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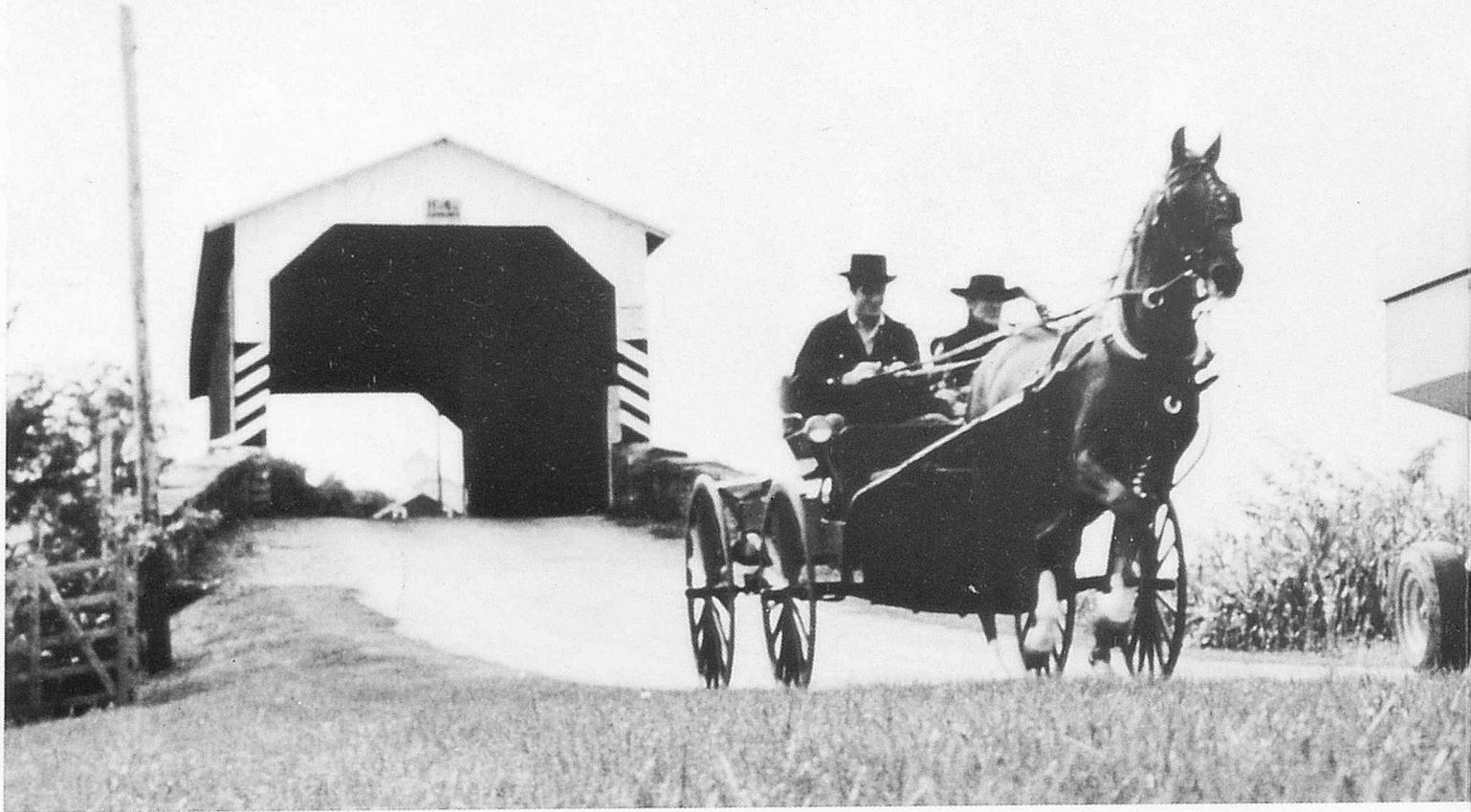
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VOL. 17, NO. 2, SPRING 1986

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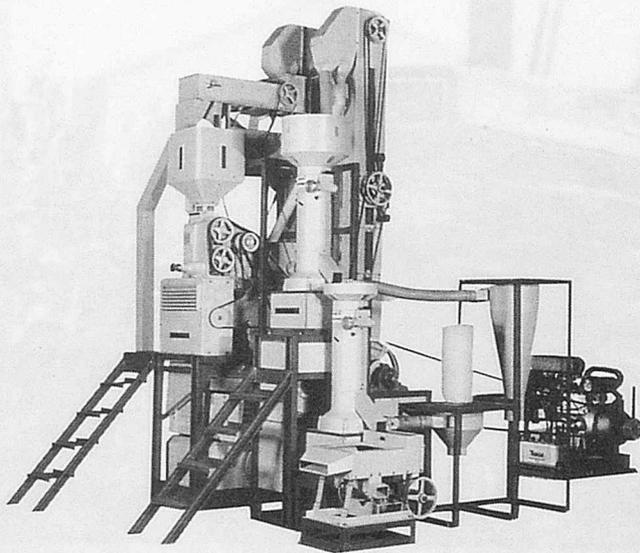
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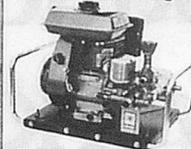
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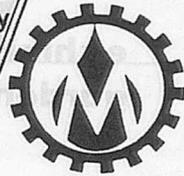
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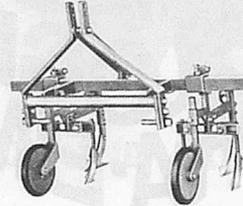
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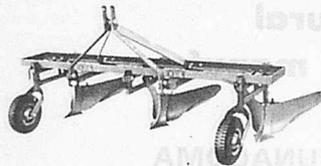
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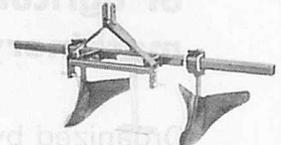
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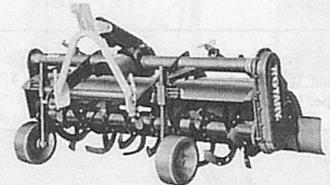
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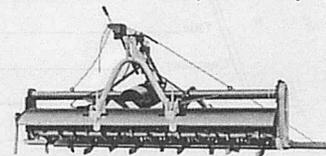
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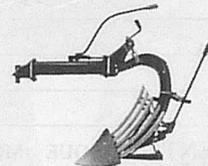


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This is the 51th issue since the issue, Spring of 1971

# A Pole-Drawn Toolbar for Animal Traction

## EDITORIAL

### Debt and Development

We have it on good authority that the accumulated debt of developing countries to advanced, industrial countries has exceeded one trillion US dollars recently. This gargantuan amount is indicative of two things: i) developing countries are hard put in catching up with the developed ones; and ii) repaying this indebtedness in full will be long in coming.

An important observation in this regard is the need for answers to a simple question as: i) how was this huge amount allocated among the sectors of the economy, i.e., industry, agriculture and the service sectors? The answers should provide a useful comparative study on sets of priorities that governments want to invest in. When such details become available, it will not be far-fetched to surmise that agriculture gets a minor share of the debt/loan available. For indeed, it is vogue among many developing countries to be fashionable, i.e., catch up and live up with the "Joneses" or industrialize at the expense of agricultural development.

In particular, agricultural mechanization is traditionally a low priority among developing countries where a mistaken belief usually prevails, i.e., agricultural machineries will displace farm labor, hence create instead of solving problems.

In order to promote agricultural mechanization, hence attract a larger share of loans available, some neutral research bodies need to evaluate the effect of farm mechanization on the country's economy. This neutral body must be represented by economists, engineers, policy-makers and farmers.

The AMA, then, calls upon interested parties to join hands and provide the answer to the question posed earlier and undertake a multidisciplinary research on the impact of farm mechanization. And AMA's subsequent issues promise to play up such studies.

April, 1986  
Tokyo

Chief Editor  
Yoshisuke Kishida

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# A Pole-Drawn Toolbar for Animal Traction



by  
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## Abstract

For animal traction different kinds of toolbars exist (a main frame to which different implements like a plough, a ridger, a cultivator, etc. can be mounted). There are two versions, chain-drawn and pole-drawn. The pole-drawn type, as far as we know from literature, has only depth-control, no width-control.

In this paper we discuss a pole-drawn toolbar, fitted both with depth-control as well as width-control. Both controls are positioned within the reach of the man operating the toolbar; adjustments

can be made without making a halt. VADA-DENK-1 is the name the designers gave this new toolbar for animal traction.

## Introduction

In order to meet the increasing demand for agricultural products, the farmers in the low-income countries need to extend production by intensification and increase of the acreage. Because of the limited every of man, other resources have to be found.

In many countries, motorized mechanization is not the first priority because of limited financial and technical resources. Animal traction, however, can still be very much extended and increased. Development of better implements for animal traction should, therefore, be one of the focal points in agricultural research.

One such implements that needs our attention is the toolbar. It consists of a frame to which various tools can be mounted such as a plough, a ridger, a cultivator, etc. With a toolbar the farmer has a wide range of implements at least cost.

Ploughing is generally regarded as a highly important tillage operation. It is also the most demanding, not only with respect to adjustability, but also with respect to strength and durability of the toolbar. In order to achieve good ploughing results, width and depth

of the work must be controllable within close limits.

Chain-drawn implements vary the working-depth and -width by changing the position of the attachment of the chain to the implement.

Pole-drawn implements vary the working-depth by turning the plough with regard to the frame in the vertical plane. It is remarkable that, as far as we know, none of the existing pole-drawn toolbars incorporates width-control. However, in order to perform well, width and depth of ploughing are closely related, viz. a width-depth-ratio of approx. 1.5.

A most important feature of a toolbar is a "quick-coupling" action to attach different implements to the frame.

Another feature is that the construction should be as simple as possible, by using locally available materials to encourage local manufacture.

Bearing the above-mentioned points in mind, the objectives of our study were:

1. Development of a pole-drawn toolbar for animal traction, built of locally available elements and materials;
2. Incorporating a depth- and a width-control, to be handled from the operator's position behind the frame to enable adjustments during the work; and
3. Incorporating a quick-coupling-system for the exchange of tools

**Acknowledgements:** The research was carried out at the Department of Agricultural Engineering (DAE) of the Wageningen Agricultural University (WAU) in the Netherlands, as a part of our graduate study in agricultural engineering.

The field tests were carried out on the fields of the University of Zambia (UNZA) in Lusaka and on the fields of the Institute of Agricultural Engineering (IMAG) in Wageningen in the Netherlands.

The manufacturing company Rumptstad in the Netherlands supplied the ploughbody (share, mouldboard, etc).

The Technical and Physical Engineering Research Service (TFDL) in Wageningen assisted in the construction of the toolbar.

Advise was given by Dr. J.K. Kouwenhoven (senior lecturer soil tillage laboratory of the WAU) and Prof. C.E. van't Klooster (NUFFIC-lecturer at the DAE of the UNZA).

General supervision was carried out by Prof. T.van der Sar (senior lecturer mechanization of tropical crops at the DAE of the WAU) and Prof. A.Moens (head of department of the DAE of the WAU).

From this place we would like to thank these persons and institutes for their cooperation.

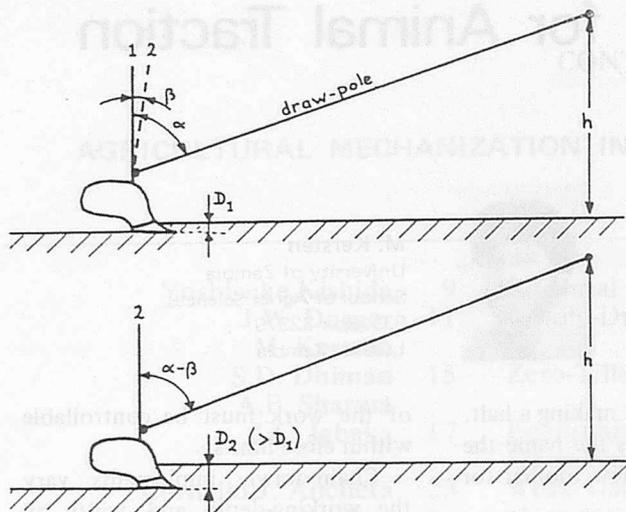


Fig. 1 Principle of changing the working-depth of a pole-drawn plow. 1 - initial position; angle between the draw-pole and the plow is  $\alpha \rightarrow$  plow-depth  $D_1$ .  $\beta$  - change in the initial position. 2 - new position; angle becomes  $\alpha - \beta \rightarrow$  plow-depth  $D_2$ .  $h$  - height of hitch.

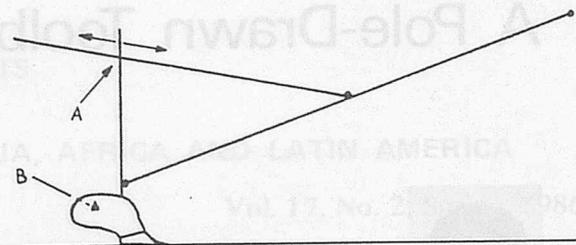


Fig. 2 Basic shape of the tool-frame. A - position of the depth-control; B - position of the width-control.

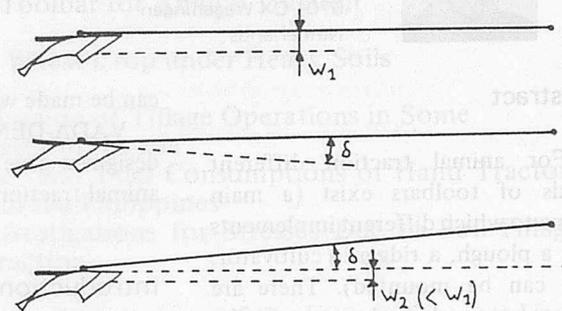


Fig. 3 Principle of changing the working-width of a pole-drawn plow.  $W_1$  - initial working-width.  $\delta$  - change in the initial position of the plow with regard to the draw-pole.  $W_2$  - new working-width.

## Designing the Pole-Drawn Toolbar

Adjusting the working-depth of a pole-drawn implement is done by changing the position of the plough with regard to the draw-pole in the vertical plane as shown in Fig. 1.

Fig. 2 shows our solution to fix any position of the plough with regard to the draw-pole: a triangle of which the length of one side can be changed and fixed (in point A).

This integrated solution places the depth-control within the reach of the man operating the implement.

Changing the working-width of a pole-drawn plough can be done by changing its position with regard to the draw-pole in the horizontal plane as shown in Fig. 3.

Width-control is only necessary for ploughing; so it was decided to design it as a part of the plough, and not as a part of the toolbar. Point B in Fig. 2 indicates the position of the width-control.

The shape of the toolbar depends on how the depth control will be

realized. For the prototype we applied only standard materials: square tube (50x50x2 mm and 40x40x2 mm) and strip iron (50x5 mm) for making the joints and reinforcements.

The column is made of square tube 50x50x2 mm and is open on the bottom-side; square tube 45x45x2 mm fits inside the column easily. Implements fitted with such a vertical piece of tube can thus be easily coupled to the toolbar, without the need of handtools (Fig. 4).

Putting a pin (a) through the column (b) and the square tube of the implement (c), the implement is fixed to the toolbar.

## How the Depth-Control was Realized

For depth-control we take it as desirable that the working-depth can be varied in steps of approx. 2 cm. Assuming a draw-pole length of 300 cm, the height of hitch to the yoke of 125 cm and the height of the handles of 90 cm (Fig. 5), changing the working-depth with

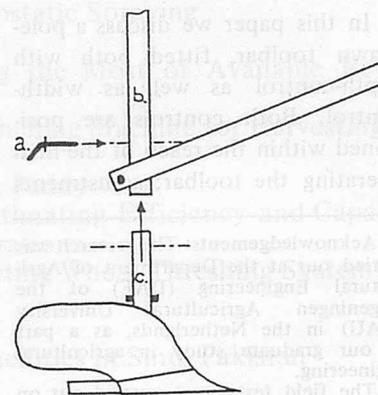


Fig. 4 The "quick-coupling" of the toolbar. a - lock pin. b - column. c - implement's square tube.

2 cm means such a little transposition of the column with regard to the handle-bar, that a direct pin-hole-coupling between the two to fix a new position, is impossible.

Therefore an additional bar is put on top of the column and fixed to it with a pin-hole-coupling. Fig. 6 shows how this additional bar (the control-handle) is fixed to the handle-bar.

By moving this lever from one outmost position to the other, the column is transpositioned only

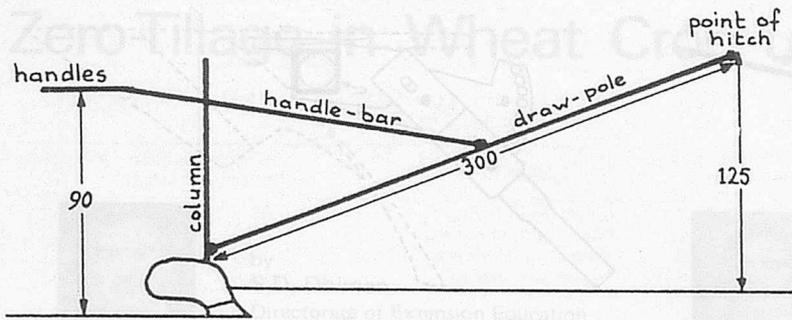


Fig. 5 Overall dimensions of the pole-drawn toolbar.

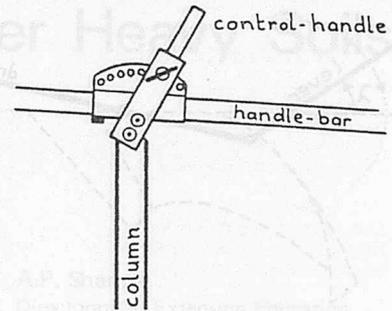


Fig. 7 Eventual shape of the depth control.

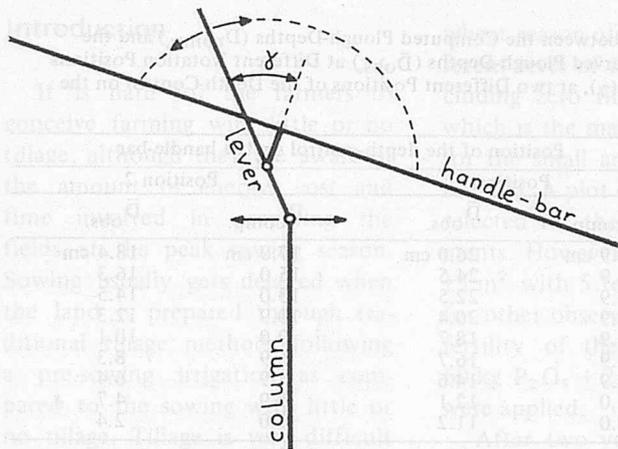


Fig. 6 Principle shape of the depth control with additional lever.

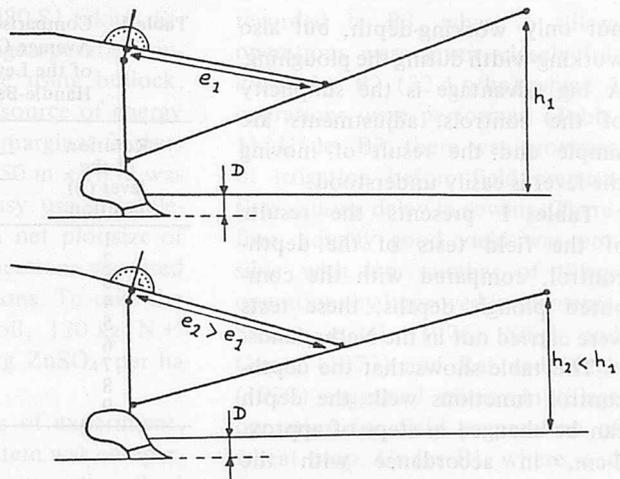


Fig. 8 Adjusting the toolbar from a high to a low point of hitch. In order to achieve the same working-depth  $D$  with smaller animals ( $h_1 > h_2$ ), it is necessary to enlarge the handle-bar from  $e_1$  to  $e_2$ .

slightly with regard to the handle-bar. The dimensions of the lever result from the relation between the rotation of the lever ( $\gamma$ ) and the changing of the working depth ( $D$ ), regarding the overall dimensions in Fig. 5.

The leverage has an additional advantage: moving the control-handle during the work (e.g. ploughing) is easier because of a more favourable transmission of forces.

The top of the lever is fitted with a pin, with which its position can be fixed in one of the holes of a circular plate fixed to the handle-bar (Fig. 7).

The depth-control can be moved along the handle-bar and fixed to it in a number of positions. This makes it possible to operate with different heights of hitch in order to use large as well as small animals (Fig. 8).

### How the Width-Control was Realized

In Fig. 3 it can be seen that we have a similar problem in constructing a width-control as in constructing the depth-control. Rotating the plough only a little with regard to the draw-pole, results in a large changing of the working-width. Because of the limited space for the width-control as a part of the plough, the same principle is used as in the depth-control: adding an extra bar, a lever, which can be fixed with a pin in one of the holes of a circular plate.

Regarding the overall dimensions of Fig. 5, it is possible to get a relation between the rotation of the lever ( $\lambda$ ) and the change of the working-width ( $W$ ) (Fig. 9).

The result of this construction is that changes of the working-

width in steps of approx. 4.5 cm can be achieved.

Fig. 10 shows a top-view of the width-control: the circular plate with holes (a) is fixed to the plough, while the lever (b) is (indirectly) fixed to the plough's quick-coupling square tube (c) and through it to the toolbar (Fig. 4).

### Field Tests

This toolbar for animal traction was tested (with the plough as implement) in Lusaka at the University of Zambia, as well as at the Wageningen Agricultural University in the Netherlands.

In Zambia, only a qualitative test with oxen was carried out: the toolbar proved to be very easy to handle. It is possible to change

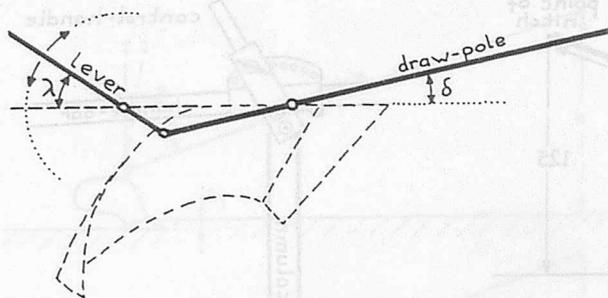


Fig. 9 Principle shape of the width-control with additional lever. Rotating the lever over an angle  $\lambda$  results in a rotation  $\delta$  of the draw-pole with regard to the plow.

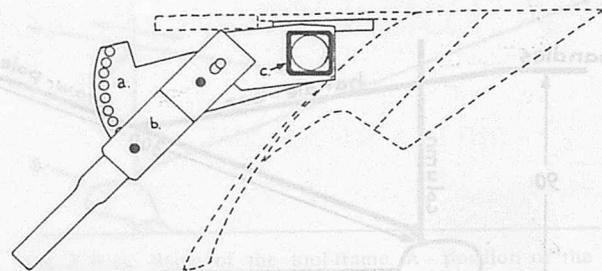


Fig. 10 Top-view of the width-control. a— circular plate with holes. b— control-handle. c— plow's quick-coupling square tube.

not only working-depth, but also working-width during the ploughing. A big advantage is the simplicity of the controls; adjustments are simple and the result of moving the lever is easily understood.

Table 1 presents the results of the field tests of the depth-control, compared with the computed plough depths; these tests were carried out in the Netherlands.

The table shows that the depth-control functions well: the depth can be changed in steps of approx. 2 cm, in accordance with the demand.

Separate tests were carried out with the width control; Table 2 presents the results of these tests.

This table indicates a good functioning of the width-control: there is a good response of the working-width on the changing of the lever's position.

### Discussion

In this study, focused on designing a toolbar with a good functioning depth- and width-control, a plough was used as implement; other implements like a weeder, a cultivator, a lifter, a ridger, a seeder, etc. will be the next step in this project.

Table 1 Comparison between the Computed Plough-Depths ( $D_{comp.}$ ) and the Average Observed Plough-Depths ( $\bar{D}_{obs.}$ ) at Different Rotation Positions of the Lever ( $\gamma$ ), at two Different Positions of the Depth-Control on the Handle-Bar.

Rotation of the lever ( $\gamma$ ) position	Position of the depth-control on the handle-bar			
	Position 1		Position 2	
	$D_{comp.}$	$\bar{D}_{obs.}$	$D_{comp.}$	$\bar{D}_{obs.}$
1	24.9 cm	26.0 cm	17.0 cm	18.4 cm
2	22.9	24.5	15.0	16.3
3	20.9	22.5	13.0	14.5
4	18.9	20.4	10.9	12.3
5	16.9	18.7	9.0	10.1
6	14.9	16.7	6.9	8.3
7	12.9	14.6	4.9	6.4
8	11.0	12.1	2.9	4.7
9	9.0	11.2	1.0	2.4

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Table 2 Comparison between the Computed Plough-Widths ( $W_{comp.}$ ) and the Average Observed Plough-Widths ( $\bar{W}_{obs.}$ ) at Different Rotation Positions of the Lever ( $\lambda$ ).

Rotation of the lever ( $\lambda$ ) position	$W_{comp.}$	$\bar{W}_{obs.}$
1	31.4 cm	31.8 cm
2	26.8	25.0
3	22.3	21.5
4	18.0	18.0
5	13.7	15.4
6	9.2	11.5
7	4.6	6.8

# Zero-Tillage in Wheat Crop under Heavy Soils



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## Introduction

It is hard for the farmers to conceive farming with little or no tillage, although they are aware of the amount of energy, cost and time involved in preparing the fields at the peak sowing season. Sowing usually gets delayed when the land is prepared through traditional tillage methods following a pre-sowing irrigation as compared to the sowing with little or no tillage. Tillage is very difficult in heavy soils, particularly after harvesting the crop of paddy. Therefore, considering the high cost of energy required for tillage operation and limitation of time for sowing of wheat after paddy, the present study was undertaken at the experimental farms in Haryana, India.

## Methodology

The work was started at Kaul experimental farm of the Haryana Agricultural University during the

wheat season of 1980-81 taking different level of tillage operation, including zero tillage using bullock, which is the main source of energy for the small and marginal farmers in India. A plot of 50 m x 10 m was selected for the easy use of implements. However, a net plot-size of 15 m<sup>2</sup> with 5 replications was used for other observations. To raise the fertility of the soil, 120 kg N + 60 kg P<sub>2</sub>O<sub>5</sub> + 25 kg ZnSO<sub>4</sub> per ha were applied.

