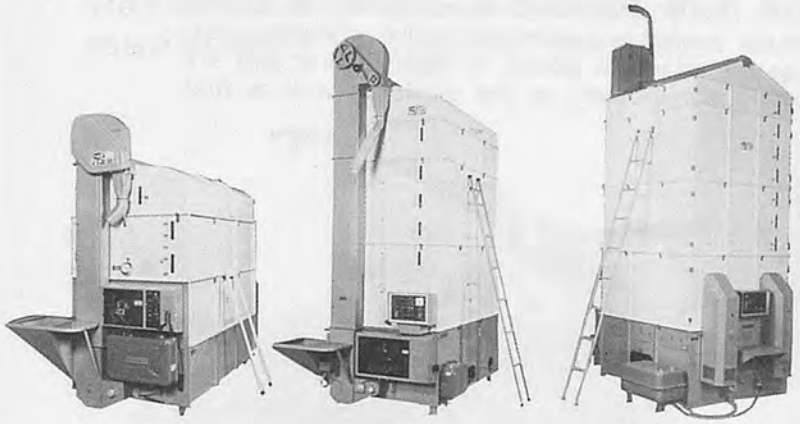
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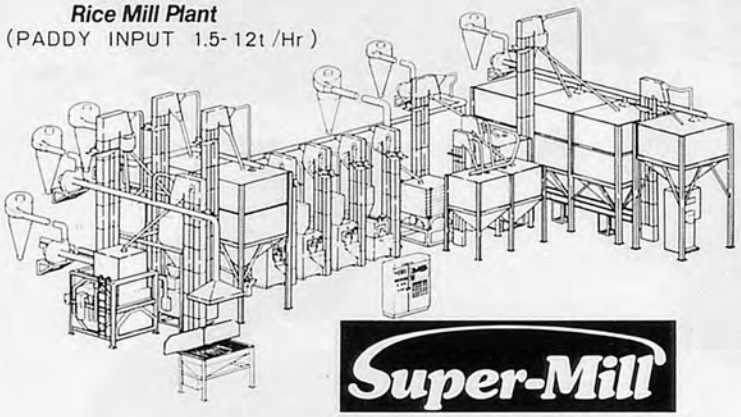
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