After two years of experiment, the zero tillage system was compared with the conventional method of wheat sowing. Two-row bullock-drawn disc drills were used. The physical properties of the soil were also studied at the boot stage of the crop. Other cultural operations were given as per requirement of the crop. Herbicide was used for weed control.

## Results and Discussion

On the average, the maximum wheat grain yield (33.7 q/ha) was

recorded in B3, where 6 tillage operations were given, closely followed by B2 (32.4 q/ha) where 4 operations were performed (Table 1). Under B3, there was provision of irrigation before field preparation causing delay in sowing. Therefore, equally good yield was possible with less number of tillage operations by improved implements. Saxena et al. (1976), Singh and Gupta (1973) and Rai and Singh (1970) suggested minimum tillage operation for field preparation of wheat crop. Under B1, where seed was placed by seed drill without disturbing the soil, quite comparable yield (31.0 quintal grain/ha) with other treatments, except B3 was recorded during 1980-81. Murthy and Patil (1970) also found the effect of different tillage operations in the infiltration rate of red soils. In 1981-82, all the treatments were at par for grain yield. Godwa et al (1978) found encouraging results at Karnataka by using this technique in wheat. Therefore, it can be concluded that a good crop is possible by using treatment B1.

**Table 1** Effect of Different Tillage Operation on Wheat Crop

Treatment	No. of seeding/m <sup>2</sup>		Number of ears/m <sup>2</sup>		Straw yield (q/ha)		Grain yield (q/ha)		
	1980-81	1981-82	1980-81	1981-82	1980-81	1981-82	1980-81	1981-82	Mean
B1	113	79	413	220	79.83	67.50	31.00	25.25	28.13
B2	135	118	334	312	77.83	81.34	31.39	35.25	32.32
B3	158	128	394	307	89.67	82.53	36.13	31.25	33.69
B4	123	135	344	355	75.73	78.56	31.33	32.50	31.92
B5	122	83	408	280	84.17	78.71	31.92	32.00	31.96
C.D. 5%	7.9	9.8	19.5	15.6	5.42	6.51	2.79	N.S.	

B1 - Drilling the seed without field preparations + hoeing after irrigation. B2 - Lister plough + irrigation + 2 harrowings + planking + sowing by traditional (pora) method. B3 - Irrigation + 2 harrowings + planking + triphali + harrowing + planking + sowing by Pora method. B-4 Moldboard plough + irrigation + triphali + roller + triphali + planking + sowing by traditional Pora method. B5 - 2 harrowing + seed broadcast (soaked) + harrowing + 2 plankings + irrigation (whenever available).

**Table 2** Effect of Field Preparation and Sowing Methods on Wheat Variety Sonalika, 1980-81 and 1981-82.

Item	Treatment		
	B1	B3	B5
Grain yield (q/ha)	28.1	33.7	31.9
Straw yield (q/ha)	73.8	86.1	81.4
No. of ears per m <sup>2</sup>	317	350	344
Time required (h/ha) by			
Bullocks	21.5	59.3	27.5
Labourers	21.5	59.3	34.2
Energy required (kWh/ha)	18.2	48.6	23.1
Expenditure on sowing (Rs/ha)	80.7	222.2	111.6
Expenditure (Rs/q grain)	2.9	6.6	3.5

**Table 3** Effect of Zero Tillage on the Yield of Wheat Variety Sonalika, 1982-83

Item	Zero tillage	Conventional	Response (%)
Grain yield (q/ha)	41.7	36.8	13.3
No. of grains per ear	32.7	30.4	7.5
Weight of 1000 grains (g)	54.2	50.8	6.7
No. of ears per m <sup>2</sup>	314.2	253.9	23.7

**Table 4** Influence of Tillage Operations on Soil, 1982-83

Depth (cm)	Soil moisture (%)						Time (min)	infiltration (cm)		Depth (cm)	Bulk density (g/cc)	
	Sowing time		Harvesting time		Availability			Z	C		Z	C
	Z	C	Z	C	Z	C						
0-15	23.7	21.8	18.2	15.1	15.0	12.0	5	0.40	0.70	0-10	1.67	1.56
15-30	21.7	21.1	16.3	17.5	12.7	11.1	15	0.73	1.33	10-20	1.67	1.64
30-60	22.8	21.8	16.5	18.1	13.7	10.5	30	1.03	1.95	20-30	1.70	1.67
60-90	22.3	21.1	16.3	18.3	13.3	9.3	60	1.48	2.73	—	—	—
90-120	23.4	20.1	17.5	19.8	10.2	11.4	90	2.08	3.33	—	—	—
							Basic (cm/h)	0.90	1.00			

Z— Sowing of wheat by seed drill without field preparation + planking, C— Two harrowings + broadcast of seed + harrowings + 2 planking.

The requirement of energy and cost of operation in preparing the field for subsequent sowing were on the basis of time and power utilized in each treatment. Zero tillage (B1) was compared with conventional method (B5) along with the best treatment (B3) and these observations are given in Table 2. Energy requirement and expenditure on sowing operation was maximum (49.6 kWh/ha and 222.2 Rs/ha) in B3 whereas these figures were 18.2 kWh/ha and 80.7 Rs/ha for B1. Obviously, more tillage operations required higher energy consumption and thus more expenditure with Rs. 2.9 per quintal grain production in B1, which is less than half of B3.

#### Zero Tillage vs Conventional

The results of another experiment conducted during the wheat season of 1982-83 are given in Tables 3 and 4. There is a 13.3% increase in the grain yield by using zero tillage (41.7 q/ha) over broadcast (36.8 q/ha) method of sowing. The other yield attributing characters also showed similar trend. However, the number of ears/m<sup>2</sup> is more responsible for increasing the yield. Table 4 shows that sufficient

amount of moisture is available under zero tillage than the conventional method at the boot stage (20th Feb., 1983) of the crop. Naturally, there should be more in the upper profile of soil under zero tillage treatment as the sowing was done 5 days earlier in this treatment.

The data given on infiltration rate and bulk density showed the effect of compaction of soil under zero tillage treatment used in growing paddy crop.

It is clear that greater quantum of water was drained by the crop raised under zero tillage (moisture data at harvesting, 4th April), on the growth of crop. The advancement of 5 days in sowing, advantages in yield under late sowing (Sharma, et al 1978) is under progress to standardize the technique of zero tillage sowing for wheat crop under heavy soils.

#### Summary

Keeping the amount of time required and power invested on field preparation for wheat crop, the minimum tillage operation appears promising. Yield of higher

grain of wheat may be harvested by the zero tillage method of sowing over broadcasting method, which is a common practice in wheat growing under the rice-wheat crop rotation. Under the technique, the advantage of early sowing may also be gained.

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# Economic Evaluation of Tillage Operations in Some Mechanized Farms in Nigeria



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## Abstract

Investigations into the economic use of machines in tillage operations in some mechanized farms were carried out. The parameters investigated were field capacity, fuel consumption rate, lubrication, labour cost and total cost of each operation per hectare. Also, the types and number of breakdowns were surveyed and analysed. It was found that, on the average, there has been a marked improvement in the economic management of mechanized farms in Nigeria over the years resulting from the availability of more skilled operators and spares. In all the farms, the cost of plowing was highest while that of ridging was marginally higher than that of harrowing. Most of the breakdowns were dealt with within 24 hours.

## Introduction

In Nigeria and other developing countries, the key to economic development lies in raising the agricultural productivity. This can be achieved by bringing more land under cultivation and mechanizing the essential operations. Some of the essential operations that need to be mechanized are the tillage operations – plowing, harrowing

and/or ridging. Tillage has been described as the most costly single item in the budget of farmers.

In most mechanized farms, economic management of power and machinery is often overlooked as a factor in farm profits; yet it is usually a most significant factor (1).

Cost surveys have shown that the cost of operating machinery in mechanized farms represent 36% of the yearly farm costs. This is the largest single yearly farm expenditure, followed by the interest charged on the remaining capital investment (land) which is about 26% of the total yearly cost. Therefore, it is obvious that a slight economic improvement in the management of machinery will bring substantial increase in a farm's profit. Good machinery management requires that individual operations in a machine system must be adjusted and combined in such a manner that their over-all performance returns the greatest profit to the farm business (1).

It must be remembered that the economic performance of a machinery system is measured in terms of money per unit output. In this context maximum system performance occurs when the production cost per unit is low. This can only be achieved by continuously monitoring the management

of the production inputs and making sure that wastage is minimized or eliminated entirely.

In Nigeria power-operated farm machines are becoming popular in the advent of farm mechanization. Some of these machines are owned by private farmers while others are owned and operated by the government and rented out to farmers. Also, private-owned machine hiring units are coming on stream gradually.

It is, therefore, necessary that data concerning the economic use of these machine should be available to the farm manager for planning mechanized farm operations.

Some authors (2), (3), (4) and (5) have investigated the economic use of farm machinery in Nigeria but because of changing factors with time a continuous revision and reevaluation of the data is very necessary.

This paper investigates the economic operation of these machines in different farms or units by estimating the cost of tillage operations as regards tractor, implement, fuel, lubrication and labour. The tillage operations considered were plowing harrowing, and ridging. Also, the breakdowns during operations were recorded and analysed.

## Materials and Method

### Project Area

The field survey and analyses were limited to five farms and units in Oyo State of Nigeria. There were three farms and two hiring units.

Oyo State is located in the north-west of the former Western Region with two dominant vegetation of tropical rain forest and tropical secondary forest. The state is made up of fairly level to moderately rolling plains of less than 180 m above sea level. The soils are mainly sandy loam ranging from medium to high productivity potential. Temperatures range from 28°C in the cold days to 38°C in the hot months but the mean temperature throughout the year is about 32°C. The mean annual rainfall is about 315 mm.

### Method

Information and data were acquired or collected through two methods. First, questionnaires were designed and distributed to the mechanization or engineering supervisory personnel in each farm or unit. The information sought in the questionnaires included inventory of tractors and machinery (make, size, serviceable state, purchase price and year and average annual use), tillage operations performed with rate of operation, speed, fuel and oil consumption at each operation and hours of operation of each tractor or machinery. Also, the breakdown history of each tractor and machinery during the tillage operations and the nature of breakdowns were sought. The maintenance and service records of the tractors and machinery and the labour costs were likewise sought in the questionnaires. The questionnaires were distributed just before the tillage operations commenced to enable the officers

obtain on-the-spot records, during the season's operations.

Secondly, unexpected random visits were paid by the author to the operation sites and measurements taken on the spot. A total of four such visits were made to each site during each tillage operation. It was not possible to measure the oil and lubrication consumption during such visits. Also, the breakdowns could not be measured, hence, the author relied solely on the information from the questionnaires.

At the end of the operations, the data collected from the two sources were analysed and the costs were estimated. The farms were designated as F<sub>1</sub>, F<sub>2</sub> and F<sub>3</sub> while the hiring units are designed as H<sub>1</sub> and H<sub>2</sub>.

### Mechanization Costs Calculations

Cost calculations for mechanized farm operations are almost similar everywhere. Usually there are basic assumptions and few other adjustments are made to suit the particular needs and locality. For example, while in some countries taxes are paid on agricultural machines and implements, in Nigeria they are tax-free.

Costings of mechanized operations can be done either on an hourly basis or an hectare basis. The former is only meaningful when accurate records of the time (machine hours) are available. In Nigeria, 34.7% of the operator's time was spent in doing unproductive work — 31.2% of this representing avoidable delays (2).

It would be unfair and inaccurate to add this idling time to the overall time for carrying out an operation. Moreover, the farmer is more interested to know how much it will cost him to farm a unit area so as to compare it with the yield per area.

Generally, the factors involved

in the calculation of operating costs of farm machinery can be grouped under two main titles — fixed and variable factors or costs.

### Fixed Factors

These include the factors whose cost must always be taken into account whether the machinery is in operation or not. They are related to machine ownership and represent a form of financial discipline, to make sure that the business does in fact pay off capital investment within a reasonable period. They are depreciation (on tractor and on implement), interest on investment, taxes, insurance and shelter.

*Depreciation on Tractors and Implements* — Many definitions of depreciation have been postulated (1), (2), (6). Here, it is defined as reduction in the value of the machinery until it is either worn out or obsolete. It has been argued that depreciation should not always assume decrease in value of equipment with age, especially in time of high inflation. During the time of high inflation rate (as it is now in Nigeria) the value of used equipment may actually appreciate. As inflation is not usually a normal and permanent period, it is accepted in this paper that the value of a tractor would decrease with age, even if not used. This is because, with the present high rate of technological development, a tractor or any equipment may become obsolete when new designs or models are placed in the market.

Many ways have been put forward for calculating depreciation. These include the inventory method, the straight line method (2), sum of the years-digits method and the sinking fund method (1). After reviewing these methods, it was found that, for the Nigerian condition, the straight line method was most appropriate. The equa-

tion used was  
Depreciation =

$$\frac{\text{Initial cost of machine}}{\text{Expected total hours of use}}$$

In Nigeria today, farm machinery has very little, if any, scrap value. Therefore, the scrap value which is supposed to be deducted from the initial cost is taken as zero.

It is very difficult to obtain the accurate total hours of use of machinery in Nigeria. Whilst there have been cases of tractors that have worked on some farms for more than 8 years at an average of 1 000 h a year, there were also cases of some types of tractors that seldom lasted 4 years working at the same rate (2). After the review of the works and surveys done in this area in Nigeria (2), (3) and (7) and in some other developing countries (8), (9), (10) and (11) some values of expected total hours of use were arrived at for the present situation in Nigeria (Table 1). These values took into account the improved technical maintenance skill and the available number of working days a year.

*Shelter* — There are essentially two buildings necessary for a mechanization unit. These would be the implement/tractor shed and the farm workshop. Surprisingly, in all farms surveyed, there were no implement/tractor sheds. They only had maintenance shed or workshop but the hiring units had both workshop and implement/tractor sheds. The maintenance sheds in the farms could only accommodate, may be, one or two tractors and implement at a time. The depreciation of the buildings were done by the following formula.

$$D = \frac{\text{Cost of building}}{\text{Life of building in h}}$$

In case the building is used only for maintenance, the life of the building is given as life of building in years multiplied by number of hours per year of use. However, when it is used for

Table 1 Expected Total Hours of Use of Tractor and Implement in Nigerian Condition

Machine	Annual use, h	Expected life, yrs.	Expected total hrs. of use
85 hp Tractor	1 200	5	6 000
50 hp Tractor	1 000	5	5 000
35 hp Tractor	1 000	5	5 000
3-Furrow disc plough	250	10	2 500
2-Furrow disc plough	250	10	2 600
Tandem disc furrow	200	10	2 000
Tined cultivators	250	10	2 500
Moldboard ridgers	250	10	2 500
Disc ridgers	250	10	2 500

implement/tractor shed, the life in hours is given as life of building in years multiplied by number of machinery and machinery hours a year.

#### Interest on Capital or Investment

—This charge represents the opportunity cost of the equipment and was calculated on the current bank lending rate. The generally accepted method of charging interest on farm machines is one half the capital investment. This is because the cost of machinery is written off regularly by depreciation charges, and hence the value of the machinery falls annually until it is zero.

*Insurance* — Of all the farms and units surveyed none had insurance on the machinery or on the buildings. Therefore, insurance was not taken into account in this work. Also in Nigeria there are no laws making it compulsory for farm machinery and buildings to be insured except tractors used for transportation, which ply the roads.

#### Variable Factors

These are the remaining operating costs that depend on particular operations and are directly proportional to the machinery usage. They include labour (operator and mechanic), spares, fuel and lubricants.

*Labour* —The usual daily rate for skilled workers like tractor operators and mechanics range between

₦10\* and ₦15 for an 8-hour day. But it is very uncommon to find operators and mechanics employed on daily wage basis; instead they are employed on the minimum monthly wage basis. The minimum wage in Nigeria is ₦120; but in all the government farms and unit surveyed, the operators were paid ₦130 per month or ₦1 560 per year and the mechanics ₦135 per month or ₦1 620 per year. The commercial farms and unit paid a little bit higher.

In calculating the labour cost per hour, a total of 220 days per year were used. This was arrived at after studying the labour laws and conditions in the country.

Total working days per month = 22

Total working days per year = 264

Assume 11 days for public holidays, 25 days annual leave and 8 days for any eventualities like sick leave and others, then we have 264-44=220 days.

From the survey, it was observed that although the operators and other workers were supposed to be in the field for 8 hours, only 6 hours were used for operations in the field. The remaining two hours were used in eating, idling and moving to and fro in the farm. Therefore, the total hours spent per year in the farm is 1 320 h. The hourly labour cost used in the project for government farms was therefore ₦1.18 for the tractor

\*Current rate of exchange is ₦1.00: U.S.\$1.45.

operator and ₦1.23 for the mechanic.

**Spare**s —Aboaba (2) estimated that on the average, a tractor uses up a set of tyres and a battery in two years under Nigerian condition. To this, he added other spares averaging 5% of initial cost of the tractor. For the implement, he used 10% of the initial cost.

The present study shows that the spares requirement varied from farm to farm depending on the condition of the farm and maintenance skill and frequency of tractor use. From the records of the breakdowns and inventory of spares used on each tractor and implement, it was decided to use 12% of initial cost for tractor and 10% for the implement to represent the total cost of spares.

**Fuel** — The variables that have direct influence on the fuel consumption for any operation, are speed of operation and soil properties (texture and moisture) and skill of operator. Fuel cost per ha can be given as

$$F = \frac{f \times p}{c} \dots \dots \dots (1)$$

where

- F = fuel cost/hectare (₦/ha)
- f = fuel consumption rate (l/h)
- p = cost of fuel (₦/1)
- c = rate performance of machine or machine capacity (ha/h).

The performance rate of the machine or machine capacity can be estimated by the following formula.

$$C = \frac{S \times W \times E_f}{10} \dots \dots \dots (2)$$

where

- C = Effective field capacity, (ha/h)
- S = Ground speed, (km/h)
- W = Machine width, (m)
- E<sub>f</sub> = Field efficiency (decimal)

But Renoll (12) developed an expression useful in predicting farm machinery performance rates. It could be used to predict machine

capacity for individual field and farm conditions rather than for average field conditions. It uses 14 input coefficients and is expressed in two parts as follows:

$$T = A + B \dots \dots \dots (3)$$

$$C = 1/T \dots \dots \dots (4)$$

where

- A = time spent actually to perform the specific operation (h/ha)
- B = time used for support activities, row-end turning and other delays (h/ha)
- T = total time (h/ha)
- C = performance rate (ha/h)

The value of A and B are calculated using various inputs as follows:

$$A = \frac{10}{S \times W} \text{ (h/ha)} \dots \dots \dots (5)$$

where

- S = machine ground speed (km/h)
- W = machine width (m)

$$B = \frac{2.8P}{WM} + (f_2 + f_3 + f_4 + f_5 + f_6 + f_7) \times \frac{10}{S \times W} + \frac{VU}{60D} \dots \dots \dots (6)$$

where

- P = average time per turn (s)
- M = row length (m)
- f<sub>2</sub> = coefficient for adding seed
- f<sub>3</sub> = coefficient for adding fertilizer
- f<sub>4</sub> = coefficient for adding water and chemicals

- f<sub>5</sub> = coefficient for adjustment
- f<sub>6</sub> = coefficient for idle field travel

- f<sub>7</sub> = coefficient for rough field surface

V = time for round trip, barn to field and return (min)

U = number of round trips to field and return required to complete the field operation

D = hectares in the field.

The values of the coefficients are given in Table 2. For purposes of this research, the relevant equation used was

$$T = \frac{10}{S \times W} + \frac{2.8P}{WM} + (f_5 + f_6 + f_7) + \frac{VU}{60D} \dots \dots \dots (7)$$

From the above, the field capacity was calculated. The fuel consumed was measured directly.

**Lubrication** —Aboaba (2) estimated that with an annual use of 1 000 h of a tractor, and following the recommended frequency of lubrication, a tractor uses 48 l of engine oil and 40 l of transmission oil in a year and charged 50% of the two oils for grease. From records kept by some of the farms and units the estimations of Aboaba were very reasonable and were adopted for the purpose of this research.

Table 2 Some Typical Coefficient for Predicting Capacity

Machine operation	Coefficient values	
	f <sub>5</sub> Adjustments	f <sub>6</sub> + f <sub>7</sub> Other delays
Harrowing	0.01 - 0.03	0.00 - 0.01
Plowing (4-bottom)	0.02 - 0.05	0.01 - 0.03
Plowing (6-bottom)	0.03 - 0.06	0.01 - 0.03
Cultivation (4-row)	0.05 - 0.07	0.03 - 0.04
Cultivation (6-row)	0.05 - 0.08	0.03 - 0.05

Table 3 Rate Performance of Machine Using Equations 2 and 4 ha/h

Operation	Farm or Unit					
	F <sub>1</sub>	F <sub>2</sub>	F <sub>3</sub>	H <sub>1</sub>	H <sub>2</sub>	Ave
Plowing (3-bottom disc)	0.25	0.28	0.30	0.28	0.29	0.28
Harvesting (Tandem disc)	0.37	0.38	0.37	0.40	0.38	0.38
Ridging (3-row disc)	0.31	0.32	0.36	0.36	0.33	0.34

## Results and Discussions

### Rate Performance

The rate performance (Table 3), for plowing is the lowest while those for harrowing is the highest. Very low rate performance was recorded in F<sub>1</sub> for plowing. This could only be explained from the fact that the farm was a virgin forest and was being tilled for the first time. It was observed that the stumping was not very thorough as many underground roots from fallen trees were still present. This contributed to plowing at reduced speed and spending more time for de-clogging and other things. This has also affected the rate of fuel consumption during plowing in this field and hence the total cost of plowing. Comparing the average field capacities with earlier ones in the literature (2) there has been marginal increase over the years—0.21, 0.34 and 0.32 ha/h for plowing, harrowing and ridging, respectively. This is attributed to the improvement in the maintenance and operational skills of the workers. It is believed that if the prediction equation by Renoll (12) were applied to Aboaba's data, the values could be very much lower, and the effect of the improved operational skill could have been much more apparent. The value of harrowing, 0.38 ha/h, is still lower than that experienced in Pakistan by Finney (13) which was 0.52 ha/h but plowing rate capacity of 0.28 ha/h was higher than those reported in Pakistan (0.2 ha/h) and in Malaysia (0.1 ha/h) by Finney (13) and Chancellor, (14) respectively.

### Fuel Consumption Rate

The fuel consumption rates of 8.1 l/h for plowing and 6.8 l/h for harrowing are still high when compared with the findings of Bukhari and Baloch (15) in Pakistan who

Table 4 Average Fuel Consumption Rate in Each Farm, l/h

Operation	Farm or Unit					
	F <sub>1</sub>	F <sub>2</sub>	F <sub>3</sub>	H <sub>1</sub>	H <sub>2</sub>	Ave
Plowing	8.8	8.1	8.0	7.0	7.6	8.1
Harrowing	7.0	7.5	7.0	6.3	6.2	6.8
Ridging	7.4	7.6	7.1	7.3	7.4	7.3

Table 5 Total Cost of Different Tillage Operations, ₦/ha

Operation	Farm or Unit					
	F <sub>1</sub>	F <sub>2</sub>	F <sub>3</sub>	H <sub>1</sub>	H <sub>2</sub>	Ave
Plowing	47.8	37.7	36.6	36.9	37.4	39.3
Harrowing	32.4	28.9	27.0	27.2	28.1	28.7
Ridging	34.7	30.4	28.8	29.7	30.4	30.8

reported an average fuel consumption rate of 7.4 l/h for the same size of disc plow and 5.77 l/h for equivalent size of disc harrow. It is, therefore, necessary to identify the source of wastage especially during harrowing.

### Cost of Operation

The average total costs per ha of plowing, harrowing and ridging were ₦39.3, ₦28.7 and ₦30.8, respectively. It is not possible to compare these figures with those from other countries as there are many factors like labour, fuel, lubrication costs and others which vary from place to place. However, the economics of these operations could be evaluated by comparing these computed values with what are charged by some hiring units (commercial and governmental). The government hiring unit H<sub>1</sub>, performs tillage operations for the public at subsidized rate. It charges ₦40/ha for plowing, ₦29/ha for harrowing and ₦23/ha for ridging. From Table 6, it is seen that the unit gains or breaks-even in plowing and harrowing but runs at a loss in ridging. Considering the three operations together, it costs the unit ₦93.8 while it charges ₦92; resulting in about 2% loss.

On the other hand, the commercial hiring unit, H<sub>2</sub>, runs at a profit at all levels of the operations, even though its costs of operation are

Table 6 Comparison of Cost of Operation and Amount Charged by Two Hiring Units

Item	Plowing	Harrowing	Ridging
-H <sub>1</sub> - Cost, ₦	36.9	27.2	29.7
Charges, ₦	40.0	28.0	23.0
Profit or loss, %	48.4	+3.0	-22.5
-H <sub>2</sub> - Cost, ₦	37.4	28.1	30.4
Charges, ₦	52.0	40.0	38.0
Profit or loss, %	+39.0	+42.3	+25.0

higher than that of H<sub>1</sub>. The higher cost is a result of higher wages for the operator. For the three operations, it costs ₦95.9/ha while it charges ₦130/ha resulting in 35.5% profit.

It is pertinent to note that the two units charged less for ridging than for harrowing: implying that it costs more for harrowing than ridging. This is contrary to the findings of this survey which has shown, consistently, that the cost of ridging is a little bit higher than that of harrowing. It was understood from the units that the figures they used were arrived at by using many assumed data instead of experimentally or field tested data. The data in this work will now help in fixing charges for the different operations.

### Breakdowns

An analysis of the breakdowns (Table 7) does not show any speci-

**Table 7** Level of Breakdowns Encountered during A Season's Operations as % of Total Breakdown

Level of breakdown	Farm or Unit					Ave
	F <sub>1</sub>	F <sub>2</sub>	F <sub>3</sub>	H <sub>1</sub>	H <sub>2</sub>	
Minor*	24	42	52	52	29	
Medium**	42	31	28	27	44	
Major***	34	27	20	21	27	

\* Any breakdown that interrupts operation for up to 1 h. \*\* One that grounds operation from 1 to 4 h. \*\*\* One that grounds operations for more than 4 h.

fic trend in the level of breakdowns across the farms and unit. The only noticeable trend is that except for F<sub>1</sub>, the percentage of major breakdowns in each farm and unit was the least. From the data of the types of breakdowns, it was observed that there were not much breakdown that involved highly technical engine repair. The cause of most of the major breakdowns was lack of spare parts which in some cases paralysed operations for more than one week. In almost all the farms and units, there were competent skilled mechanics to handle most of the breakdowns.

On the average, engine repair constituted 9.6%, clutch 10.5%, transmission 4.9%, hydraulic system 9.4%, steering 6.2%, cooling system 3.8%, 3-point hitch 5%, tyres 2.8%, electrical systems (including batteries) 14.6, V-belt 8.6%, machinery 2.6%, etc.

### Conclusion

From the above study, it can be said that there has been a marked improvement in the management of mechanized farms over the years. This is evidenced by the improved field capacity of the machines, less breakdowns and delays due to unavailability of spares and skilled labour and judicious use of fuel and

lubricants. Although the cost of labour and initial costs of tractors and machines have increased considerably, due mainly to inflation, there has been noticeable increase in the labour productivity.

The data in this study will be of great use for practicing mechanized farmers and to those who intend to go into mechanized farming in planning their operations. It will also be of use to commercial tractor and machinery hiring units to fix their charges.

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# Work Capacities and Fuel Consumptions of Hand Tractors Manufactured in the Philippines



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## Abstract

Test results of 10 hand tractors manufactured in the Philippines were compiled and analyzed. Farmers' rice fields in Laguna and Nueva Ecija were used as test areas. Field performance data show the actual plowing capacity ranged from 0.098 ha/h to 0.25 ha/h with an average of 0.14 ha/h (or 7.86 h/ha) and the field efficiencies ranged from 53.6 to 94.4% with an average of 83.6%. Six of the hand tractors tested were gasoline-fed and the average fuel consumption was 2.491 l/h (18.73 l/ha) and a specific fuel consumption of 1.89 l/ha/hp. On the other hand, the four diesel-fed hand tractors had an average fuel consumption of 0.82 l/h (6.12 l/ha) and an average specific fuel consumption of 1.22 l/ha/hp. Obviously, the hand tractors with diesel engines have lower fuel consumption which will offset in the long run their high initial purchase cost.

## Introduction

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Hand tractor utilization in the Philippines dates back to the early 1960s. Bautista and Castro (1980) reported that there were 65 manufacturers of hand tractors in the Philippines in the latter part of 1979. However, with the increase of fossil fuel costs, there had been a decrease in the number of Philippine fabricators of hand tractors during the succeeding years. Despite this unfavorable situation, hand tractors remain to be an essential motive power in farming operations, especially land preparation. It saves time, reduces drudgery in the farm and increases land productivity.

Bautista (1967) undertook field studies on the usage of hand tractors in the lowland ricefields in Laguna, Philippines. Some of the findings were as follows; a) all the hand tractors were imported units, b) the soil-cutting implements predominantly used were of either the metal cage wheels - rake harrow combination or a rotary cultivator, c) several passings of the hand tractor were made at one given operation wherein the next hand tractor pass was carried out perpendicular to the previous pass, d) two operators were employed for one hand tractor who took turns every half an hour of operation.

On the economic aspects of im-

ported hand tractors and ownership in the Philippines, Orcino (1972) reported that data on the fuel and oil consumption costs were based mostly on the recollections and estimates of the respondents as none of them made records of machine and labor performance. The survey showed that the actual field capacity of the machine (plowing and harrowing) was 44.1 h/ha (0.02 ha/h) and an average fuel consumption of 1.18 l/h.

Johnson (1968) conducted a survey on the performance and economics of the use of small equipment in the Philippines. Results on the tractive type hand tractor studies show an average fuel consumption of 15.3 l/ha and an average actual field capacity of 12.9 h/ha (0.08 ha/h) for plowing operation.

Test work conducted by AMTEC (1980) of a front-located power drive type hand tractor indicates a puddling work output of 16.7 h/ha (0.06 ha/h). The average fuel consumption was 1.04 l/h.

Results of a survey of 125 tractor owners in Nueva Ecija province, Philippines, show that a two-wheeled tractor can finish plowing 1 ha of land in 11.3 h, on the average (Maranan, 1983).

Bautista (1982) fabricated a hydraulic type power absorbing

unit fitted at the wheel axle of the hand tractors. Three different models of French-made hand tractors were tested at varying speed and load using this dynamometer. Graphical presentation of the various test results on the engine power output, hourly fuel consumption and the specific fuel consumption show specific curve patterns. The engine power output and hourly fuel consumption are characterized by an upward curve as the engine speed increases up to about three-fourth of the maximum and then their curve patterns go downward. While the specific fuel consumption curve had exhibited a curve that goes downward to about three-fourths of the engine maximum speed and its direction then changes upward as the engine speed is further increased.

In procuring a hand tractor, there are three vital questions buyers usually ask: How much does it cost?, What is its capacity?, and What is its fuel consumption? These questions consider the initial investment cost, field performance and maintenance cost of the machine. Oftentimes, a buyer wants a machine that is capable of doing the job well, with low investment and maintenance cost. However, lack of information on the actual field performance data of hand tractor is a serious problem in selecting the desirable unit prior to purchase.

This paper attempts to analyze and show application of field performance data of hand tractors which should be beneficial not only to the farmer-users but also to financing institutions and policy-makers concerning agricultural development. It is also useful on the cost analysis for feasibility studies on the adoption and/or

## Materials and Methods

Ten Philippine-manufactured hand tractors were tested in 1983 in

the farmers' irrigated rice fields in Calauan, Laguna and in Muñoz, Nueva Ecija. Two of them utilized a pair of spiral plows which are mounted in the wheel axle. A rake-harrow is used as a supplementary implement (Fig. 1). The other eight hand tractors employed 2-bottom disc plow (Fig. 2).

The tests were carried out by the Agricultural Machinery Testing and Evaluation Center (AMTEC), an institution jointly established by the Philippine Ministry of Agriculture and the University of the Philippines at Los Baños with financial assistance from the World Bank and Central Bank of the Philippines.

## Field and Soil Conditions

Soil conditions such as height and space of rice crop stubbles, depth of water and soil hardness are shown in Table 1. Soil hardness was measured using a Proctor penetrometer, CN-419 and values obtained ranged from 1.63 to 2.81 kg/cm<sup>2</sup>.

## Measurement of Plow Depth and Width of Cut

The width and depth of cut were measured at random using the depth and width gauge (Fig. 3). Which consists of a meter stick with a horizontally sliding indicator to facilitate the measurement of the width of cut, and a vertical rod with sliding marker to determine the depth of cut.

## Measurement of Speed of Operation

Two poles 20 m apart were placed in the middle of the test run. The speed was calculated



Fig. 1 Hand tractor with spiral plow installed at the wheel axle (Courtesy of AMTEC).



Fig. 2 Hand tractor with 2-bottom disk plow hitched at the rear (Courtesy of AMTEC).



Fig. 3 Depth and width gauge (Courtesy of AMTEC).

from the time required for the machine to travel the pre-set distance of 20 m.

Speed of operation (m/sec.) =  $\frac{\text{operation of hand tractors for a given set of conditions. It could also be used in the comparative analysis between hand tractor and other sources of power in the farm. Moreover, it serves as a useful guide for agricultural economists in investment appraisal.}}{\text{time required (sec)}}$

## Measurement of Fuel Consumption

Table 1 Soil and Field Conditions, Philippines

Place of tests	Rice crop stubbles		Depth of water (cm)	Penetration resistance (kg/cm <sup>2</sup> )
	Spacing (cm)	Height (cm)		
Calauan, Laguna	21 x 21	22.7	4.2	1.63
Calauan, Laguna	22 x 22	9.8	5.1	2.81
Calauan, Laguna	21 x 21	12.5	7.1	2.04
Muñoz, Nueva Ecija	20 x 20	12.5	7.1	2.52

The fuel tank was filled to full capacity before and after each trial. The amount of refuelling measured by a graduated cylinder was considered to be the actual fuel consumption for each test trial.

tractor buyers to choose the engine of their preference and the choice is from among the imported units. Thus, in actual practice, a particular hand tractor model may have other possible brands of engines when the

tractor units are released from the factory.

Results of the plowing capacity tests of the 10 hand tractors are shown in Table 3. They registered an average actual field capacity of

## Calculations

### Field Capacity

Field capacity is the rate of machine performance in terms of quantity per unit time. It is a measure of the relative productivity of a machine under field conditions.

The theoretical field capacity was calculated by using the formula:

Theoretical field capacity (ha/h) = width of cut (m) x working speed (km/h)/10

The effective field capacity was computed in terms of area plowed and the total time spent.

Effective field capacity (ha/h) = area plowed (ha)/time spent (h)

Field efficiency was computed using the effective field capacity and theoretical field capacity.

Field efficiency (%) =

$$\frac{\text{effective field capacity}}{\text{theoretical field capacity}} \times 100$$

### Fuel Consumption Rate

The fuel consumption is reported as quantity per unit time.

Fuel consumption (l/h) =

$$\frac{\text{amount of fuel consumed (l)}}{\text{time elapsed (h)}}$$

Fuel Cost (\$/ha) = l/h x h/ha x \$/l

Labor Cost (\$/ha) = h/ha x day/8-h x \$/day

## Discussion of Results

Table 2 shows the specifications of the hand tractors and engines. The prime movers of the hand tractors tested had a horsepower rating ranging from 4.2 to 16 hp. Some manufacturers allow the hand

Table 2 Machine and Engine Specifications

Hand tractor number	Specifications of hand tractor				Engine (all are four stroke cycle)				
	Length (mm)	Width (mm)	Ground clearance (mm)	Weight with engine (kg)	Brand name and model	Rated hp	Rated rpm	Fuel used	
1	2673	1368	398	169.5	Honda G-400	10	3600	gasoline	
2	2274	1170	92	175	Briggs & Stratton	10	3600	gasoline	
3	2210	1200	140	187	Ducati IS 9	9	3200	diesel	
4	2427	1183	147	186	Motor 1 ADN 48W	12	3200	diesel	
5	2410	1163	125	169.5	Briggs & Stratton	10	3600	gasoline	
6	2270	1205	137	194	Briggs & Stratton	16	3600	gasoline	
7	2350	1320	127	218	Kohler K-301	10	3600	gasoline	
8	2203	1126	93	186.2	Kubota EP 84-ND	7	3000	diesel	
9	2472	1062	98	194	Kubota ER 40-N1	4	2000	diesel	
10	2295	1135	115	157.5	Kubota GS 300	7.2	3600	gasoline	

Table 3 Plowing Performance Data of 10 Test Hand Tractors Manufactured in the Philippines, 1983.

Hand Tractor Number	Travelling speed (km/h)	Depth of tillage (c) (mm)	Width of tillage (c) (mm)	Field capacity		Field efficiency (%)
				Actual ha/h (h/ha)	Theoretical ha/h (h/ha)	
1 a)	0.49	11.0	12.5	0.25 (4.00)	0.27 (3.73)	93.2
2 b)	2.45	10.8	40.2	0.11 (9.52)	0.12 (8.47)	89.0
3 b)	3.53	10.2	44.0	0.15 (6.67)	0.17 (5.88)	88.2
4 b)	4.68	9.4	42.7	0.19 (5.05)	0.22 (4.48)	88.8
5 b)	1.36	10.4	44.9	0.12 (8.33)	0.22 (4.48)	53.7
6 b)	3.35	10.6	40.3	0.16 (6.06)	0.17 (5.88)	97.0
7 a)	1.02	9.0	-	0.11 (9.09)	0.20 (4.87)	53.6
8 b)	2.76	10.5	30.5	0.10 (9.81)	0.11 (9.25)	94.4
9 b)	2.92	10.5	35.5	0.09 (10.2)	0.11 (8.85)	86.7
10 b)	2.82	10.5	35.5	0.10 (9.2)	0.11 (9.09)	91.8
Average	2.54	10.3	36.2	0.14 (7.86)	0.17 (6.50)	83.6

a) with spiral plow. b) with 2-bottom disc plow. c) average of 15 readings.

0.139 ha/h at an average travelling speed of 2.54 km/h. A minimum actual field capacity of 0.098 ha/h for 4 hp hand tractor and a maximum of 0.25 ha/h for 10 hp hand tractor were noted. The eight tractors using a 2-bottom disc plow and the other two using a spiral plow had an average actual field capacity of 0.13 ha/h (7.84 h/ha) and 0.18 ha/h (5.55 h/ha), respectively. The hand tractor efficiency varied from 53.6% to 94.4% with the average of 83.6%.

Table 4 shows the fuel consumption of the four hand tractors with diesel engines and of the six hand tractors with gasoline engines. Fuel consumption ranged from 0.71 l/h to 1.2 l/h with an average of 0.82 l/h for the diesel engines while 1.7 l/h to 3.5 l/h with an average of 2.49 l/h for the gasoline engines.

### Estimated Cost of Operation

The estimated cost of operation for gasoline and diesel hand tractors is shown in Table 5. The calculated variable cost for gasoline and diesel hand tractors was \$1.76/h (\$13.43/ha) and \$0.79/h (\$6.12/ha), respectively. The high cost for gasoline engine hand tractors is due mostly to its high fuel consumption rate as reflected in Table 4 and higher cost of gasoline. The fixed cost for the gasoline engine hand tractors was \$243.07/year while the diesel engine hand tractors, \$276.78/year.

### Summary

Ten hand tractors, including their attached implements manufactured in the Philippines were tested in 1983 by the AMTEC at the University of the Philippines at Los Baños. Two of them utilized a pair of spiral plows which are mounted on the wheel axles. A rake harrow is fitted at the rear of the hand tractor which enables the operator

Table 4 Fuel Consumption of 10 Test Hand Tractors Manufactured in the Philippines, 1983

Hand Tractor Number	l/h		l/ha		l/h/hp	
	diesel	gasoline	diesel	gasoline	diesel	gasoline
1		3.16		12.64		0.32
2		1.70		16.19		0.17
3	0.80		5.33		0.09	
4	1.12		5.65		0.09	
5		2.05		17.08		0.21
6		2.75		16.67		0.17
7		3.5		31.8		0.35
8	0.64		6.27		0.09	
9	0.71		7.24		0.18	
10		1.82		18.02		0.25
Average	0.82	2.49	6.12	18.73	0.12	0.24

Table 5 Estimated Cost of Operation for Gasoline and Diesel-fed Hand Tractors Manufactured in the Philippines, 1983 (Based on exchange rate of ₱ 14=US\$1)

Items	Gasoline-fed hand tractor		Diesel-fed hand tractor	
Initial machine cost with engine (\$ <sup>a</sup> )	1035.71		1178.57	
Fixed cost (\$/year)				
Depreciation <sup>b</sup> )	116.5		132.64	
Repair & maintenance <sup>c</sup> )	58.21		66.36	
Interest on investment <sup>d</sup> )	68.36		77.78	
Total fixed costs	243.07		276.78	
Variable cost	\$/h	\$/ha	\$/h	\$/ha
Fuel <sup>e</sup> )	1.16	8.71	0.26	1.96
Oil <sup>f</sup> )	0.12	0.95	0.05	0.39
Labor <sup>g</sup> )	0.48	3.77	0.48	3.77
Total variable costs	1.76	13.43	0.79	6.12

- a) All tillers are assumed to have an 8-year life for transmission and diesel engine and 4-year life for gasoline engine. For the gasoline hand tractors, the cost of an additional engine was assumed to ensure a total of 8-year working life for the machine.
- b) Straight line basis with 10 % salvage value
- c) Repair cost equals 0.45 P/n where P=initial cost of the machine; n=machine life in years and 0.45=constant
- d) 12 % on average balance over the life of machine
- e) From Table 4, 0.82 l/h or 6.12 l/ha for diesel-fed engines at \$0.37/l and 2.49 l/h or 18.73 l/ha for gasoline-fed engines at \$1.36/l. Single plow-pass.
- g) \$1.90 per 8-h day per person. Two operators are employed for each tractor.

to control the rate of advance movement of the machine.

The other eight hand tractors were provided with 2-bottom disc plow installed at the rear position. Good traction during operation was assured by the metal cage wheel mounted at the wheel axles.

At an average travelling speed of 2.54 km/h, the average actual plowing capacity of the hand tractors was 0.14 ha/h or 7.86 h/ha with an average field efficiency of 83.6%. Under normal field conditions wherein the soil is adequately soft and the weeds are less dense, the operator plays a major role in the actual work output of the machine. Overlapping of cut may be minimized and good working technique is properly followed.

Six of the test hand tractors were gasoline-fed and the average fuel consumption was 2.49 l/h (18.73 l/ha) and a specific fuel consumption of 0.24 l/h/hp. On the other hand, the diesel-fed hand tractors had an average fuel consumption of 0.82 l/h (6.12 l/ha) and an average specific fuel consumption of 0.12 l/h/hp. These figures were obtained from a single pass of the plow.

The calculated total variable cost for gasoline-fed and diesel-fed hand tractors was \$1.76/h (or \$13.41/ha) and \$0.79/h (or \$6.12/ha), respectively. The fixed cost was \$243.07/year for the gasoline-fed hand tractors, and \$276.78/year for the diesel-fed hand tractors.

(Continued on page 34)

# Photoelastic Investigations for Stresses Due to Soil-Tillage Disc Tool Interaction



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## Abstract

An overall perfect design of tillage tools and implements requires the knowledge of stresses and strains developed in the various components due to tillage action. This study outlines a whole field photoelastic analysis of soil-disc tool interaction. The resulting fringe patterns in the modelled transparent disc as well as the transparent soil bin reveal information pertinent to a proper tool design and to an on-the-spot manipulation of the soil during the tillage operation. An optimum depth of operation is suggested for efficient tillage action.

## Introduction

Soil manipulation through tillage is the most important step in raising a successful crop. It is accomplished by several kinds of tillage tools, equipment and machinery. An overall perfect design of such tools and implements requires the knowledge of stresses and strains developed on the various components due to tillage operation. Interest is focus-

sed in this work for evaluation of stresses due to soil-tillage disc tool interaction. Attention by workers up to the present time embraces either theoretical formulations or point-per-point analysis of forces acting on disc tools. Theoretical analyses rest on assumption which need validations through suitable experiments and the point-per-point techniques give only limited information. A whole field evaluation of the stress field in the disc element will provide relatively more information for the selection of proper materials for the tool and suitable manufacturing methods. Attempt is made to obtain a whole field stress analysis by employing photoelastic techniques. An added motivation has been to visualize the soil stress distributions under the action of disc tools by using a simulated transparent soil material for the studies.

The photoelastic method of stress analysis has been accepted as one of the standard techniques for a whole field analysis of the stresses in any member subjected to loads (Frocht 1948, Dureli et al 1958, Dally and Riley 1965). It is an ex-

perimental analogy combining the principles of optics and theory of elasticity. It depicts the behaviour of light passing through an elastically stressed transparent medium. The resulting fringe patterns in the form of Isoclinics and Isochromatics reveal the principal stress directions and their differences in magnitude. A separation technique is used to evaluate the magnitudes of the principal stresses separately.

Photoelastic techniques have not been used to a large extent for the study of agricultural implements. This is because of the simulation difficulties in preparing transparent soil bins, which in addition, should behave as a photoelastic material. Photoelastic gelatin mixtures which have high optical sensitivity can be used as a simulated soil, but its early use was restricted because of its extremely fickle and weak mixture characteristics. However, with the advent of large field diffused light polariscopes, gelatin has been used on a few occasions for modelling soil-machine systems. Farquharson and Hennes (1940) used it to study stresses in a mass of earth around tunnels. Osokina

(1957) studied its physical property and used it in modelling geological formations. Crisp (1952) and Richards (1966) used it to analyse soil mass gravity structures. Mellinger et al (1965) of the U.S. Army Engineer Division used it for the first time under dynamic loading conditions to investigate stress behaviour under the moving vehicle wheel. Kim and Staley (1970) at the University of British Columbia conducted comparative tests of differently shaped medel grousers using gelatin mixtures under static conditions. Some general studies of soil reactions to tillage implements made by Gupta and Pandya (1967) and the book by Hunter (1964) are always useful to analyse the visco-elastic nature of the soil under static and dynamic conditions of loading.

This study, performed at the Indian Institute of Technology, Kharagpur, outlines a whole field photoelastic analysis of soil-plane disc tool interaction. The resulting fringe patterns in the modelled transparent disc as well as the soil reveal several information to be taken care of for the tool design and during the tillage operation.

### Stress-optic Relation

The stress-optic relation is written as:

$$\sigma_1 - \sigma_2 = \frac{Nf_{\sigma}}{h} \quad (1)$$

where,

$N = \Delta/2\pi$  = the relative retardation in terms of a complete cycle of retardation,  $2\pi$

$f_{\sigma} = \lambda/c$  = material fringe value

$\lambda$  = wave length of light

$c$  = stress-optic coefficient

$h$  = model thickness

$\sigma_1, \sigma_2$  = principal stresses

The principal stress difference ( $\sigma_1 - \sigma_2$ ) in a model can be determined if the relative retardation  $N$  can be measured. On loading the

model in the field of the circular polariscope isochromatic fringes are obtained, thereby it provides the values of  $N$  at each point. The dark field arrangement gives integral fringes ( $N = 0, 1, 2, 3, \dots$  etc) and the light field arrangement gives half order fringes ( $N = 1/2, 1-1/2, 2-1/2, 3-1/2, \dots$  etc). Individual magnitudes of stresses are determined by employing a suitable separation technique such as shear difference or oblique incidence methods.

A plane polariscope arrangement provides the information of the isoclinic patterns which indicate the principal stress directions at each point of the model.

The material fringe value,  $f_{\sigma}$ , can be established by means of a suitable calibration technique.

### Procedure

The main objective of the experiment is to visualize the overall stress fields both in the disc tool as well as in the soil due to the interaction between them. A solid plane disc, as per Indian Standard IS : 4366 - 1972 (Part I and II), was considered. Fig. 1 shows the detailed geometrical parameters of the prototype as well as the photo-elastic model disc tool.

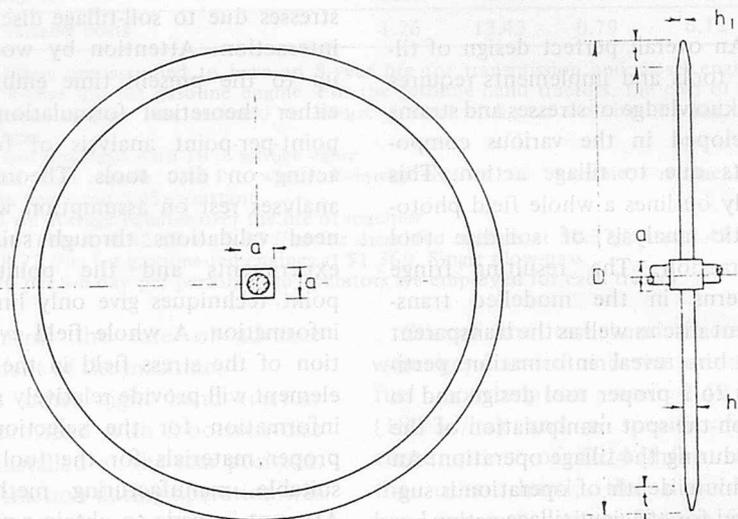
The disc tool model is machined out of an epoxy plate cast out of epoxy resin (CY 230) and the corresponding hardener (HY 951). The properties of this photo-elastic material are shown below:

Tensile modulus,

$$E = 50.9 \times 10^3 \text{ kg/cm}^2$$

Shear modulus,

$$G = 29.56 \times 10^3 \text{ kg/cm}^2$$



	PROTOTYPE	PHOTO ELASTIC MODEL
MATERIAL	HIGH CARBON STEEL	EPOXY (ARALDITE CY 230 AND HARDNER HY 951)
<u>GEOMETRY</u>		
Diameter (D)	455 mm	155 mm
Thickness (h)	6 mm	4 mm
Square shaft (a x a)	26 mm x 26 mm	8 mm x 8 mm
Taper height (t)	22 mm	7 mm
Taper thickness (h <sub>1</sub> )	1 mm	0.5 mm

Fig. 1 Disc tool geometry

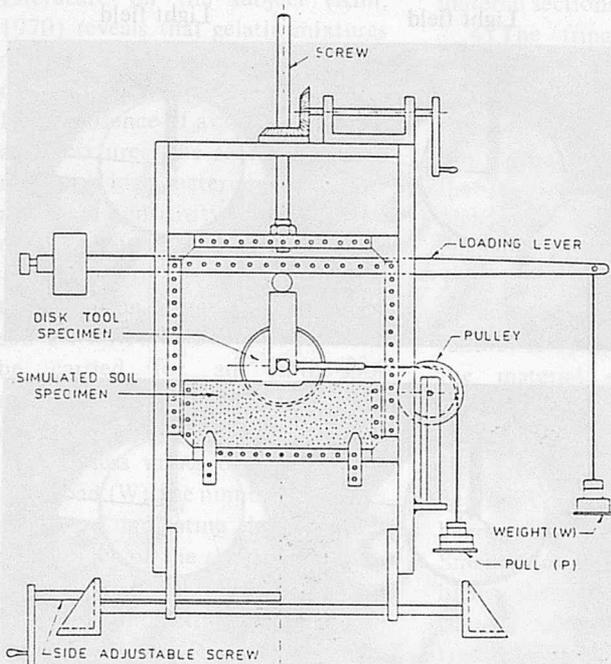


Fig. 2 Loading frame.

Poisson's ratio,

$$\nu = 0.35$$

Material fringe value,

$$f_{\sigma} = 15.349 \text{ kg/cm.}$$

As has been reported in the literature (Kim, 1970), gelatin mixtures are good for modelling of soil in any photoelastic work. But the non-availability of the gelatin mixtures has compelled the search for a suitable substitute material which will have a comparatively low modulus and high material fringe value. Gelatin mixtures have a stiffness  $E = 3.2 \text{ MN/m}^2$  and Poisson's ratio  $\nu = 0.5$ . Soft PVC sheets possessing similar properties were selected to act as the simulated soil model. These sheets have the following properties:

Tensile modulus,

$$E = 0.1091 \times 10^3 \text{ kg/cm}^2$$

Shear modulus,

$$G = 0.0361 \times 10^3 \text{ kg/cm}^2$$

Poisson's ratio,

$$\nu = 0.5$$

Density,

$$\rho = 1.2253 \text{ gm/cm}^3$$

Material fringe value,

$$f_{\nu} = 5.907 \text{ kg/cm.}$$

The disc tool- simulated soil

specimens were designed to be loaded by a suitable loading device specifically designed and fabricated for the purpose. The loading frame is kept in the field of a 25 cm diffused light polariscope. Fig. 2 shows the details of the loading frame. Fig. 3 represents the photoelastic disc tool model and the simulated soil in the transparent mould box. The dead weight (W) and the pull (P) are applied through a specially designed elbow lever such that W and P act perpendicular to each other. The dead weight (W) is effected by the lever mechanism of the main loading frame while the pull (P) is obtained by a pulley and rope device. Various combinations of W and P are applied to the disc tool-soil model assembly for the analysis of resulting fringe patterns. The transparent Perspex mould for housing the transparent simulated soil sample enables a clear visualization of the whole stress field in the soil while the disc tool interacts with the soil.

Fig. 4 represents the overall photographic view of the 25 cm diffused light polariscope along

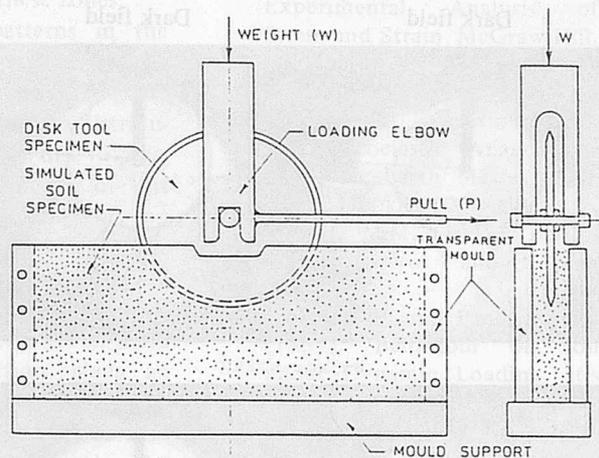


Fig. 3 Photoelastic disc tool model and simulated soil in the transparent mould box.

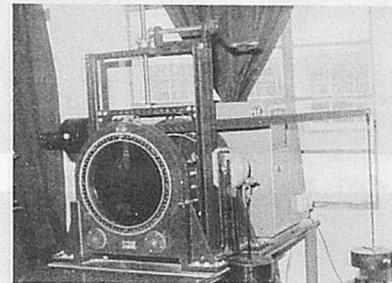


Fig. 4 Whole view of the circular polariscope with loading frame.

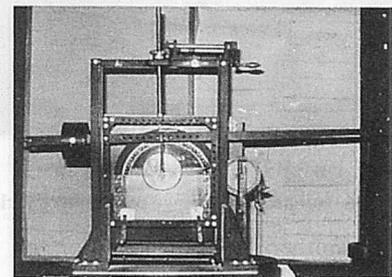


Fig. 5 The loading fixture with disc tool and the simulated transparent soil bin.

with the loading frame, disc tool and the transparent model soil bin. Fig. 5 indicates the arrangement of the loading fixture with the disc tool and the simulated transparent soil bin.

## Test Results

Fig. 6 represents isochromatic fringe patterns for various W-P combinations for a particular depth of operation,  $d_1 = 6 \text{ cm}$  and Fig. 7

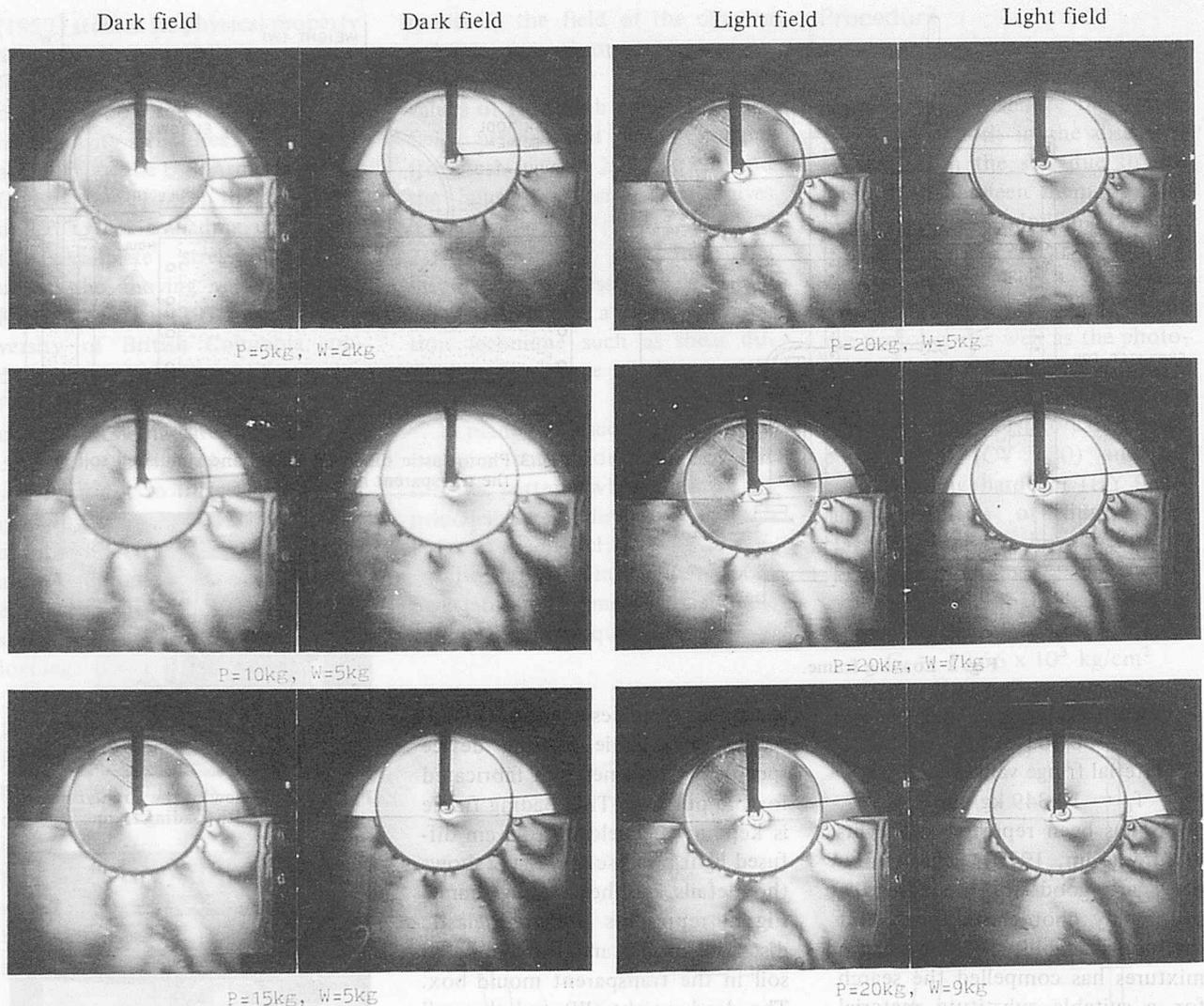


Fig. 6 Isochromatic fringe patterns for various P-W combinations: Depth of operation,  $d_1 = 6$  cm.

for another depth of operation,  $d_2 = 5$  cm. These include both dark field and light field fringe patterns depicting integral fringe order ( $N = 0, 1, 2, 3, 4, \dots$  etc) and half order fringes ( $N = 1/2, 1-1/2, 2-1/2, 3-1/2, 4-1/2, \dots$  etc), respectively. These fringes represent constant ( $\sigma_1 - \sigma_2$ ) lines, which in turn are the true pictures of the maximum shear stress contours. Accordingly, these fringes in the simulated transparent soil will give an idea of how the soil failure occurs due to the tillage action.

### Conclusions

1) Epoxy resin with moderate material fringe value and sensitivity index, and PVC material with high-

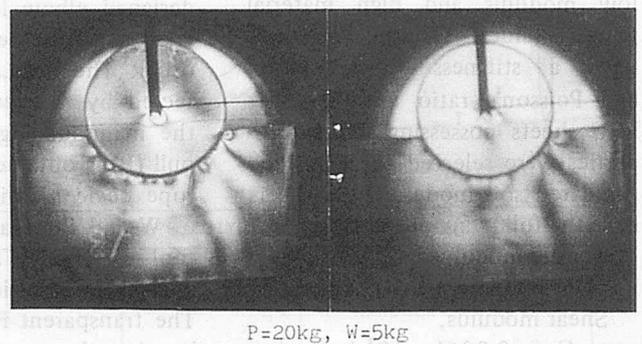


Fig. 7 Isochromatic fringe patterns: Depth of operation,  $d_2 = 5$  cm.

er material fringe value and sensitivity index can be used for modeling the agricultural disc tool and the soil, respectively. The fringe patterns reveal the overall stress field due to the disc-soil interaction.

Literature on the subject (Kim, 1970) reveals that gelatin mixtures may be used to simulate some type of clay soils for qualitative analysis. In the absence of availability of gelatin mixtures, the soft PVC materials with high material fringe value and high sensitivity index can be effectively used for the purpose.

2) Some of the general observations on the fringe pattern in the soil are noted below. This idea can be carried for an on-the-spot manipulation of the soil tillage operation.

With less values of pull (P) and dead load (W), the number of fringes are less, indicating lower order magnitudes of the shearing stresses. With high P and W, the fringes multiply, indicating the requirement of proper P and W for the effective tillage action.

The concentration of fringes in the soil are more in the leading edge of the disc compared to the trailing side. This is due to the existence of loose soil at the trailing end. This is a true picture of the tillage action, indicating the development of pressure at the cutting edge.

The highest order shearing stress in the soil takes place at the topmost interface point between the disc and the soil. The point represents the starting of the tillage action.

3) In the disc, stress concentration is observed at the surrounding zones of the shaft. Accordingly, a recommendation is stipulated for the use of high strength, thick

material sections at these zones.

4) The fringe patterns in the disc, in the zones near the shaft, have a shape clearly indicating the effect of pull on the stress distribution in the disc. As the disc rotates, the position of occurrence of this high stress concentration goes on changing with respect to the disc. This alternate stress reversal will initiate fatigue, leading to final failure. Keeping the above in mind the material selection plays an important role.

5) The pull (P) and dead load (W) remaining unchanged, the depth of operation has a definite bearing on the stress distribution. Smaller depth of operation induces higher shearing stresses in the soil, thereby causing more effective tillage action. Too high values of P and W may be uneconomical, since an optimum depth of operation can always be determined for particular soil condition and a specific tool in use.

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# Seed Distribution Performance of the Furrow Openers Used on Drill Machines



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## Introduction

The seed distribution in the vertical and horizontal planes affect the growth of plants directly. Furrow openers (coulters) on the drill machines have an important effect on seed distribution. In our country where the number of the drill machines and drill machine manufacturers has been increasing very much recently, it is necessary to determine the seed distribution of the coulters to improve their performance. In this research the seed distribution of four different types of coulters were investigated. Single, double, disc, hoe and shoe coulters were randomly selected for this research. The effects of forward speed, working depth and chain cover to the seed distribution were investigated. With the results obtained from the experiments, the working conditions of these coulters were determined.

## The Study

All the experiments were carried out in the soil bin to avoid the effects of soil structure on the seed distribution. The structure of soil is

clay-loam. Throughout the experiments, the moisture content of the soil was determined to be about 18.04%. The sowing with the coulters was done at the seed rate of 15 kg/day and the distance between the rows is 15 cm. In this drilling condition the theoretical distance between the seeds on the row was 17.32 mm. The experiments were conducted at the forward speeds of 3.6 km/h and 7.2 km/h.

The vertical and horizontal seed distributions in the soil were determined throughout the experiments. The distances between the nearest neighbour seeds and the distance in the transverse direction of seeds to a straight line parallel to the row were measured in the horizontal plane. The depth of the seeds to the soil surface were measured in the vertical plane.

## Results

The results show that the seed distribution related to four types coulters and their working conditions were in the following values:

Working depth of the coulters (mm): 64.8 – 151  
Mean sowing depth (mm):

30.96 – 104.50  
Standard deviation of the sowing depth distribution (mm):  
1.88 – 9.56  
Coefficient of variation for the sowing depth distribution (%):  
3.01 – 16.93  
Ratio of mean sowing depth to the working depth (%):  
40.00 – 89.10  
Standard deviation of the seed distribution in the transverse direction (mm): 4.99 – 11.94  
Ratio of the sown area to the total area (%): 6.65 – 15.92  
Mean distance between the nearest neighbour seeds (mm):  
13.46 – 23.92  
Standard deviation of the distribution of the distance between the nearest neighbour seeds (mm): 5.78 – 17.19  
Ratio of the distance between the nearest neighbour seeds to the theoretical distance between the seeds (%):  
77.71 – 138.11

When the results obtained throughout the research were evaluated, with respect to coulters the following conclusions can be put forward:

Of the forward speed, cover and the working depth of coulters, the

working depth was observed to influence the seed distribution more than the others. The single-disc type coulter was affected very much by these factors and their variations.

The working and sowing depths of the shoe coulter varied in the large ranges. But the working and sowing depths of double disc and hoe coulters were determined to be in the small ranges. The shoe type coulter was determined to be suitable for both deep and shallow drilling. It was concluded that the hoe type coulter was suitable for deep drilling.

The results showed that the single disc type coulter was suitable for both shallow and medium drilling, but the double disc type coulter was suitable for medium drilling only.

Of the shoe, hoe, single and double disc type coulters, the evenness of the depth distribution for the double disc type coulter was better than the others, but the evenness of the seed depth distribution for the hoe type coulters was not good.

The single disc type coulter has a wider transverse width than the others. Except the single disc coulter, the transverse width of the double disc type coulter was better than the shoe and hoe type coulters. The transverse width of the coulter which was the narrowest in the coulters was the hoe type coulter.

The distance between the nearest neighbour seeds of the double disc type coulter was determined to be very close to the theoretical distance between the seeds. This distance of the single-disc and shoe coulters varied in a large range, but this distance values for the hoe coulter were determined to be smaller than the theoretical distance. As a result, the area for the plant life was the smallest in drilling with the hoe coulter.

In the coulters, it was determined that the sowing depth was dif-

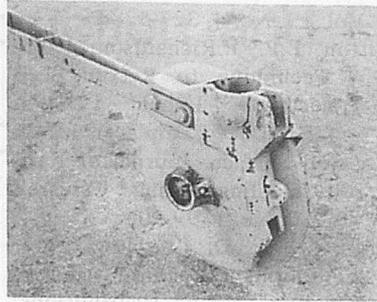


Fig. 1 Single disc type furrow opener.

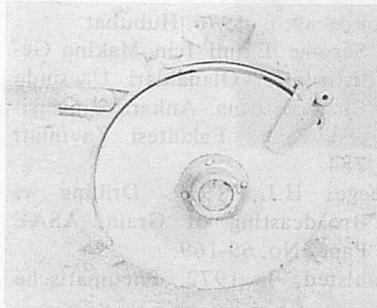


Fig. 2 Double disc type furrow opener.

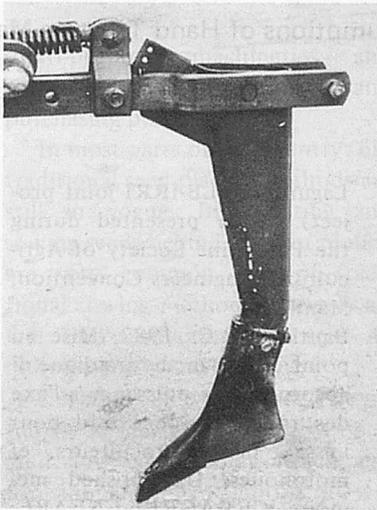


Fig. 3 Hoe type furrow opener.

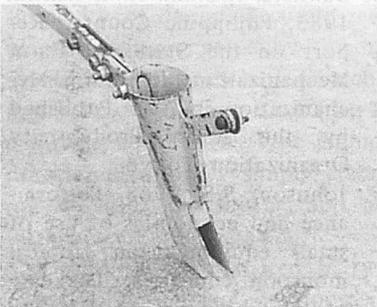


Fig. 4 Shoe type furrow opener.

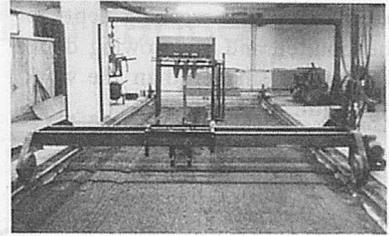


Fig. 5 Soil bin in which experiments were carried out and experiment rig.

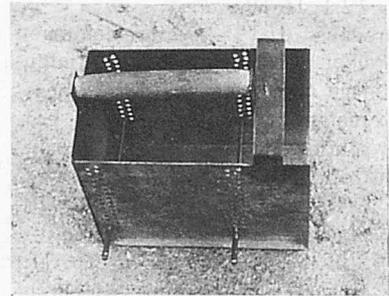


Fig. 6 Soil grader.

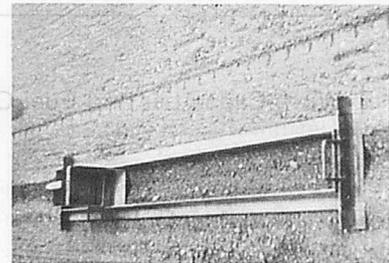


Fig. 7 The application of soil grader.

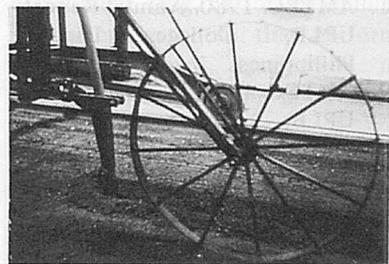


Fig. 8 The working of furrow opener in the soil.

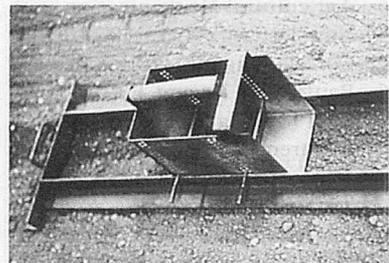


Fig. 9 Soil grader.

ferent from the working depth of the coulter and the sowing depth was always smaller than the working depth.

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### Work Capacities and Fuel Consumptions of Hand Tractors Manufactured in the Philippines

(Continued from page 26)

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# Design, Construction and Performance of a Manually-Operated Seeding Attachment for an Animal-Drawn Cultivator



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## Abstract

The seeding device for attachment with a three-tine or a five-tine animal drawn cultivator discussed in this paper was designed and developed at the Agricultural Institute, Allahabad. The power transmission from the ground was eliminated to simplify the machine and reduce the cost. It was provided with a manually-operated, single-fluted feed roller and a seed distributor for equal distribution of seeds in furrows. The test results indicate good performance for wheat and barley.

## Introduction

Since 90% of the Indian farmers have small land holdings and are much below the normal living standard, it is very difficult for them to have costly agricultural machineries and equipment. It is, therefore, essential to introduce

multi-purpose machineries and equipment to suit their needs and purchasing power.

In most parts of the country, old traditional seed placing methods are still in vogue. Broadcasting and sowing seeds behind the *desi* plough are very common. Use of traditional sowing methods adversely affect the production and seed requirement per unit area.

Keeping in view the average Indian farmer, the manually operated, low cost seeding attachment for animal drawn cultivator was designed and developed to suit the following requirements: low cost; simplicity of design; accurate seed placement in comparison with commonly practiced traditional methods, suitable for attachment to a three-tine or a five-tine animal-drawn cultivator by simply changing the seed distributor; and adjustable seed rate.

The work was conducted in two stages: i) design and development of seeding attachment and ii) test-

ing of the seeding attachment.

## Design and Development

Efforts were made to design different components of seeding attachment (Fig. 1) for an animal drawn cultivator so that uniform and equal seed distribution in all the furrows can be done without any seed breakage.

The following points were considered in the design of the seeding attachment: moderately accurate metering of seed, proper distribution of seed in furrows, capacity of seed hopper in relation with the field area to be sown and weight of machine, and minimum number of moving parts so that farmers may operate and maintain the machine easily.

Assumptions: i) Speed of the manually operated handle, 60 rpm; ii) Exposed surface of the roller, 12.5 cm; iii) Linear sowing speed of the animal drawn cultivator,

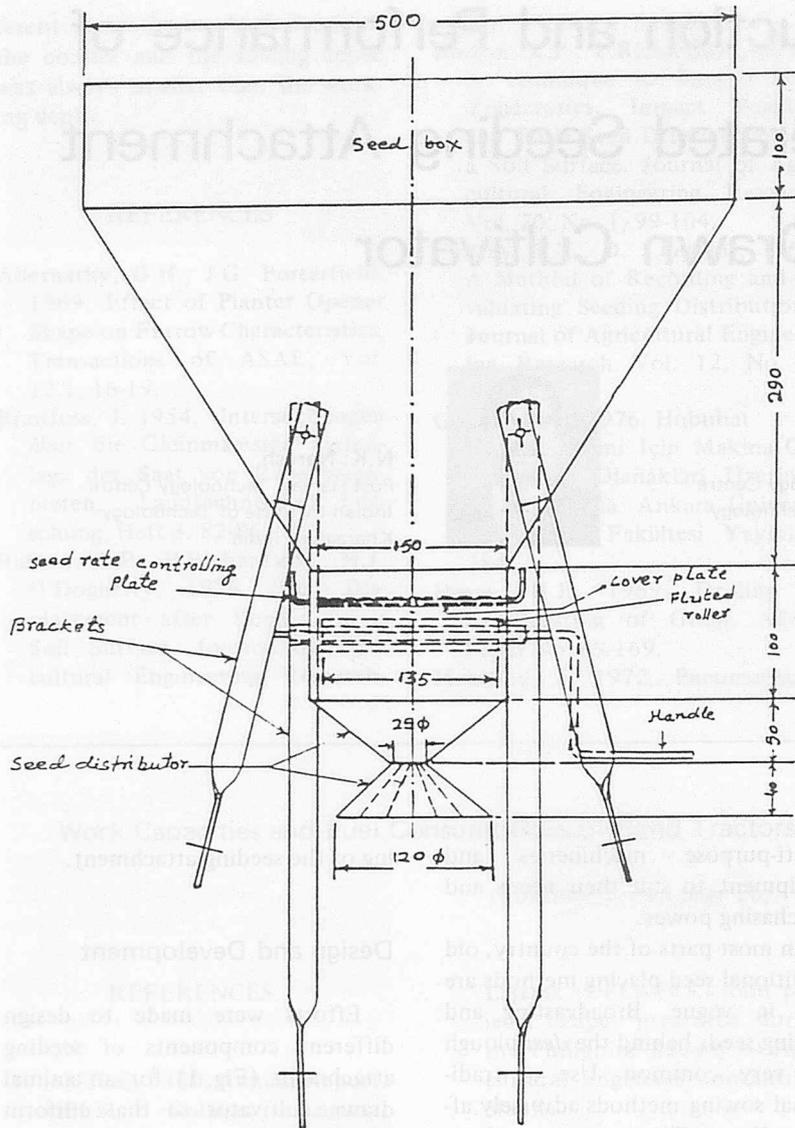


Fig. 1 Front view of seeding attachment.

3 km/h; iv) Bulk density of wheat  $800 \text{ kg/m}^3$ ; and v) Size of the five-tyne cultivator, 94 cm.

#### Basic Components

**Seed Box** —This was designed to contain 25 kg of wheat grain. The rectangular top portion of the seed box was  $50 \times 20 \times 10 \text{ cm}$ . The trapezoidal shape bottom portion of the seed box was  $15 \times 7.5 \text{ cm}$  (L x B), respectively. The entire seed box was made of 16 gauge M.S. sheet (Fig. 1).

**Seed Metering Device** —A simple and inexpensive fluted roller type seed metering device was used.

The roller size was  $13.5 \text{ cm} \times 5 \text{ cm}$  (L x Diam.) (Figs. 1 and 4). The roller had 10 grooves on its surface. It was made of 22 gage M.S. sheet. The roller was mounted over a 12.5 mm diameter shaft and rested over two bushes.

**Handle** —A wooden handle  $2 \text{ cm} \times 11 \text{ cm}$  (Diam x L) was attached to the roller shaft. The handle was used to rotate the fluted roller (Figs. 1 and 4)

**Cover Plate** —A semi-circular cover plate of 18 gage M.S. sheet was placed over the roller. At the centre of the cover plate a slit  $1 \text{ cm} \times 12.5 \text{ cm}$  (W x L) was pro-

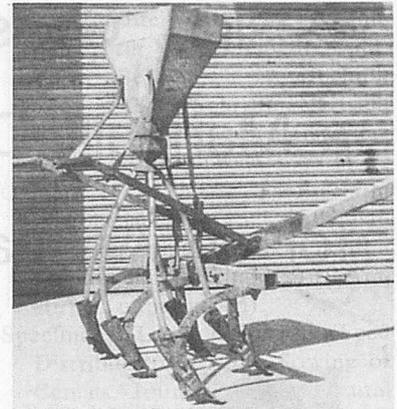


Fig. 2 Animal-drawn cultivator with seeding attachment.



Fig. 3 Testing of manually-operated seeding attachment.

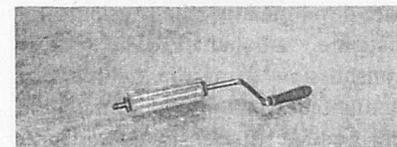


Fig. 4 Fluted feed-roller with handle.

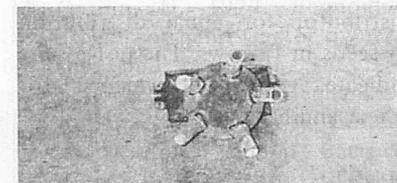


Fig. 5 Seed distributor assembly showing seed tubes.

vided for easy feeding of seed on the roller (Fig. 1).

**Seed Rate controlling plate** — Two plates of 16 gauge M.S. sheet were provided over the cover plate from both sides for varying the length of the slit. These

plates were kept adjustable in order to vary the opening exposed to the roller (Fig. 1).

**Seed Distributor** – A conical shape seed distributor was made of 16 gauge M.S. sheet consisting of two cones (Figs. 1 and 5). The upper cone, 12 cm in diameter, was fitted below the metering device. It has an opening of 2 cm diameter at centre. The lower cone, 5.5 cm in diameter, was placed below and was kept concentric with the upper one. The annular space between the cones was divided into five channels to match with the five furrow openers.

**Seed tube** – The seed tubes were made of polythene, 70 cm in length and 2 cm in diameter. Each seed tube was attached to the seed distributor at one end and the other end was attached to the boot at the cultivator (Figs. 2 and 5).

**Brackets** – Mild steel strips were provided to attach the seed metering unit. Two strips were in front and two strips were attached in the back (Figs. 1, 2 and 3)

## Operation

From the seed box, the seed was fed to the roller through a slit of the semi-circular cover plate. The controlled quantity of seeds was allowed to fall on the fluted roller by the seed rate controlling plate. The seed was metered by the fluted roller which was operated manually with the help of a handle. The seeds so metered were allowed to fall over the apex of a cone-shaped distributor which distributed the seed equally into five furrow openers. The fluted roller was operated at a fixed rpm and the seed rate was varied by changing the length of the roller exposed to seed. For this, two sliding plates were provided which could be fixed in any position to give a particular seed rate.

## Design Calculations

The fluted feed roller was designed to give a maximum seed rate of 150 kg/ha. The calculations were:

$$\text{Area covered in ha/h} = WS/1000$$

where, W = Total width covered by the seeding device = 94 cm

$$S = \text{linear speed} = 3 \text{ km/h}$$

$$\text{Area covered} = (94 \times 3)/1000 = 0.282 \text{ ha/h}$$

$$\text{Seed dropped/h} = 150 \times 0.282 = 42.30 \text{ kg}$$

$$\text{Seed dropped in one revolution of the roller} = 42.30/60^2$$

$$= 0.01175 \text{ kg}$$

$$= 12 \text{ g (approx.)}$$

Volume of the grooves on the roller

$$= 12 \times 10^6 / (800 \times 1000)$$

$$= 15 \text{ cm}^3$$

Ten grooves each of 1.5 cm<sup>3</sup> were provided. By trial and error method, the roller diameter was selected to be 4 cm and the grooves were kept 1 cm in diam. and 0.5 cm deep, semi-circular in cross section.

Volume of each groove

$$= \frac{\pi}{4} d^2 \times 12.5 \times \frac{1}{2} = 4.9 \text{ cm}^3$$

(since d = 1 cm)

Assuming 40% fill, the effective volume of each groove = (4.9 × 40)/100 = 1.96 cm<sup>3</sup>. Effective groove size is 1.5 cm<sup>3</sup> each, by considering 4 cm roller diameter at 40% fill, the theoretical size is 1.96 cm<sup>3</sup> which is safe design value.

## Testing Seeding Attachment

The seed box was fed with wheat grains. The polythene paper bags were tied with each seed tube (Fig. 3). The fluted roller was rotated at 60 rpm through the handle attached to it. The observations were taken at 15-min intervals for different exposed roller lengths. The seed collected from each tube was weighed and breakage percentage was computed. The test observations are shown in Table 1.

## Result and Discussions

The device was tested in the laboratory and the time vs cumulative seed drop and seed breakage graphs were plotted for different exposed roller lengths (Figs. 6 and 7). The distribution of seed in different furrows was quite uniform. Variation in seed distribution was observed only when the cultivator arm was kept too high or too low. It was also observed that the seed rate could be varied successfully by shifting the seed adjusting plate.

The seed drop (kg/ha) was observed as 149, 114, 76 and 36 at full, 3/4, half and 1/4 exposed roller lengths, respectively, with an average breakage percentage of 1.81 (Figs. 6 and 7). The breakage of seed was due to small clearance between the cover plate and the fluted roller.

The cost of seeding attachment was estimated at Rs.82. The reduction in cost was mainly due to the omission of conventional power transmission mechanism for metering the seed. The cost could be further reduced to Rs. 55 by replacing the metallic seed box with a wooden one.

## Conclusion and Suggestions

The manually-operated seeding attachment for an animal drawn cultivator can be successfully used by farmers who have bullock-drawn cultivators. The device can be used for sowing seeds more accurately as compared to traditional sowing methods. Though it is designed for wheat, barley can also be sown with the same accuracy. It is easily adoptable to farmers due to its low cost.

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Table 1 Seed Collected in Different Seed Tubes at Different Roller Lengths.

Roller length exposed to seed	Time min	Weight of seed collected in kg in seed tube number...					Total wt. of seed collected kg	Seed breakage %
		1	2	3	4	5		
Full roller length exposed to seed	15	2.10	2.20	2.05	2.30	2.25	10.9	1.7
	30	4.15	4.21	4.20	4.25	4.10	20.91	1.9
	45	6.30	6.35	6.25	6.30	6.30	31.4	1.9
	60	8.15	8.28	8.25	8.30	8.25	41.5	1.95
	75	10.40	10.45	10.50	10.45	10.35	52.5	1.77
90	12.50	12.55	12.60	12.55	12.65	62.85	1.8	
3/4 roller length exposed to seed	15	1.60	1.65	1.59	1.63	1.65	8.12	1.85
	30	3.22	3.20	3.25	3.15	3.20	16.02	1.78
	45	4.75	4.80	4.85	4.80	4.87	24.07	1.81
	60	6.45	6.40	6.50	6.55	6.50	32.40	1.8
	75	8.05	8.00	7.95	7.97	8.07	40.08	1.81
90	9.65	9.60	9.63	9.58	9.65	48.08	1.81	
Half roller length exposed to seed	15	1.10	1.12	1.07	1.08	1.11	5.48	1.82
	30	2.16	2.14	2.17	2.15	2.20	10.82	1.80
	45	3.25	3.24	3.20	3.30	3.22	16.21	1.78
	60	4.31	4.30	4.32	4.29	4.31	21.53	1.85
	75	5.38	5.35	5.42	5.40	5.36	26.91	1.83
90	6.46	6.45	6.46	6.50	6.43	32.30	1.81	
1/4 roller length exposed to seed	15	0.58	0.56	0.57	0.52	0.55	2.78	1.80
	30	1.00	1.02	1.04	1.03	0.98	5.07	1.78
	45	1.52	1.50	1.54	1.48	1.55	7.59	1.84
	60	2.00	2.03	2.05	2.04	2.00	10.12	1.78
	75	2.50	2.55	2.58	2.49	2.53	12.65	1.82
90	3.00	3.05	3.20	2.88	3.05	15.18	1.80	

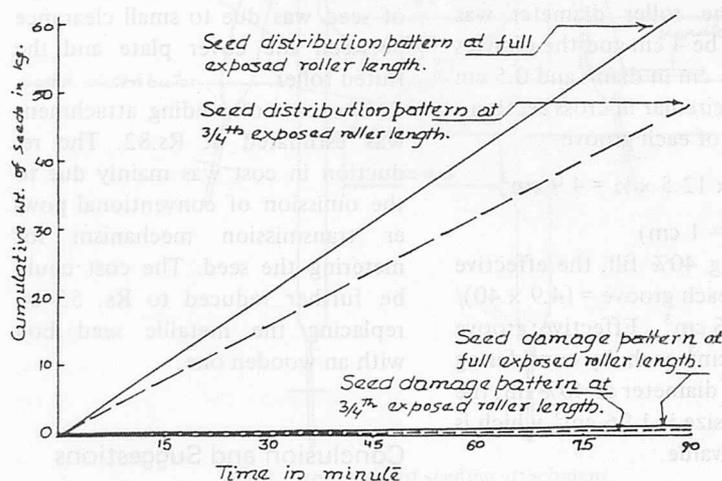


Fig. 6 Seed distribution and seed damage pattern.

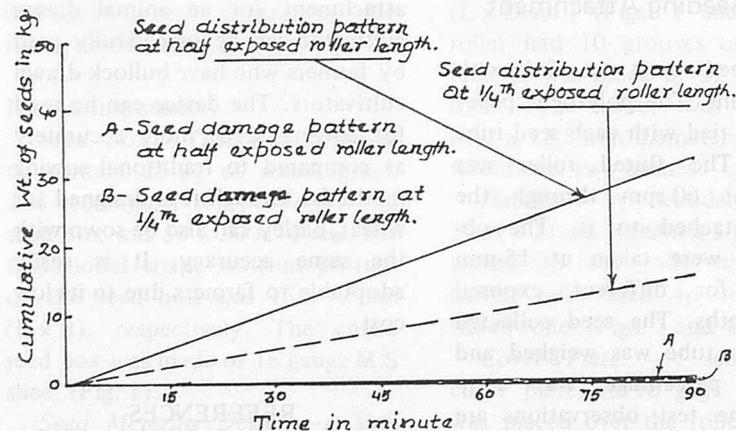


Fig. 7 Seed distribution and seed damage pattern.

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# Some Fundamentals of Electrostatic Spraying



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## Abstract

Present crop spraying practices often fail to meet the requirements of developing countries both in terms of cost and speed of application.

The introduction of electrically-charged sprays can provide greater control of droplet transport to increase deposition and reduce downwind drift reducing wastage of chemical ingredients.

Portable sprayers used for plant protection can be modified by installing electrostatic charging method with relatively small technical and financial input in order to achieve a more appropriate application technique which cuts down the demand of total pesticide requirement.

The electrostatic charging methods and the factors that effect the mass deposition are described for possible applications in the developing countries.

## Introduction

In most of the developing countries, farmers use imported hand- and shoulder-carried sprayers for plant protection and domestic purposes. But the spray recovery of these sprayers is very poor. Only about 20% of pesticide spray re-

aches the targets. An electrostatic system could raise this percentage to 80% or more (1), reducing pesticide consumption. This would mean tremendous savings to farmers in developing countries.

The presently used hand-and shoulder-carried sprayers could be easily converted into the electrostatic model.

Proper techniques for plant protection have not yet reached a stage of development where a satisfactory quality of work can give guarantee under all operating conditions. Some work, of course, has been done in application techniques but these are not sufficient to meet the increasing demand for an economical, biologically effective technique to preserve the earth's atmosphere and water bodies.

The electrostatic charging of droplets produces electrical forces which act between the individual droplets, lead to an improved deposition of the droplets on the targets' surfaces and moreover to the reduction of drifts (1,2,3).

Investigation into electrostatic charging of droplets for chemical plant protections, which were carried out in a special research project at the Institute of Agricultural Engineering, University of Hohenheim, West Germany is the subject of this paper.

## Electrostatic Charging Systems

There are three electrostatic charging systems which can be successfully used for the production of charged droplets in plant protection machineries (1,4,5,6): corona, contact and induction methods.

### Corona Charging Method

The schematic diagram of the working principle of the corona charging method is shown in Fig. 1a. In this method, the electrode at its sharp edge is raised to high voltage and discharge occurs from this sharp edge and has maximum field strength in the zone of the electrode. In this electric field, a large number of positive and negative ions are produced. Ions with an opposite sign to that of the electrode are immediately attracted to it and neutralized. Ions with similar potential are repelled by the electrode and ionize zone around it by imparting single polarity. After intensive bombardment, liquid droplets are charged with the same polarity as the electrodes (7). Corona charging is possible with both pressure and rotary atomizer and the number of electrodes may be 1 to 4 or more. This method, frequently used in the painting industry, at present is being adopted in the area of agri-

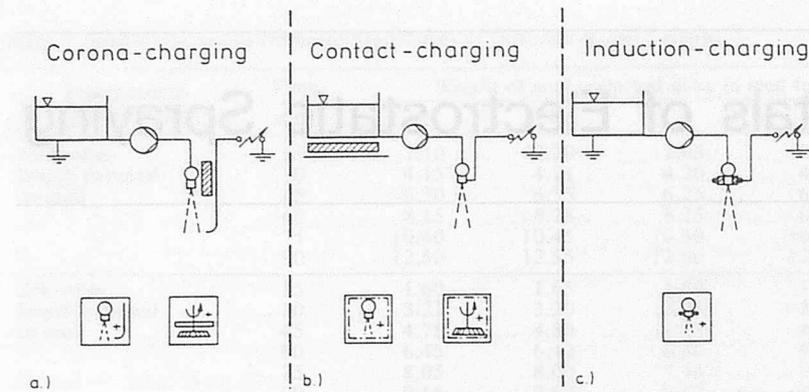


Fig. 1 Electrostatic charging systems.

cultural pesticide spraying (5,8). By using this method, it is possible to charge spray-liquids having a wide range of electrical conductivities and dielectric constants.

The corona charging method creates no health hazard problem. The total amount of current in the spray-liquid is very low. This system requires not so much high technology in construction, and the overall cost is low.

For the safety of operation, the sprayer should be grounded during operation and insulation should be provided between the gap of the sprayer and the high voltage generator to avoid shock.

#### Contact Charging Method

Fig. 1b shows the working principle of the sprayer. Contact charging occurs when high potential is directly connected and maintained to the nozzle or to the liquid flow system. When employing the contact charging method, charge transfer occurs by conduction to the spray-liquid and finally to the generated spray-droplets during disintegration. This system works well for conductive-liquids. The total system needs very good insulation and that is why there are limitations as to its use because personal hazards are involved. This system may be used in some hand-held sprayers with disc-rotary atomizers.

#### Induction Charging Method

Fig. 1c illustrates the working

principle of the sprayer. Electric field force is used to charge the spray droplets. This system needs insulation between the conductive liquids and the charging electrodes. This can be achieved by supplying high velocity air-streams. The induction charging method will work within the resistivity limit  $10^{-2}$  to  $10^6$  ohm-m.

#### Physics of Droplet Charging

In the case of corona charging, the charge attained on a spherical droplet can be computed from the following equation:

$$q_d = f \left( \frac{3 \cdot \epsilon_r}{\epsilon_r + 2} \right) 4 \cdot \pi \cdot \epsilon_0 \cdot E \cdot r_d^2 \quad (1)$$

Where,

- $q_d$  droplet charge
- $f$  dimensionless, depends on time and ion mobility
- $\epsilon_r$  dielectric constant of spray-liquid,  $\epsilon_r = 80$  for water
- $\epsilon_0$  permittivity of air,  $8.86 \times 10^{-12}$  C/V-m
- $r_d$  droplet radius, m
- $E$  electric field strength, V/m

The value of  $f$  varies from 0 to 1 and its value can be computed from the following empirical formula (7). If the ion mobility is faster,  $f$  becomes greater and the droplet acquires higher amount of charge.

$$f = 1 - \frac{1}{1 + (\varphi_E \cdot U \cdot t) / 4 \cdot \epsilon_0} \quad (2)$$

where,

- $\varphi_E$  space charge density,  $q_d/m^3$
- $u$  ion mobility,  $2.1 \text{ cm}^2/V \cdot s$

$t$  charging time, sec

When using contact charging, the charge attained by a spray droplet depends on the electrical capacity of a spray-droplet and the voltage strength and can be computed from the following equation:

$$q_d = C \cdot U_E \quad (3)$$

where,

$C$  electrical capacity of a spray droplet,  $q_d/V$

$U_E$  electrostatic potential, V

When using induction charging, the ultimate charging of the spray droplet depends on the electrical conductivity of the spray liquid.

#### Electrostatic Force on a Spray Droplet

In an ionizing field, a spherical droplet acquires charge and simultaneously it exerts a force on the charged droplet and the force is given by:

$$F_E = q_d \cdot E \quad (4)$$

When a droplet is released from a spray-nozzle, it experiences some forces, such as gravitational force, electrostatic force, drag force and buoyancy force. The forces acting on droplets of different diameters are shown in Fig. 2.

#### Maximum Droplet Charging

In 1879, Rayleigh established an equation for maximum charge attained by a spherical droplet. The Rayleigh limit for droplet charging (10) is as follows:

$$q_d \text{ max} = 8 \cdot \pi \cdot (\epsilon_0 \cdot \sigma)^{1/2} r_d^{3/2} \quad (5)$$

where,

- $q_d \text{ max}$  maximum charge attained by a droplet
- $\sigma$  surface tension of spray-liquid, mN/m

When any droplet attains a charge more than the  $q_{d \text{ max}}$ , the surface rupture of the droplet takes place due to hydrodynamic instability. The droplet charge mainly depends on the surface tension of particular liquid and the size of the droplet. If the surface tension increases, the overall charge on the droplet in-

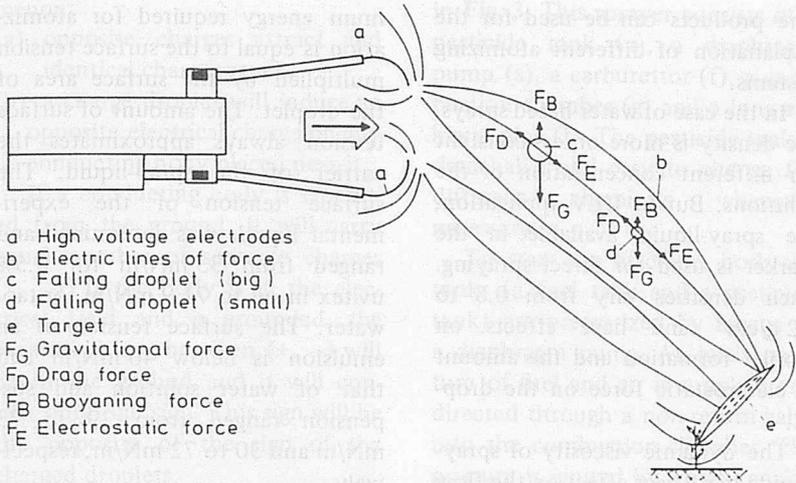


Fig. 2 Forces acting on spray droplets.

increases also. The disintegration of a spray-liquid at the nozzle depends mainly on the surface tension of the spray-liquid and the constructional design of the atomizer.

### Terminal Velocity of Charged and Uncharged Spray-Droplets

The theoretical terminal velocity of a droplet can be computed by equating electrostatic force and drag force or by equating weight and drag force on a spray-droplet. The terminal velocity for charged droplet can be computed from the following equation:

$$V_{tc} = \frac{2r_d[\vartheta(\epsilon_0 \cdot E^4) + (r_d^2 \cdot \rho_l^2 \cdot g^2)]^{1/2}}{\vartheta \eta a} \dots \dots \dots (6)$$

where,

- $V_{tc}$  terminal velocity of charged droplet, m/s
- $g$  acceleration due to gravity,  $m/s^2$
- $\rho_l$  density of spray-liquid,  $10^3 \text{ kg}/m^3$  for water
- $\eta a$  air-viscosity,  $18.27 \text{ N}\cdot\text{s}/m^2$  at  $20^\circ\text{C}$

The terminal velocity of an uncharged spray-droplet can be obtained from:

$$V_{tu} = 2/9 (r_d \cdot \rho_l \cdot g) / \eta a \dots \dots (7)$$

where,

- $V_{tu}$  terminal velocity of uncharged droplet, m/s

The electro-mechanical forces

and the terminal velocities of water droplets of varying sizes are computed. The average intensity of the charging voltage was considered  $10^5 \text{ V}/m$ .

Table 1 shows that the ratio of terminal velocities of charged and non-charged water droplets is higher for a small droplet than for the big droplets. The ratio decreases by increasing the diameter of droplets. The terminal velocity due to the electrostatic force is prominent up to less than  $200 \mu m$ ; above that the terminal velocity due to the gravitational force is always prominent. Normally, all ULV sprayers give VMD less than  $50 \mu m$ . In that case, the terminal velocity due to the electrostatic force can effectively be utilized for better deposition.

### Effect of Relative Humidity on Electrostatic Deposition

In electrostatic spraying, the relative humidity has great influence

upon deposition. Bowen et al found a decrease in deposition of charged dust with increase in relative humidity (11). The time constant for droplet charging lags behind as relative humidity increases. Moser et al found that with constant air-temperature and varying relative humidity (using traditional method of spraying), the deposition on a certain target is almost constant (5). On the other hand, a distinct influence of relative humidity appears with the electrostatic charging systems. When the relative humidity changed from 10 to 96%, the corresponding weight of deposition was reduced by a factor of approximately 2 (5). With high relative humidity value (about 95%) a doubling of the weight of deposition can still be expected compared to the traditional method of spraying.

### Effect of Electrical Conductivities and Dielectric Constants of Spray-Liquids on Electrostatic Deposition

The electrical conductivity decides what system of electrostatic charging method has to be used, the method that may be appropriate for the charging of spray-liquids: contact and induction charging systems are not at all possible for use when spray-liquids have very low electrical conductivities. When very good conductive liquids are used, the aforesaid systems need very good insulation of the whole spraying system. It is problematic to insulate the whole spraying unit for economic reasons. The corona charging system can be used for a

Table 1 Electro-mechanical Forces and Terminal Velocities of Water Droplets of Varying Sizes.

Droplet size ( $\mu m$ )	El. force $F_E$ (nN)	Gravity force $F_G$ (nN)	Terminal Vel. $V_{te}$ (m/s)	Terminal Vel. $V_{tu}$ (m/s)	Vel. Ratio ( $V_{te}/V_{tu}$ )
10	0.163	0.0051	0.01626	0.0029	5.5
50	4.07	0.64	0.10983	0.0745	1.47
100	16.3	5.1	0.33945	0.2983	1.13
200	65.1	41.1	1.23618	1.193	1.03
500	98.3	104.0	2.7733	2.683	1.03

wide range of electrical conductivities.

Laboratory studies show that the charge attained per litre of water-sprays depends on the electrical conductivities and the amount of charging voltages. When using contact charging, water-based sprays acquired a maximum droplet charge. The contact and the induction charging systems are not effective and cannot be used at all when the electrical conductivity is less than  $10^{-4}$  mS/m.

The dielectric constant of spray-liquids is very important for corona and induction charging of spray-liquids. The charge attained by a droplet can be computed by using the equation (1). The charge on a droplet depends on the dielectric constant of the spray-liquids. With a high dielectric constant, the droplet may acquire a high amount of electrical charge.

Laboratory studies show that the spray-liquids having dielectric constant above 40 may acquire a charge more than 90% of the maximum possible droplet-charge. Droplets from an ULV chemical preparation have dielectric constants that range from 2 to 10 may attain 50 to 80% of the maximum possible charge.

#### Effect of Mechanical Properties of Spray Liquids on Electrostatic Deposition

The mechanical properties of spray liquids are density, dynamic viscosity and surface tension. These three properties have direct or indirect effect on the formation of droplets on transportation and on the biological effectiveness.

These properties can be related to a functional form as follows:

$$d_d = f(\rho_l, \eta_l, \sigma) \dots \dots \dots (8)$$

where,

$d_d$  droplet diameter, m

$\rho_l$  density of liquid, kg/m<sup>3</sup>

$\eta_l$  viscosity of liquid, N.s/m<sup>2</sup>

The equation can be solved in terms of dimensionless products.

The products can be used for the explanation of different atomizing systems.

In the case of water-based sprays, the density is more or less constant for different concentration of the solutions. But in ULV application, the spray-liquid available in the market is used for direct spraying. Their densities vary from 0.8 to 1.2 g/cm<sup>3</sup> and have effects on droplet formation and the amount of electrostatic force on the droplet.

The dynamic viscosity of spray-liquids has direct effect on the flow of the spray-liquid through the nozzle. The formation of droplets and the deposition onto the target-objects are influenced by dynamic viscosity. Increasing dynamic viscosity delays atomization and increases the size of droplets.

Laboratory studies show that the dynamic viscosity of oil-based solution varies from 14 to 58 mPas and sometimes exceeds this range. Oil-based spray-liquids are used with small hand-held sprayers. In practice, it is difficult to handle the oil-based spray-liquids due to their high dynamic viscosity. In small hand-sprayers, the gravity pressure is used for the flowing of liquids through the nozzle (without rendering any external pressure). The dynamic viscosity of the spray-liquid itself plays an important role as to the amount of discharge through the nozzle. This happens also in the case of electrodynamic atomization. For good spraying with small sprayers, the dynamic viscosity of spray-liquid should be adjusted to an appropriate range. This requires more research work.

#### Surface Tension

The surface tension of spray-liquids has great influence on the formation of droplets, on the capacity for wetting on the target's surface (12) and on the maximum possible electrical charge that the droplet can accumulate. The mini-

imum energy required for atomization is equal to the surface tension multiplied by the surface area of the droplet. The amount of surface tension always approximates the carrier of the spray-liquid. The surface tension of the experimental liquids was determined and ranged from 33 mN/m for 0.5% uvitex in oil to 71.9 mN/m for tap-water. The surface tension of an emulsion is below 40 mN/m and that of water solution and suspension ranged from 29 to 73 mN/m and 30 to 72 mN/m, respectively.

The surface tension of tap-water changes with the amount of voltages applied. At 10 kV, the surface tension of tap-water amounted to 55 mN/m.

The surface tension limits the electrostatic charge on a droplet (Rayleigh limit). The charge attained on a droplet by using the corona charging method was less than the Rayleigh limit. By using the contact charging method, it was possible to break the limit. It helped to form a narrow droplet spectrum and to form small droplets.

As a result, the deposition was high by using the electrostatic charging method as compared to the traditional method of spraying. In electrodynamic atomization, droplets are formed by electrostatic force. The formation of droplets is highly influenced by the surface tension of the spray-liquids as well as the constructional design of the atomizer.

#### Physics of Electrostatic Charged Droplets' Deposition

The attraction phenomenon of a charged body with non-charged bodies has been described in many text books on physics. This attraction phenomenon can be used to explain the adhesion of charged droplets with the target-object. The following two laws of electrostatic explain this depositional pheno-

menon:

- (a) opposite charges attract and identical charges repel.
- (b) a charge droplet will induce an opposite electrical charge on any conducting body placed near it.

If a conducting body is separated from the ground, it will carry equal number of separate charges (+, -). If the body is in the electrical field and is grounded, the separating line between (+, -) will be in the ground and it will contain only one sign. This sign will be the opposite of the sign of the charged droplets.

The phenomenon of electrostatic deposition occurs in the following manner: The charged droplet near the target will repel the identical charge and attract the opposite charge existing on the target. This process is called electrostatic deposition.

Because of the nature of curves of the electric lines of forces, it is possible to place the spray droplets on all sides of the targets just by spraying from one side.

### Sources of Power for Electrostatic Spraying

For aircraft, tractor drawn or engine operated knapsack sprayer, a small DC generator may be mounted with the sprayer or a 12 volt battery may be employed. Dry cells may be used for hand-carried or air-compressed knapsack sprayer. Alternatively, solar cell can be used as an electric power source for electrostatic spraying. Normally, solar cells are used to charge the batteries. Afterwards, the batteries are used in the field work. For the moment, the prices of solar cells are very high. This is the only drawback for using solar cells.

### Functions of an Electrostatic Sprayer

The functions and details of a fogging machine's head using the corona charging method are shown

in Fig. 3. This sprayer consists of a pesticide tank (a), a diaphragm pump (s), a carburettor (f), a combustion chamber (g) and a long exhaust pipe (i). The pesticide tank is detachable and easy to change for different chemicals whenever necessary.

To start the machine, both the tanks (a fuel tank and a pesticide tank) are pressurized by means of a diaphragm pump. An initial mixture of fuel and air is supplied and directed through a non-return valve into the combustion chamber. The mixture is ignited by a high-tension spark obtained from a battery powered vibrator. Once the machine has started, the high tension

spark is no longer required and can be stopped. The exhaust gases from the combustion chamber escape at a higher velocity through the long exhaust pipe (i) of smaller diameter than the combustion chamber. Simultaneously, the system draws a fresh charge (a mixture of fuel and air) through the non-return valve and the cycle continues. By means of a check valve (o), the pressure is maintained in the pesticide tank.

When the machine is being warmed up, the two-way valve (b) is opened to permit the flow of the pesticide solution into the end of the exhaust pipe (d). Fog (m) leaves through the outlet port (l) and simultaneously acquires charge

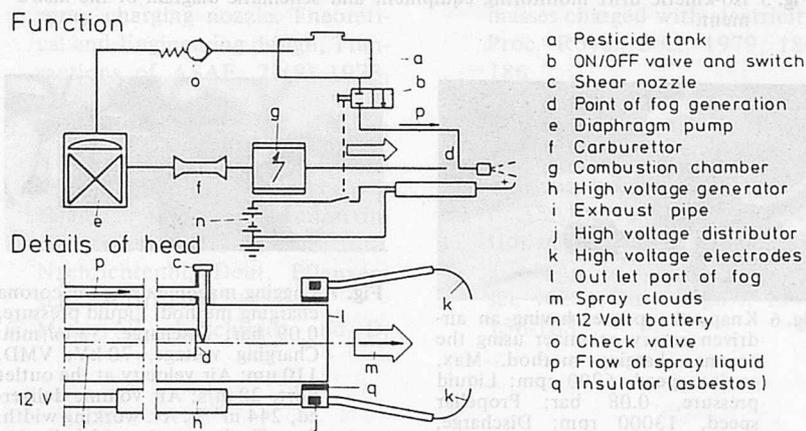


Fig. 3 Functions and details of the sprayer's head using the corona charging method.

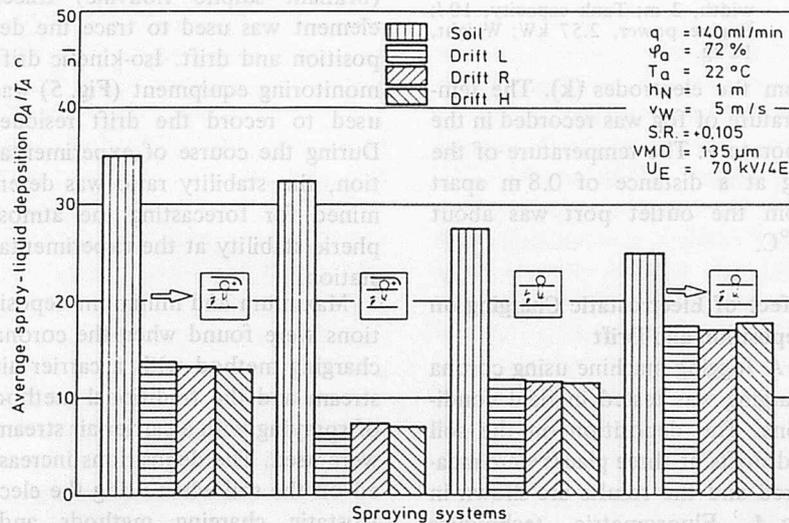


Fig. 4 Average deposition on the soil and drifts at different distances using a fogging machine.

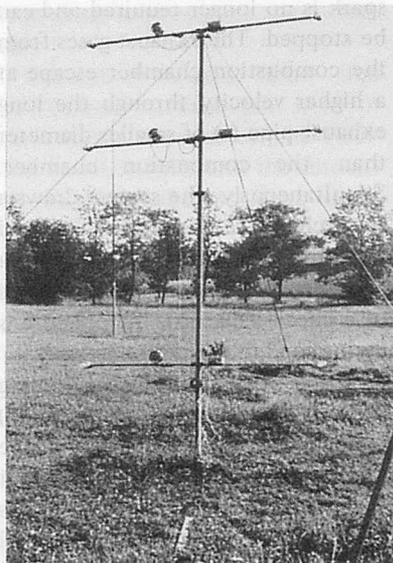
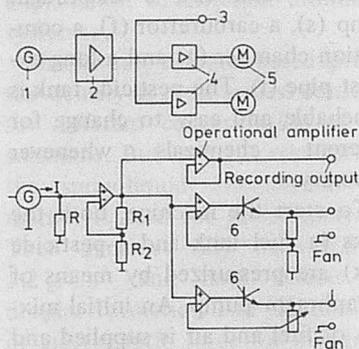


Fig. 5 Iso-kinetic drift monitoring equipment and schematic diagram of the instrument.



Instrumentation system

1 Vane type anemometer	4 Power amplifier
2 Amplifier	5 Fan
3 Recording output	6 Transistor

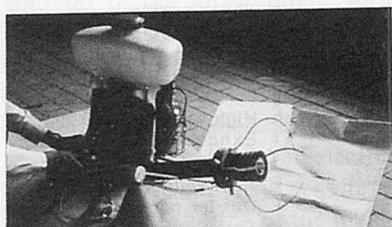


Fig. 6 Knapsack sprayer having an air-driven rotary atomizer using the corona charging method. Max. engine speed, 6200 rpm; Liquid pressure, 0.08 bar; Propeller speed, 13000 rpm; Discharge, 120 ml/min; Charging Voltage, 70 kV; VMD, 78  $\mu$ m; Air velocity at the nozzle, 50 m/s; Air volume delivered, 353 m<sup>3</sup>/h; Av. working width, 2 m; Tank capacity, 10 l; Engine power, 2.57 kW; Weight, 12 kg.

from the electrodes (k). The temperature of fog was recorded in the laboratory. The temperature of the fog at a distance of 0.8 m apart from the outlet port was about 20°C.

#### Effect of Electrostatic Charging on Deposition and Drift

A fogging machine using corona charging was tested in field conditions. The deposition on the soil and drifts at three places were measured and the results are shown in Fig. 4. Fluorometric techniques were used to quantify the deposition and drift residue. 0.2% BSF

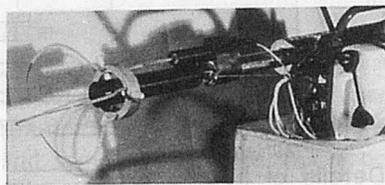


Fig. 7 Fogging machine using the corona charging method. Liquid pressure, 0.09 bar; Discharge, 53 ml/min; Charging voltage, 70 kV; VMD, 110  $\mu$ m; Air velocity at the outlet port, 28 m/s; Air volume delivered, 244 m<sup>3</sup>/h; Av. working width, 2 m; Tank capacity, 10 l; Engine power, 1.5 kW; Weight, 8 kg.

(brilliant sulpho flouvine) tracer element was used to trace the deposition and drift. Iso-kinetic drift monitoring equipment (Fig. 5) was used to record the drift residue. During the course of experimentation, the stability ratio was determined for forecasting the atmospheric stability at the experimental station.

Maximum and minimum depositions were found when the corona charging method with a carrier air stream and the traditional method of spraying with a carrier air stream were used. The depositions increased on the soil when using the electrostatic charging methods and, thereby, the total drift to the adjoining areas were reduced to a



Fig. 8 Knapsack sprayer having a pneumatic nozzle using the corona charging method. Engine speed, 5500 rpm; Liquid pressure, 0.07 bar; Discharge, 46 ml/min; Charging voltage, 70 kV; VMD, 50  $\mu$ m; Air velocity, 210 m/s; Air volume, 35 m<sup>3</sup>/h; Av. working width, 2 m; Tank capacity, 4 l; Engine power, 1.4 kW; Weight, 10 kg.

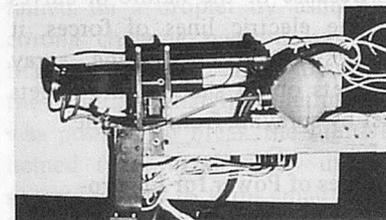


Fig. 9 Disc-rotary sprayer using the contact charging method. Motor speed, 9900 rpm; Liquid pressure, gravity; Discharge, 61 ml/min; Charging voltage, 35 kV; VMD, 75  $\mu$ m; Av. working width, 2 m; Tank capacity, 2 l; Motor power, 0.12 kW; Weight, 4 kg; Disc diam., 3.5 cm.

great extent. By using the traditional method with a carrier air stream, the deposition on the soil was lower than the drift recorded. When using the traditional method of spraying, the drift was about 2.5 times higher than that of the drift recorded by the corona charging method under experimental conditions.

#### Conclusions

- (i) The electrostatic charging units can be successfully used with the existing sprayers.

- (ii) The spray-liquids should be good conductive to electric current.
- (iii) The droplets should be very small ranging from 10 to 50  $\mu\text{m}$  for better deposition.
- (iv) The contact charging method is more efficient than the corona or the induction charging method.
- (v) At the time of field work with electrostatic sprayer, the operator as well as the sprayer should be grounded properly. This can be achieved using an iron chain with the operator's leg.
- (vi) There will not be any health hazard during field operation because of micro-ampere in the high voltage circuit.
- (vii) Requirement of pesticide will be less due to ULV application.
- (viii) Electrostatic sprayer is economically suitable for farmers in the developing countries.

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# Irrigated Agriculture:

## Making the Most of Available Resources

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### Abstract

It is argued that irrigation, supplemental or total, is an effective means of involving human and natural resources in an important process to produce wealth for the human beings themselves. It is conceded that irrigation being a form of mechanization may, under given circumstances, create problems of unemployment and attendant social ills. It is then shown that those circumstances do not presently exist in the Nigerian context and fears on those grounds are not justified.

### Introduction

This paper springs from a profound belief that many people are worried about mechanization — worried because they lack faith in its promise of improved productivity, worried about its unemployment-creating possibilities, and above all, worried because they know that they do not completely understand the very thing they are

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worried about.

Much of this worry is unnecessary. It stems not from a genuine problem of mechanization but from a lack of understanding that disproportionately magnifies foreign situations and thus they become worrisome. This paper uses irrigation which is indispensable for Nigeria agriculture, to demonstrate the benefits of mechanization, to show that mechanization can become catalytic in the interaction between human and natural resources to produce rewarding results, and to dispel the fear of mechanization by outlining the conditions under which mechanization may become a threat to human beings who engineer it, and showing finally that these conditions do not presently exist in Nigeria's situation.

### Mechanization and Wealth Creation

First, we shall define national wealth as comprising natural resources such as land and water, and human resources; that is, man with all his knowledge, skills, etc. There is still another important dimension to wealth — all the man-made products such as rail lines, machinery, dams, irrigation systems, crops growing in the fields, etc, which man has wrested from the earth. These together with the

natural resources are man's assets. There is constantly an important process between the assets and their human possessors to produce new wealth. This process is important because the assets by themselves are silent and sterile, the human beings by themselves weak and ineffective, but a proper blend of the two resembles a chemical reaction in which an inert substance and a weak reagent combine to deliver an explosive result (Heilbroner and Bernstein 1963). How to achieve this "proper blend" is the question in which we are ultimately interested. It is here that professionals disagree. The disagreement arises because some scientists like to argue that man introduces a "foreign" self-defeating element — mechanization — into the process. They argue that mechanization invariably excludes some men from participation in this process that engages their time and skills. This process we shall designate as employment and those excluded from participation are the unemployed.

Those who argue that mechanization may create unemployment and attendant social ills may have a case. But that is something quite different from arguing that mechanization is bad and that we are better off without it.

There are other scientists who argue that mechanization is the shortest route to development and

increased wealth. They argue that if we are to achieve economic independence and self-sufficiency in food, only mechanization can provide the necessary leverage.

There is an element of perplexity here. On the one hand, we are told by men of great reputation that if we are to attain a high standard of living, we must mechanize our production machinery. At the same time others of no less renown tell us that mechanization is a monster that eventually turns on its creator. Definitely no one can accuse any of the two groups of willfully seeking the ruination of this country. It is, therefore, very hard for the interested observer — who is most of the population — to know what to think. This paper discusses the situation in simple and vivid terms in the hope of making it more comprehensive, and permitting wider participation in the discussion by those interested observers.

All, including the scientists with differing points of view, should agree that unemployment is undesirable. For the unemployed it is an angering, humiliating, and frightening experience. The unemployed are liable to react to this humiliation in an unpredictable manner, including threats and violence to the lives and property of the rest of society. It is obviously in the interest of all persons that all the men and all the assets be involved in the important process that produces more wealth\*. The important question is whether mechanization works to bring about this balance or to upset it. This writer uses mechanization in agriculture, with irrigation providing specific illustration, to show that mechanization is sorely needed in

\*It is literally impossible to involve all the men and all the assets in the process at any one time. The statement should be understood to mean that unemployment should be kept as low as possible while as much of the assets as possible should be engaged in the production of new wealth.

Nigeria today for effective utilization of all resources to produce new wealth.

This will be done by demonstrating the benefits of mechanization; by examining how and when mechanization can upset the interaction between man and his asset and showing that the conditions do not exist in Nigeria today.

### On-the-Field Observation

In the summer (dry season) of 1978, the writer was part of ABU Agricultural Engineering Department team that undertook an educational tour of an experimental irrigation project of a colleague. The project was at Kyauda village, near Hukuyi, approximately 26 km north of Samaru. In the village, several farmers were irrigating their crops using the "Shaduf" (jigo in Hausa), a simple device for lifting water using the principle of the lever. A bucket or calabash is suspended from one end of a long pole. With the aid of a counter weight at the opposite end of this pole and a fulcrum between the ends, water is lifted from a source such as a stream or a shallow well. The shaduf is generally used on the "fadama", a Hausa word for low-lying lands, often with a very high water table (Nwa 1980).

All the farms had similar characteristics — they were all small (less than 0.4 ha per farm family, Nwa 1980), and invariably narrow, following along the banks of a tiny creek from where the irrigation water was drawn. There was generally extensive farm area laying fallow upslope away from the creek. Asked why they were not farming more of the land, the farmers gave the predictable answer that they could not get water to the areas upslope and, furthermore, the small areas along the creek absorbed all the labour available to them, which comprised the farmer

and his family. The unusually high labour requirement is confirmed by Nwa (1980) who found that 150 man-h are required per ha to make one irrigation application.

An important observation must be made here. A combination of very low pumping head and high labour requirement severely limits the size of area that can be irrigated. The low pumping head also imposes the additional constraint that the area to be farmed must be near the water source.

Nwa (1980) found that by replacing the jigo with a small pump the same number of persons can farm considerably more land. The farmer would no longer be constrained to stay within the area next to the stream which may sometimes be water logged and unsuitable for growing crops.

### Interpretation of Observations

Some important facts come into sharp focus from the brief discussion with the farmers and the research findings of Nwa. First, the farmers were able to farm the narrow strips along the stream because they have the Shaduf — a crude but mechanical device for lifting water from the stream and unto the farm. Without mechanization this land would lie waste and the human beings idle. The wealth previously accumulated would be steadily depleted to sustain the idle human beings.

As Nwa (1980) has shown, productivity would increase, with reduced labour, if the Shaduf were replaced with a pump. The comparison is subtle but significant. It is important to retain the point that both the shaduf and the pump are mechanical devices and any differences between them are merely differences of degree rather than of kind. What we have here is a situation where production would be totally impossible without mechanization, and would steadily improve

as the level of mechanization improves.

Let us consider a slightly different problem. Duru (1980) has shown that soil moisture from natural rainfall in Samaru can sustain crop growth for about 4 months. If a particular crop has a growing period longer than 4 months artificial water application will be necessary to maintain soil moisture in the available range through that crop's growing period. Without the facilities for applying this supplemental irrigation water — without mechanization — the farmer would be constrained to growing only those crops whose water requirement characteristics match the water availability pattern. We would not be making maximum use of our resources.

The situations so far examined are where both human and natural resources languish idly or where all human resources can engage only an insignificant part of the natural resource to produce new wealth. This is the situation in developing countries. It is diametrically opposed to the situation in the technically advanced countries.

Suppose that the Shaduf farmers and others with comparable level of technology are capable of producing all the food the nation needs. To simplify the argument we shall exclude international sales of agricultural products from consideration. In this case it is very obvious that by making the production apparatus more mechanical, more self-regulating, — by automation — the human input required to produce the same amount of food dwindles. In other words, machines exclude some men from participation in the wealth producing process. Though somewhat an over-simplification, this is basically the situation in the countries with high level technology.

The mistake many people make is to confuse the situation where the pool of men can effectively

engage the natural resources to produce as much as the population can afford to buy with the fundamentally different situation where natural resources languish idly because all the available men can, for operational inefficiency, engage only a small portion of the natural resources for an output miserably inadequate for the population. Obviously the prescription in the latter case is to eliminate the obstacles that make it difficult to engage more of the available natural resources in the production process, to make the production machinery more efficient; in other words to mechanize the production apparatus. This would amount to making the most of our resources.

The former situation has a solution that is different. This solution is not directly relevant to our situation today and will not be discussed.

### Any Cause for Concern ?

Mechanization constitutes an outside invasion of the natural system. Predictably it carries with it some undesirable fallouts. The examples will make a long list but only a few drawn specifically from the field of irrigation will be cited for illustration. The point is to show that the more threatening ills of mechanization are not the same as those that worry us.

Aremu (1970) has shown that the infiltration rate of soils is drastically reduced by tractor ploughing. It would be preferable to disturb the soil minimally in keeping with the so-called minimum tillage theory.

It has earlier been argued that irrigation can lead to maximum utilization of resources and increased productivity. But irrigation does create its own problems, the most prevalent of which is water logging. Water logging occurs when the infiltration rate of the soil exceeds

the percolation rate so that more water enters the soil than is evacuated by drainage into the groundwater reservoir. Water logging may also result from the groundwater table being too close to the surface. The soil is water-logged when it retains moisture above the field capacity.

Salty groundwater, use of irrigation water of poor quality, and a lack of adequate drainage aggravate salt problems in irrigated lands. Excessive salts in the soil affect plants in various ways, with the ultimate effect being reduction in plant growth and productivity (Wesseling 1968, Nwa 1978, Singh and Maurya 1979).

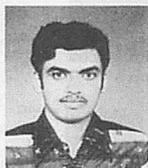
The solution to these problems is proper drainage. Depending on the source of the trouble the solution may be complicated and expensive. Thus, in an attempt to improve productivity through mechanization we are creating problems that could render the soil more barren than the initial state. But then these are not the problems we hear about.

### Summary and Conclusion

This paper has sought to use irrigated agriculture to show that mechanization, despite the apprehension it evokes from different people, is sorely needed in Nigerian agriculture to sustain the population. The problems associated with mechanized agriculture are real but if the choice turns out to be between mechanization with the attendant problems and a floundering subsistence agriculture, the former appears to be an infinitely wiser choice. History has shown mechanization, and automation particularly, to create social ills by displacing humans from positions of employment. However, the Nigerian situation today is such that the humans

*(Continued on page 54)*

# An Improved Cutting and Bunching Machine for Harvesting Grain Crops in Bangladesh



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## Abstract

A test rig is described which was designed to test a mechanism consisting of two rotary cutting discs with a view to optimising the design of a low-powered device to cut and bunch grain crops, suitable for manufacturing in Bangladesh and elsewhere.

A Silsoe College field simulator was used to test the machine on wheat. The pull and disc separating force was measured at the time of cut. The power requirement was calculated from the pull. The nature of cut was also recorded. An experimental technique was described and the results showed that the mechanism gives an effective performance with the discs overlapping by 10 mm or more.

A basic design for a field machine is proposed.

Further work is required to develop the proposed system which is suggested.

## Introduction

In Bangladesh, 80% of the population lives in rural areas and 95% of them are involved with agricultural production. The average farmer has 3 to 5 ha of cultivable land, suitable for grain crops. The average annual income of a typical farmer is very

low and variable. It varies according to the occurrence of annual natural hazards. From experience it has been observed that 3 to 10% of matured rice grain is lost at harvesting time because of over-maturity, diminished number of labourers obtainable at harvesting time, uncertain climate, such as hail storms, heavy rain, gusty winds, etc. This figure goes very often as high as 50%. The loss represents 30 to 40% of farmers' net profit.

The socio-economic and agro-climatic conditions of Bangladesh have prevented the adoption of western mowers and combines for harvesting grain crops.

For this reason the average farmer desires low-cost, low-powered man- or animal-powered devices which can perform at least 3 man-day work in harvesting grain crops.

## Operation of Proposed Harvester

The machine consists of one sharp and one serrated edged disc rotating in opposite directions for single row cutting. (Provision could be made to increase the capacity by adding more discs and adding the necessary power input). The discs were mounted on low-friction bearings. A safety mechanism was introduced to allow the discs to

move apart at 180N separating force, in case it hits some obstacles like stone or broken bricks in the field.

A simple low-powered mechanism was introduced to the proposed design of the field machine to bunch the harvested crops into desirable shape. A second man bundles to facilitate transport.

## Technical Concept

The proposed mechanism has been used on sugarcane and safflower and has a low power consumption, with good cutting efficiency (3,4). This principle was developed for use on the proposed crops. The design had theoretically none of the disadvantages of a reciprocating cutting mechanism. The relationship between the power requirement and the parameters of the machine, such as disc rotational speed and position were investigated.

When the power requirement was known, a suitable driving mechanism was specified, based on either man or animal power. The speed of the machine was within the range of 0.22 m/s to 0.89 m/s. The expected capacity of the machine was 0.048 ha/h.

## Design

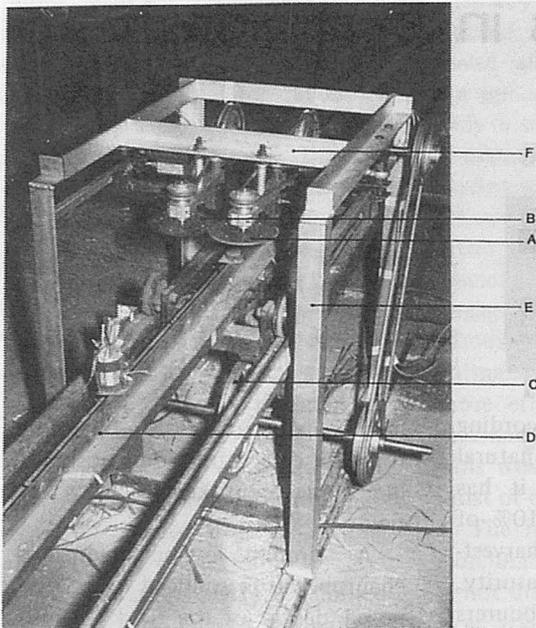


Fig. 1 Test rig. A—Serrated disc. B—Smooth disc. C—Ground wheel. D—Field simulator carriage. E—Vertical support. F—Cross stay angle.

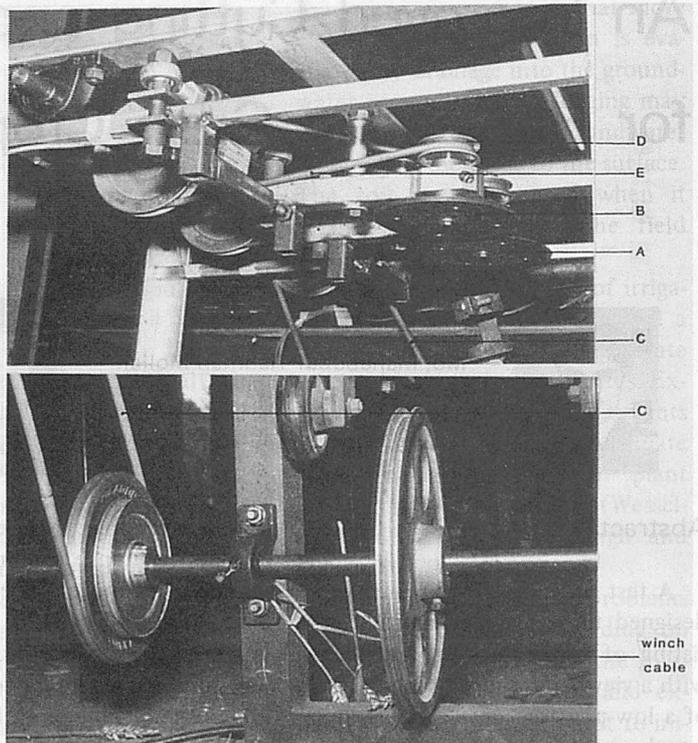


Fig. 2 Driving mechanism. A—Serrated disc. B—Smooth disc. C—Belt from ground wheel. D—Disc pulley. E—Disc driven by twisted belt.

### Test Rig

The design was primarily functional and generally dealt with only one machine element, the cutting mechanism, rather than the complete machine. The main objective was to test and develop the idea of using counter rotating discs as a cutting mechanism.

The rig was built using mainly 50 x 50 x 5 mm steel angle, with a frame measuring 800 x 650 x 884 mm high. Two 150 mm diameter x 3mm thick ground stock steel discs with one sharpened edge and one serrated edge were used for the cutting mechanism. The discs were powered by the winch cable used to pull the field simulator carriage (Fig. 2). The vertical rotation was transferred into horizontal disc rotation by means of cross belt (Figs. 1 and 2).

To enable adjustment of the disc overlap, the 50 x 50 x 5 mm steel angle disc holders were provided

with 45 x 12 mm slots. Provision was made to prevent the discs from swinging in the vertical plane and to pivot in horizontal plane at a particular separating force.

### Estimation of Disc Size

To estimate the critical size of the cutting disc, the following formula was used (Fig. 3a).

$$R = \frac{r \cos \phi}{1 - \cos \phi} \quad (1) \text{ (Hatibu, N(2))}$$

$$\tan \phi = \mu \quad (2)$$

where,

R = Radius of the cutting disc

r = Radius of the material to be cut

$\phi$  = Cutting angle

$\mu$  = Dynamic coefficient of friction

### Cutting Force

According to Sing (3) the cutting force (F) required to cut a single wheat stalk is 10.75 N at 45%

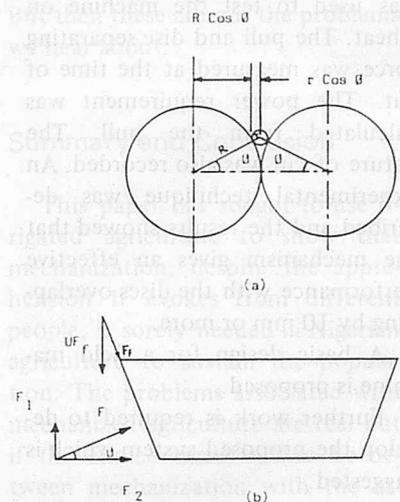


Fig. 3 Estimation of disc sizes.

stalk moisture content, or 107.5 N for 10 stalks. The expected pull  $F_1 = F \sin \phi$  and the separating force  $F_2 = F \cos \phi$  were calculated 39.93 N and 99.81 N, respectively, for 10 stalks to verify it with the observed values ( $\mu = 0.4$ , i.e.,  $\phi = 21.8^\circ$ ).

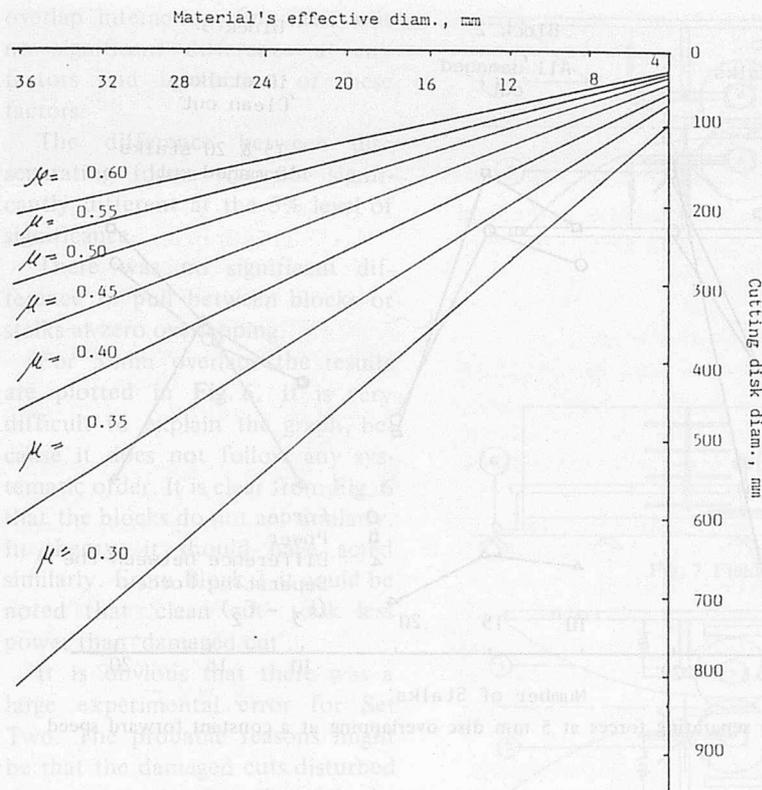


Fig. 4 Diameter of the cutting disc for different effective diameters of the material to be cut at different coefficients of friction.

### Materials and Method

The pull and disc separating forces were measured by pre-calibrated load cells of range  $0 \pm 1\ 000$  kN and  $9 \pm 1\ 000$  lbf. To measure pull, one load cell was mounted between one end of the carriage and winch cable. Disc separating forces were measured by mounting two load cells between the rig frame and cutting disc supporting arm.

All transducer outputs were taken by cable to strain gauge bridges and the bridge output voltage were amplified and measured by a Manarp oscillograph.

In the first set of experiments, the overlapping of discs was kept constant at 10 mm. Four different carriage speeds, 0.8 km/h, 1.6 km/h, and 3.2 km/h were used. Six different hill sizes, 10, 12, to 18 and 20 stalks were investigated. Experiments were replicated thrice and the replication was called

block. The speeds and bill sizes were randomised within the block, using a random numbers table.

The second set of experiments was similar to the first, except that the speed was constant at 2.4 km/h and four different disc overlappings, i.e., 0 mm, 5 mm, 10 mm and 15 mm were varied. In this set only 10, 15 and 20 stalk

Table 1 Total Pull Required to Cut Different Numbers of Stalk for 10 mm Disc Overlap

Stalk	10	12	14	16	18	20	LSD
Mean pull, N	72.2634	70.1375	81.9242	80.7650	106.6191	105.9091	18.63
Speed, km/h	1.6	2.4	3.2	0.8			
Mean pull, N	102.4883	92.1017	85.0750	65.4139			23.27
Block	B <sub>1</sub>		B <sub>2</sub>		B <sub>3</sub>		
Mean pull, N	93.5179		78.3325		86.9588		

Table 2 Total Power Required to Cut Different Numbers of Stalk for 10 mm Disc Overlap

Stalk	10	12	14	16	18	20	LSD
Mean power, W	40.4583	40.3783	45.8175	45.8075	63.5992	58.5641	11.1
Speed, km/h	0.8	1.6	1.4	3.2			
Mean power, W	14.5367	45.5484	63.4417	72.8900			9.73
Block	B <sub>1</sub>		B <sub>2</sub>		B <sub>3</sub>		
Mean power, W	52.3038		44.7529		50.2558		

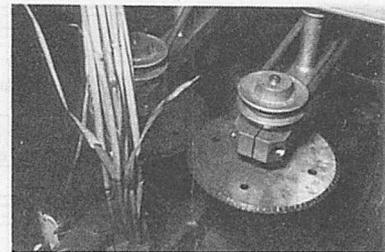


Fig. 5 Wheat stalk fixed by clips into carriage ready to be cut.

sizes were investigated.

For all experiments, the tests were conducted by cutting one hill at a time. The hill to be cut was mounted on the carriage by a clip (Fig. 5). The average moisture content of the stalks used was 45.13% (w.b.). The cutting took place when the carriage was pulled through the test rig cutting assembly. Forces were recorded on the Manarp oscillograph.

### Results and Discussion

A sample of the results is shown in Tables 1 and 2. The nature of the cut was also noted and categorised as 'not cut', 'clean cut' and 'damaged cut'.

Analysis of variance was conducted on the split plot of the first set for the pull, power and difference between the discs separating forces. In this set, out of 72 readings, the nature of cut of three

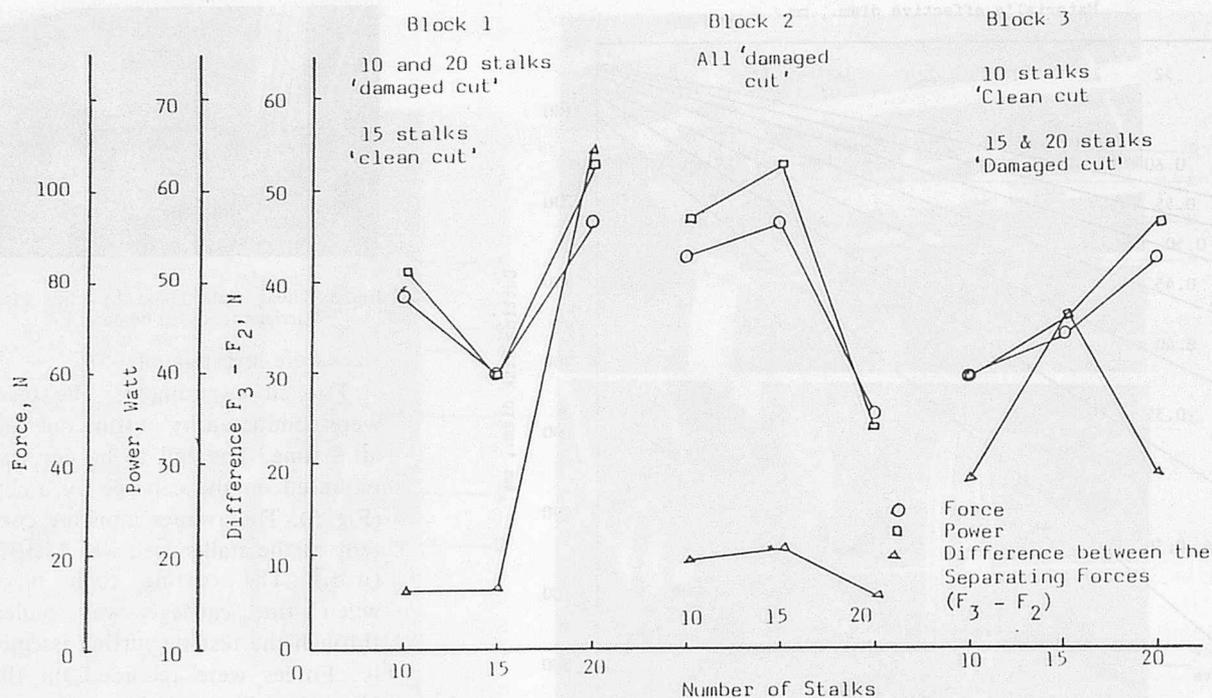


Fig. 6 Force, power and the difference between the separating forces at 5 mm disc overlapping at a constant forward speed (2.4 km/h).

readings was different, the rest of it was clean cut.

For set 2, the analysis was divided into three parts because of dissimilarity in the nature of cuts.

- i) Split plot analysis of variance for 10 and 15 mm disc overlapping.
- ii) Randomised block analysis of variance for zero overlapping.
- iii) The analysis for 5 mm disc overlapping was difficult because the nature of cuts were mixed ('clean' and 'damaged cut'). Instead of analysis of variance, this situation was explained by graphical method (Fig. 6).

A computer programme was used to work out the analysis of variance. Treatments with the same underlining are not significantly different at 5% level of significance.

#### Results of Set One

The average pull required to cut 18 stalks was a maximum of 106.6 N. The individual maximum pull was 187 N at 1.6 km/h carriage speed to cut 14 stalks.

There was a significant difference in the pull at different carriage speeds and different numbers of stalks. Pull did not hold any linear relationship with carriage speed. It was found that the pull (without friction) required to cut 10 stalks was 37.3250 N, which was very close to the expected pull of 39.92 N. It implies that the theory used to estimate disc size was adequate.

The maximum average power requirement was 63.6 Watts to cut 18 stalks. The individual maximum power requirement was 83.11 Watts to cut 14 stalks at 1.6 km/h. The maximum average power requirement was less than the expected value of 74.6 Watts (1) and the individual maximum power requirement was slightly higher than expected.

The power requirement was higher at higher carriage speeds and significantly different at the 5% level of significance. The power required to cut different numbers of stalks was also significantly different.

The difference between disc separating force increased with the increase of stalk numbers, but not significantly different at the 5% level of significance. The difference significantly varies with the variation of carriage speed.

From the observations the maximum individual separating force was 160.74 N. For most of the cases, the top disc separating force was higher than the bottom disc separating force. The measured average disc separating force for 10 stalks was 50 N, just half of the expected value (99.81 N). The most likely reason is that no allowance has been made for friction in the pivot mechanism.

#### Results of Set Two

The pull of 10 and 15 mm overlaps did not vary significantly at the 5% level of significance. The coefficient of variation was significantly high, because of the large error term.

There was a significant difference in power requirement with the number of stalks and degree of

overlap interaction, but there was no significant difference at any factors and interaction of these factors.

The difference between disc separating forces was not significantly different at the 5% level of significance.

There was no significant difference in pull between blocks or stalks at zero overlapping.

For 5 mm overlaps the results are plotted in Fig. 6. It is very difficult to explain the graph, because it does not follow any systematic order. It is clear from Fig. 6 that the blocks do not act similarly. In theory, it should have acted similarly. From Block 1 it could be noted that 'clean cut' took less power than 'damaged cut'.

It is obvious that there was a large experimental error for Set Two. The probable reasons might be that the damaged cuts disturbed the setting significantly and the system had to readjust.

The split plot design did not provide much information for the analysis, but the reason that the split plot design experiment was used was that time would not allow a complete randomized experiment.

A 10-mm overlap was the best overlap to cut satisfactorily.

Overlapping changed the conditions for the theory as described. With disc overlapping the value of the friction angle will be reduced which will again reduce the frictional force to grab the materials to be cut. Disc serration will improve the situation.

### Design of Field Machine

It was considered that the requirements of the field machine should be to cut the crops as close as possible to the ground, avoiding dirt and foreign materials and then the crops should be bundled into a reasonable size to facilitate transport. The basic layouts of two

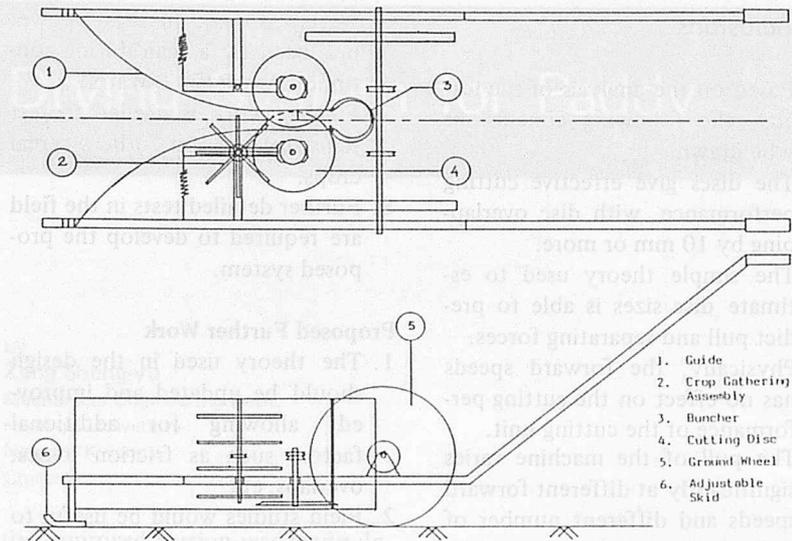


Fig. 7 Field machine A (diagrammatic only).

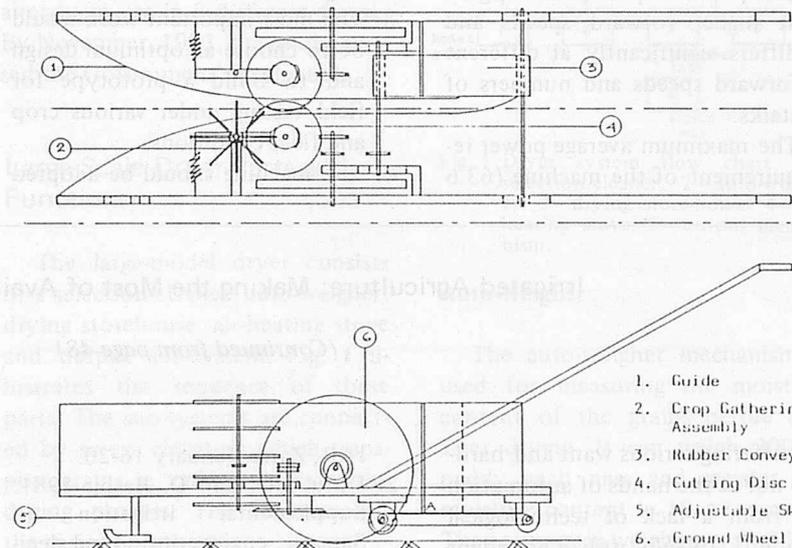


Fig. 8 Field machine B (diagrammatic only).

types of machine are shown in Fig. 7 and 8.

The unit would be pushed through the row of crops to be harvested (Fig. 7). If the machine moves forward, the standing crops would be cut and collected inside the buncher. When the buncher is full, the operator will stop the machine and tie the bunched crops with twisted straw or rope. Then the clamped fingers of the buncher will be opened to collect the crops.

The unit can be pushed by men or pulled by an animal (Fig. 8). The bunching mechanism consists of a

rubber conveyor, a pair of guides, rollers and stoppers. The mechanism is driven by pulleys and belts from ground drive. The cut material is guided and discharged on the conveyor. As the conveyor moves, the cut material is bunched at point A. Another man or the operator can collect and tie it at a convenient size.

The mechanism can be extended for two or more rows and the machine can also be pulled by animals at offset positions.

## Conclusions

Based on the analysis of the test results, the following conclusions may be drawn.

1. The discs give effective cutting performance, with disc overlapping by 10 mm or more.
2. The simple theory used to estimate disc sizes is able to predict pull and separating forces.
3. Physically, the forward speeds has no effect on the cutting performance of the cutting unit.
4. The pull of the machine varies significantly at different forward speeds and different number of stalks.
5. The power requirement is higher at higher forward speeds and differs significantly at different forward speeds and numbers of stalks.
6. The maximum average power requirement of the machine (63.6

Watts) is less than the power produced by a man during continuous work (74.6 Watts).

7. Further work is needed to test the machine on other cereal crops.
8. Further detailed tests in the field are required to develop the proposed system.

## Proposed Further Work

1. The theory used in the design should be updated and improved, allowing for additional factors such as friction losses, overlaps, etc.
2. Field studies would be useful to identify other factors which might be considered.
3. The most important work would be to choose an optimum design and to build a prototype for field testing under various crop and field conditions.
4. The machine should be adopted

for lodged crops and wet field conditions.

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## Irrigated Agriculture: Making the Most of Available Resources

(Continued from page 48)

are suffering serious want and hardship not at the hands of automation but from a lack of technological capability to fully utilize abundant natural resources. A purposeful integration of human and natural resources will direct the march towards optimal resource utilization and self sufficiency in food.

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# Large-Scale Drying System for Paddy



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## Introduction

In a situation of increasing world population, rice production need not suffer unnecessarily from undue and heavy post-harvest waste and loss.

In the southern provinces of China, rice is the most important crop that is grown twice a year in a few of those provinces. The month of July every year sees the planting of the first (regular crop) and the harvesting of the second crop. During this month, the need for farm labor is greatest, including the need to dry under the sun the harvest from the second crop. Add to this problem the fact that July is a rainy month which makes it very difficult to dry the paddy under natural drying methods. Consequently, a large amount of quantitative waste and loss from improper drying is experienced by the rice farmers.

While it is true that substantial number and kinds of small dryers are available in the domestic market, their capacities are inadequate for farmer's use. Hence in 1979, the Agricultural Development Department at Kwangsi organized a group to design and manufacture large-scale dryers at the Kwangsi University. By 1980, the first large-scale model was used on experimental basis. Within that same year,

the improved version was made. In 1982, 8 such improved models were already in use in 8 different farms. By November, 1983, the model passed the Government's evaluation.

## Large-Scale Dryer Parts and Functions

The large-model dryer consists of a selection-cleaner, auto-weigher, drying storehouse, air-heating stove and output sub-system. Fig. 1 illustrates the sequence of these parts. The sub-systems are connected by screw elevators which transport grains in various stages of the drying process. The functions of the various parts are:

### Selection-Cleaner

This part isolates such impurities as stems, leaves, powder dust and flat or empty grains. It consists of a two-layer shaking sieve and two fans located under the sieve. Longer stems of the rice plant are isolated by the movement of the sieve while the powder dust is blown away by the fans. The initially cleaned grains flow down and collected in the V-groove into the horizontal screw-elevator installed under the cleaner and then moved over to the next stage of drying.

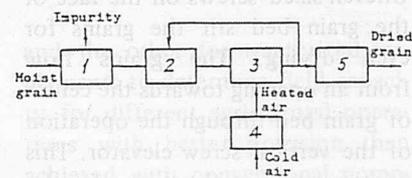


Fig. 1 Dryer system flow chart. 1—selection cleaner. 2—auto-weighter. 3—drying store-house. 4—air heating stove. 5—output mechanism.

### Auto-Weigher

The auto-weighter mechanism is used for measuring the moisture content of the grains before and after drying. It can weigh 300 kg paddy each pass and register the moisture content in  $18 \pm 2$  seconds. The accuracy in weighing is  $\pm 0.3$  kg.

### Drying Storehouse

The drying storehouse is a cylinder with 8 m diameter. It is made of concrete with steel framework. Its thickness is 0.5 m and stands at 5.1 m. Underneath the cylinder is the grain bed consisting of a steel plant in which holes of 2.8 mm are drilled and distributed uniformly. The total area occupied by the holes is equal to 25% of the total bed area. The grain bed is supported by columns and it is 0.9 m from the surface of the ground. Above the grain bed is a horizontal screw-elevator that dis-

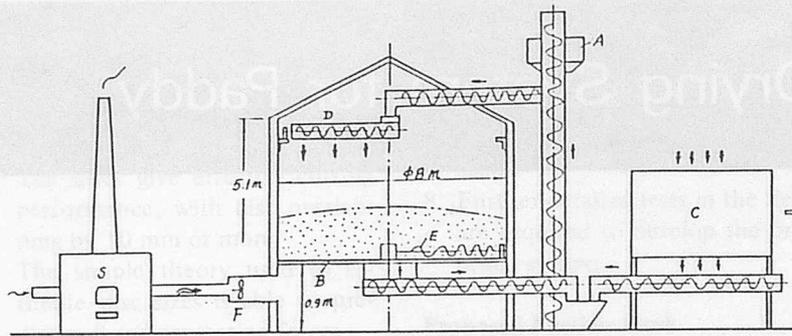


Fig. 2 The whole drying system. A— auto-wheigher. B—bed of grain. C— selection cleaner. D— distributing screw-elevator. E— unequal-step screw. F— 3 fans in parallel. S— air heating stove.

tributes grains uniformly as the latter flows downward to the grain bed for a total height of 1.7 m. Uneven-sized screws on the face of the grain bed stir the grains for even drying. The grains flow from an opening towards the center of grain bed through the operation of the vertical screw elevator. This process prepares the grains for the next stage, i.e., heating (Fig. 2).

#### Heating System

The heating system consists of a

heating stove and a 3-shaft flow fan set-up. Within the stove is a heat exchanger that is made of cast iron which is heated by coal from the outside to about 50°C with the flow of fans at about 4,500 m<sup>3</sup>/hr.

When the moisture content of the grains drops to about 13.0 to 13.5%, the fire in the stove can be extinguished but the fans must continue to operate in order to bring down the humidity of the grains to about 11%.

#### Storehouse

When the proper moisture content and humidity of the grains are attained, the grains are sent to the tube pneumatically for storage. The data below pertain to the experiment using the dryer.

Environmental temperature	23.4°C
Relative humidity	81.3%
Paddy quantity/processing:	
Pre-drying	53.35 m
Post-drying	46.51 m
Grain humidity:	
Pre-drying	22.5%
Post-drying	11.8%
Temperature of heated air:	46°C
Total weight of moisture evaporated	6,483 kg
Rate of evaporation	164.2 kg/h
No. of hours used up:	
For taking in the grains	4.14
For drying the grains	39.0
For taking out the grains	3.0
Ratio of cracked grains	3.0%
Pre-drying	1.5%
Post-drying	9.0%
Ratio of sprouted grains	85.0%

### ANNOUNCEMENT

The Japanese Society of Agricultural Machinery (JSAM) is going to celebrate its fiftieth anniversary in April, 1987. In connection to this, we are going to have a ceremony and an international symposium.

If you are interested in attending these, and present papers in the international symposium, please contact us by July 30, 1986.

Contact to: Dr. Osamu Kitani, Professor  
Dept. of Agr. Engineering, Univ. Tokyo  
Yayoi 1-1-1, Bunkyo-ku, Tokyo, Japan

#### Theme:

Fiftieth Anniversary of the Japanese Society of Agricultural Machinery, and International Symposium on Agricultural Mechanization and International Cooperation in High Technology Era

#### Main topics:

1. New technology in agricultural mechanization (a. Energy technology, b. Robotics and automation, c. Biomass and biotechnology, d. Post-harvest technology and food engineering.)
2. International cooperation and technology transfer

Participants are requested to send a manuscript of 8-16 pages (single spaced A4 size) by the end of November, 1986. Proceedings will be made by photocopying the manuscripts. You can choose any topic which is related with above ones.

**Date:** April 2, 1987; 50th Anniversary Ceremony, April 3; International Symposium, April 4 and 5; Excursion

**Location:** University of Tokyo (Faculty of Agr.), Yayoi-cho 1-1-1, Bunkyo-ku, Tokyo, Japan

**Language:** English and Japanese (Symposium is held only in English)

#### Fee for Attendance:

Ceremony and Symposium: ¥9,000 (about US\$50-) (The fee includes Proceedings and two meals)

Excursion (Two-days' bus tour: including fee for an overnight): ¥18,000 (about US\$100-)

Fee should be payed in Yen at the registration.

**Lodging:** If you have difficulties in reserving a hotel in your country we can do it for you. In this case you should suggest the preferable rate in your letter. Rate for overnight varies ¥6,000~15,000 in Tokyo. For the hotel during the excursion you need not reserve it by yourself.

# Improved Nomographs for Estimating Efficiency and Capacity of Agricultural Field Operations



by  
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## Abstract

The nomographs presented in the paper are designed for estimating field efficiency and field capacity for agricultural field operations using animal power and tractor. The field efficiency is related to speed of operation, turning time, length of the field and time efficiency. The field capacity, in turn, is achieved by relating the estimated field efficiency to the working width and speed of operation.

## Introduction

The use of nomographs for estimating field capacity is well recognized (Bowers, 1975 and Mialhe, 1984). This mathematical tool is also known as "alignment charts" are very handy for farmers, technicians and managers for plan-

**Acknowledgement:** The author wishes to thank Mr. Adão Elbío Matias da Costa, a trainee of CPATSA- Agricultural Research Centre for the Semi-Arid Tropics, Petrolina (PE) through collaborative program with CNPq- National Council of Research, for his help in elaborating on the nomographs presented in the paper. It is expected that the elaboration of these nomographs in the form of "alignment chart" would further facilitate their use. The help of specialists in the field in suggesting literature and/or providing expertise for the purpose would be highly appreciated.

ning the field operations. Apart from improving the efficiency of field level decision, it also eliminates the need for the calculator.

The general nature of the nomograph (Fig. 1) for determining field capacity (Cc) are based on equation (i) which relates the field capacity to the speed of operation (V) working width (W) and field efficiency (Ef).

$$Cc = K W V Ef \dots (i)$$

where K = conversion factor

The major limitation of these types of nomographs (Fig. 1) is that the term "field efficiency" has been considered as an independent variable just like speed of operation and working width. However, the field efficiency or operational efficiency defined as a percentage of useful working time to total registered time of machine in operation depends, apart from other factors, on speed of operation and the turning time at each end. It could also depend on configuration of the field (length to breadth ratio) and working width which would determine the time spent in turning during the operation.

The paper elaborates on a simple mathematical model relating field efficiency to the parameters mentioned earlier and develops two nomographs; one for animal-drawn

and the other for tractorized implements to determine field capacity for different agricultural operations with better precision than achieved with conventional nomographs.

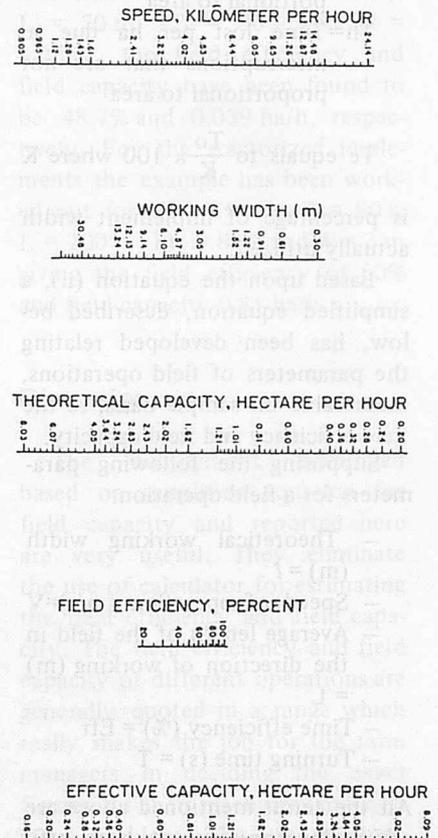


Fig. 1 A conventional nomograph for determining field capacity. (Adapted from Bowers, 1975)

## Mathematical Model Development

Kapner et al (1972) defined the field efficiency in terms of various time components for an agricultural field operation through the equation (ii):

$$E_f = \frac{T_o}{T_e + T_h + T_a} \times 100 \quad (ii)$$

where

$E_f$  = Field efficiency as percentage

$T_o$  = Theoretical time per ha of the operation depending upon the theoretical working width and speed of operation

$T_e$  = Effective time per ha of the operation depending upon the effective working width and speed of operation

$T_a$  = Time lost per ha due to interruptions that are proportional to area

$T_h$  = Time lost per ha due to interruptions that are not proportional to area

$T_e$  equals to  $\frac{T_o}{K} \times 100$  where  $K$

is percentage of implement width actually utilized.

Based upon the equation (ii), a simplified equation, described below, has been developed relating the parameters of field operations, measurable on sample basis, to the field efficiency and field capacity.

Supposing the following parameters for a field operation:

- Theoretical working width (m) =  $l$
- Speed of operation (m/s) =  $V$
- Average length of the field in the direction of working (m) =  $L$
- Time efficiency (%) =  $E_{ft}$
- Turning time (s) =  $T$

All the terms mentioned above are self-explanatory except time efficiency ( $E_{ft}$ ) which is defined as percentage of operative time, in-

cluding turning time to total time registered for the operation. It could vary between 60 and 90% (Frank 1977). The relationship between  $E_{ft}$  and time lost due to interruptions which are not proportional to area ( $T_h$ ) can be expressed through equation (iii):

$$T_h = \left(1 - \frac{E_{ft}}{100}\right) T_t \quad (iii)$$

where  $T_t$  = total registered time for the operation =  $T_o + T_h + T_a$

Based on the parameters assumed, the other components of the time can be represented through the following equations:

$$T_o = \frac{10.000/l}{V} \quad (iv)$$

$$T_a = \frac{10.000}{l \times L} \times T \quad (v)$$

$$T_e = T_o \text{ (Assuming } K=100) \quad (vi)$$

Substituting the values of  $T_o$ ,  $T_e$  and  $T_h$  in equation (ii):

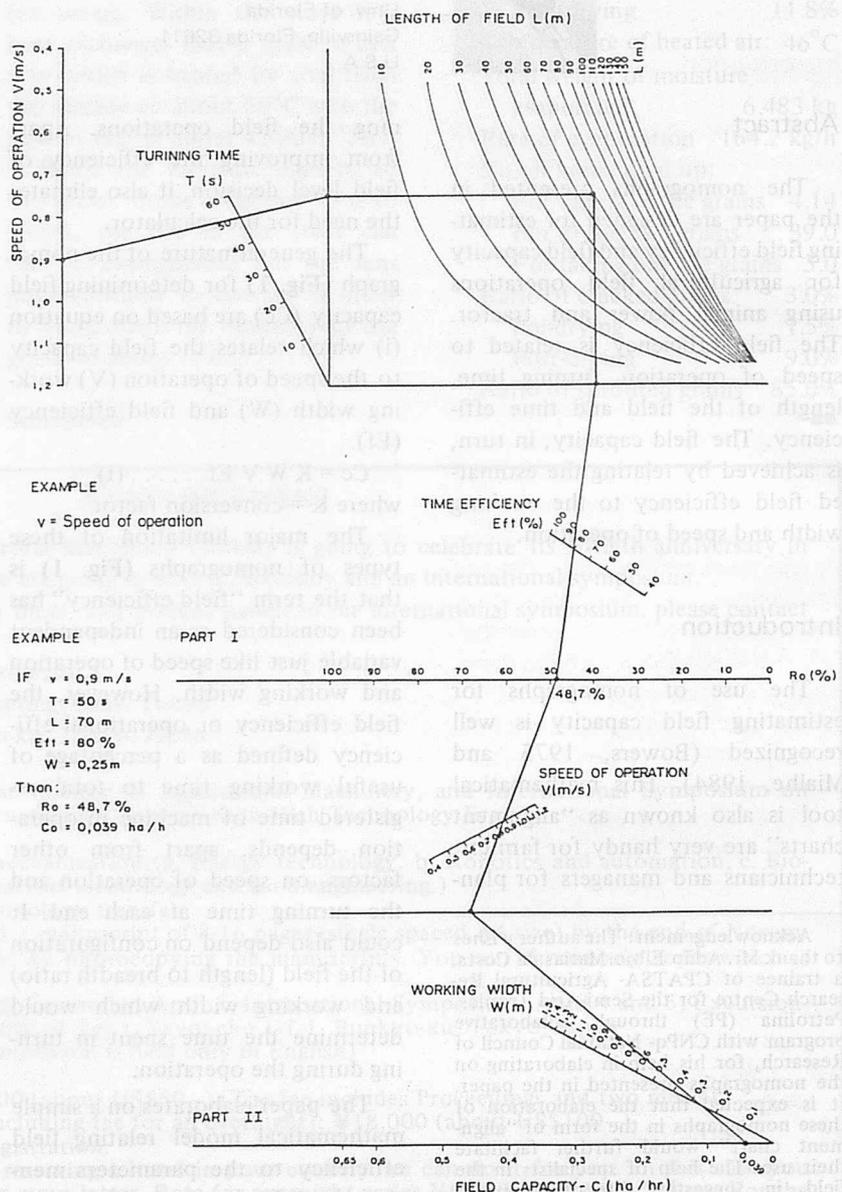


Fig. 2 Nomographs for determining field efficiency and field capacity for animal-drawn implements.

$$E_f = \frac{1/V}{\left(\frac{1}{V} + \frac{T}{L}\right) \frac{1}{E_{ft}}} \times 100 \dots (vii)$$

Substituting the value of  $E_f$  in equation (i):

$$C_c = \frac{K.W}{\left(\frac{1}{V} + \frac{T}{L}\right) \frac{1}{E_{ft}}} \times 100 \dots (viii)$$

Through the equations (vii) and (viii) it is possible to estimate the field efficiency and field capacity

based on the parameters which can be measured on the sample basis, avoiding the need to register different time components expressed in equation (ii) for full length of operation.

### Development of Nomographs

Based on the equation (viii), two nomographs (Figs. 2 and 3) have been developed. The first nomograph (Fig. 2) is designed for animal drawn implements with

variation of speed of operation from 0.4 m/s to 1.2 m/s, turning time from 10 s to 60 s, length of the field from 10 m to 150 m, time efficiency from 40 to 100% and working width from 0.10 m to 1.5 m. For the second nomograph (Fig. 3) the variation of these parameters have been selected to make it suitable for tractorized implements.

These nomographs constitute two parts, the first part estimates the field efficiency based on the speed of operation, turning time, length of field and time efficiency, and the second part calculates the field capacity based on estimated field efficiency, working width of the implement and speed of operation.

The representative examples for the usage of these nomographs are presented in respective figures. In the case of animal-drawn implements for  $V = 0.9$  m/s,  $T = 50$  s,  $L = 70$  m,  $E_{ft} = 80\%$  and  $W = 0.25$  m, the field efficiency and field capacity have been found to be 48.7% and 0.039 ha/h, respectively. For the tractorized implements the example has been worked out for  $V = 1.5$  m/s,  $T = 80$  s,  $L = 200$  m,  $E_{ft} = 80\%$  and  $W = 3$  m giving the field efficiency of 50% and field capacity 0.81 ha/h.

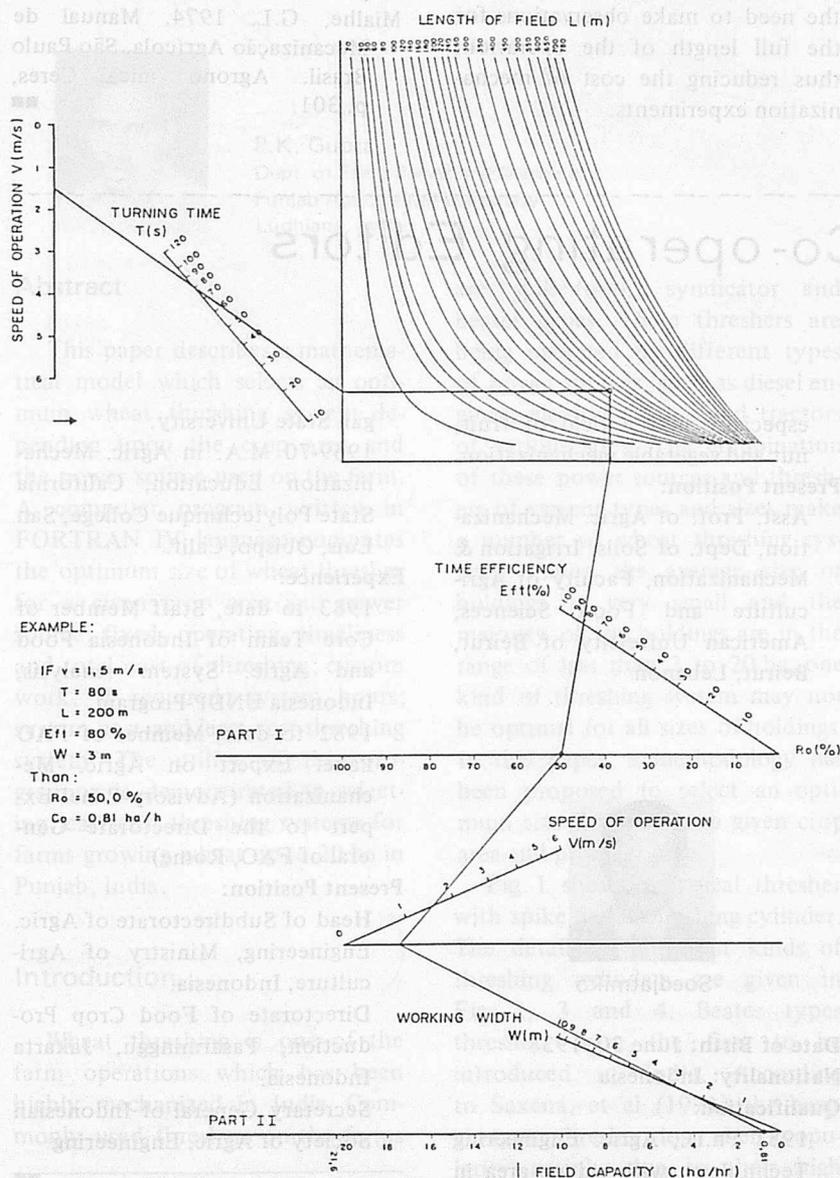


Fig. 3 Nomographs for determining field efficiency and field capacity for tractorized implements.

### Discussion

The nomographs developed based on simplified equation for field capacity and reported here are very useful. They eliminate the use of calculator for estimating the field efficiency and field capacity. The field efficiency and field capacity of different operations are generally quoted in a range which really makes the job for the farm managers in deciding the exact figures for their machinery management problem. The use of these nomographs can be made to estimate a better representative value

of field efficiency and field capacity taking into account the location specific parameters such as length of field, turning time and time efficiency.

Time required for particular operations or the sequence of operations is a common observation made during experimentation related to mechanization. The validity of such observations for different locations, without referring to various parameters which could influence these values, is limited. On the other hand, in certain cases, to arrive at exact figures of time requirement, a detailed observation of different time components (To, Te, Th and Ta) is made in a particu-

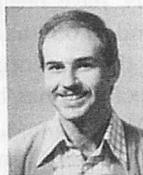
lar field situation, thus making the mechanization research very expensive.

It is expected that the nomographs presented in this paper would facilitate the job of mechanization experts in arriving at better representative values of the time required, field capacity and field efficiency figures just through observation of the parameters such as average length of field, turning time, speed of operation, effective working width and time efficiency on sample basis. This would avoid the need to make observations for the full length of the operation, thus reducing the cost of mechanization experiments.

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# Mathematical Model for Selecting Wheat Threshing Systems for Farms in North India

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## Abstract

This paper describes a mathematical model which selects an optimum wheat threshing system depending upon the crop area and the power source used on the farm. A computer program written in FORTRAN IV language computes the optimum size of wheat thresher for a given crop area and power source; fixed, operating, timeliness and total cost of threshing; custom work, if required; system hours; system cost and least cost threshing system. The utility of this programme is demonstrated in selecting least cost threshing systems for farms growing wheat up to 20 ha in Punjab, India.

## Introduction

Wheat threshing is one of the farm operations which has been highly mechanized in India. Commonly used threshers on the farms

are spike-tooth, syndicator and beater types. These threshers are being operated by different types of power sources, such as diesel engines, electric motors and tractors of various sizes. The combination of these power sources and threshers of various types and sizes make a number of wheat threshing systems. Since the average size of holdings is very small and the majority of the holdings are in the range of less than 2 to 20 ha, one kind of threshing system may not be optimal for all sizes of holdings. In this paper, a methodology has been proposed to select an optimum size thresher for a given crop area and power source.

Fig. 1 shows a typical thresher with spike-tooth threshing cylinder. The details of different kinds of threshing cylinders are given in Figs. 2, 3 and 4. Beater types threshers were the first to be introduced in India. According to Saxena, et al (1971) the beater type thresher lost their popularity mainly due to their high power requirement. Both spike-tooth type and syndicator type

threshers are very popular in Punjab. Although the spike-tooth type thresher has advantages like simple and compact design with low grain breakage but can handle only very dry crop with grain moisture content below 10%. Whenever there is rain, much time is lost in drying the crop to the desired level of moisture content for threshing. The syndicator type thresher has advantages like low energy requirement, uniform size straw and capability to handle crops of high moisture content. Banga (1981) reported higher grain breakage for syndicator type threshers compared to spike-tooth threshers. Verma et al (1980) found that the number of accidents reported using syndicator type threshers was more than those reported for other types of threshers.

## Threshing System Costs

Various costs associated with the threshing operation are:

- (i) Fixed cost, which includes depreciation, interest, insurance, taxes and shelter.

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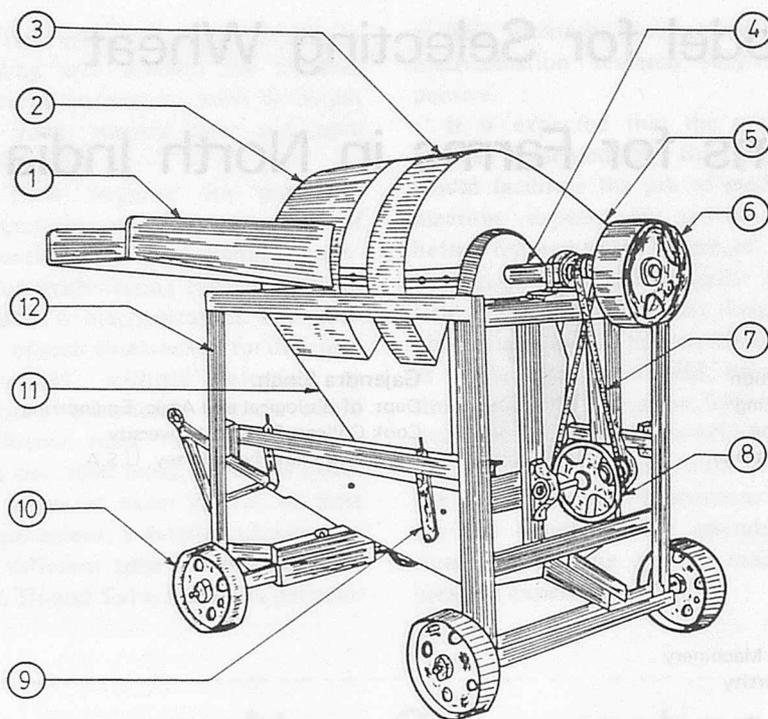


Fig. 1 A typical thresher with spike-tooth cylinder. 1- Feeding chute. 2- Cylinder housing. 3- Blower housing. 4- Main shaft. 5- Straw outlet. 6- Flat pulley. 7- V-belt. 8- V-Pulley. 9- Sieve locking mechanism. 10- Transport wheel. 11- Deflectors, 12- Frame.

- (ii) Variable cost, which includes cost of fuel, oil, labour, repair and maintenance and power source cost.
- (iii) Timeliness cost, which arises because of inability of the threshing system to perform the operation during optimum period.

**Assumptions**

Optimum selection of threshing system is based on certain assumptions, as given below:

- (i) The price of thresher is proportional to its size.
- (ii) Fuel and oil required are directly proportional to power consumption of power source used to operate the thresher.
- (iii) Optimum period available for threshing operation is negligible, as the crop may be damaged by storm, rain or any other hazard.
- (iv) Annual use of power source is known and remains fixed for the whole life of the threshing

system.

- (v) There is no limitation on hiring out of the thresher for use up to same level at which the cost of threshing equals the custom rate.
- (vi) The maxim annual use of a thresher is 300 h.

**Mathematical Model to Select an Optimum Size Thresher**

The optimum size of thresher can be determined by deriving the annual cost equation for a threshing operation and using an optimizing technique developed by Hunt (1977).

The annual cost of the thresher is given by Equation 1. All those components which depend upon the size of the thresher were expressed in terms of its capacity (t/h). The depreciation of the thresher was determined using the straight line method. Insurance charges and taxes were not considered as the threshers are neither

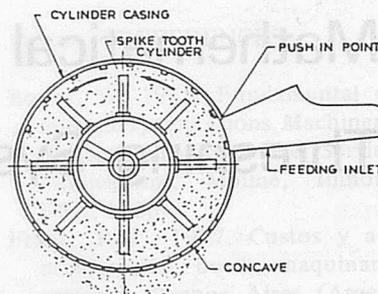


Fig. 2 Spike-tooth threshing cylinder.

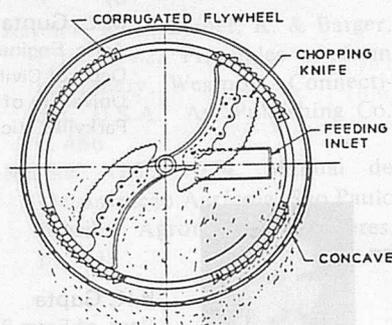


Fig. 3 Syndicator threshing cylinder.

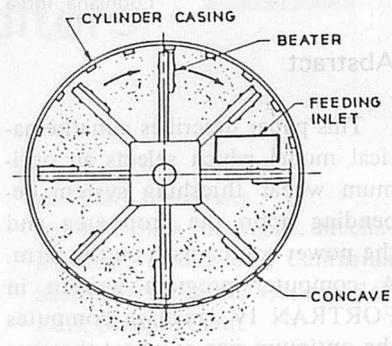


Fig. 4 Beater type threshing cylinder.

insured nor subjected to taxes.

$$AC = \frac{PUC_{TH} \times CAP_{TH} \times (1 - SVF)}{EL_{TH}} \dots \dots \dots \text{(depreciation)}$$

$$+ \frac{PUC_{TH} \times CAP_{TH} \times (1 + SVF)}{2} \times RI \dots \dots \dots \text{(interest)}$$

$$+ \frac{PUC_{TH} \times CAP_{TH} \times (1 + SVF)}{2} \times SC \dots \dots \dots \text{(shelter charges)}$$

$$+ \frac{AUC \times YC}{CAP_{TH}} \times LCTH \dots \dots \dots \text{(labour cost)}$$

$$+ \frac{AUC \times YC}{CAP_{TH}} \times \frac{ETH \times CAP_{TH}}{EPTS} \dots \dots \dots \text{(fuel cost)}$$

$$\times SFCPS \times PFUEL \dots \dots \dots \text{(fuel cost)}$$

$$+ \frac{AUC \times YC}{CAP_{TH}} \times \frac{ETH \times CAP_{TH}}{EPTS}$$

Table 1. A Program for the Optimum Threshing System

$$\begin{aligned}
 & \times \frac{\text{SFCPS} \times \text{ORPS} \times \text{POIL}}{100} \\
 & \dots \dots \dots \text{ (oil cost)} \\
 & + \frac{\text{AUC} \times \text{YC}}{\text{CAPTH}} \\
 & \times \frac{\text{RMFTH} \times \text{PUCTH} \times \text{CAPTH}}{10000} \\
 & \dots \dots \dots \text{ (repair \& maintenance cost)} \\
 & + \frac{\text{AUC} \times \text{YC}}{\text{CAPTH}} \times \text{PSCPH} \\
 & \dots \dots \dots \text{ (power source cost)} \\
 & + \frac{\text{AUC} \times \text{YC}}{\text{CAPTH}} \\
 & \times \frac{\text{YLTH} \times \text{AUC} \times \text{YC} \times \text{PC}}{\text{WHDTH} \times 2} \\
 & \dots \dots \dots \text{ (timeliness cost)} \\
 & \dots \dots \dots \text{ (1)}
 \end{aligned}$$

- where
- AUC = area under crop, ha
  - CAPTH = capacity of thresher, t/h
  - ELTH = estimated useful life of thresher, years
  - EPTS = efficiency of power transmission system, decimal
  - ETH = energy required for threshing operation, kWh/t
  - LCTH = labour cost of threshing, Rs/h
  - ORPS = oil requirement of power source, expressed in % of fuel consumption
  - PC = price of crop, Rs/t
  - PFUEL = price of fuel, Rs/l
  - POIL = price of oil, Rs/l
  - PUCTH = price per unit capacity of thresher, Rs/(t/h)
  - RI = rate of interest per year, decimal
  - RMFTH = repair and maintenance factor for thresher, expressed as % of purchase price per 100 h of operation
  - SC = shelter charge per year, decimal
  - SFCPS = specific fuel consumption of power source, 1/kWh
  - SVF = salvage value factor,

- decimal
- WHDTH = working hours per day for threshing operation, h/day
- YC = yield of crop, t/ha
- YLTH = yield loss due to delay in threshing operation, kg/kg-day

The power source cost per hour (PSCPH) was determined by using Equation 2 which is applicable for different power sources such as tractors, engines and motors. In the case of motors used for agricultural purposes, the electricity charges are paid in two ways: (i) on the basis of energy consumption, and (ii) on the flat rate basis, which means that the farmer has to pay the fixed amount per year based on the size of motor. Therefore, the electricity charges for the second case were taken as a fixed cost.

$$\begin{aligned}
 \text{PSCH} = & \left[ \text{PPS} \times \frac{(1-\text{SVF})}{\text{ELPS}} + \frac{(1+\text{SVF})}{2} \right. \\
 & \times (\text{RI} + \text{RIN} + \text{SC}) \left. \right] / \text{AUPS} \\
 & \dots \dots \dots \text{ (fixed cost per h)} \\
 & + \frac{\text{RMFPS} \times \text{PPS}}{10000} \\
 & \dots \dots \dots \text{ (repair \& maintenance cost)} \\
 & + \frac{\text{EFR} \times 12 \times \text{HPPS}}{\text{AUPS}} \\
 & \dots \dots \dots \text{ (electricity charges)} \\
 & \dots \dots \dots \text{ (2)}
 \end{aligned}$$

- where previously undefined symbols are:
- AUPS = annual use of power source, h/year
  - ELPS = estimated useful life of power source, years
  - HPPS = size of power source, kW
  - RIN = rate of insurance and taxes per year, decimal
  - RMFPS = repair and maintenance factor for power source
  - PPS = price of power source, Rs
  - EFR = electricity flat rate,

Rs/kW-month

The optimum size of thresher, (CAPTH)<sub>opt</sub>, was determined by setting:

$$\frac{d(\text{AC})}{d(\text{CAPTH})} = 0$$

$$\begin{aligned}
 (\text{CAPTH})_{\text{opt}} = & \left[ \text{AUC} \times \text{YC} \right. \\
 & \times (\text{LCTH} + \text{PSCPH} + \text{YLTH}) \\
 & \times \text{AUC} \times \text{YC} \times \text{PC} \\
 & \times 0.5 / \text{WHDTH} \left. \right]^{1/2} \times \left[ \text{PUCTH} \right. \\
 & \times \left. \left[ (1-\text{SVF}) / \text{ELTH} + (1 + \text{SVF}) \right. \right. \\
 & \left. \left. \times (\text{RI} + \text{SC}) / 2 \right] \right]^{-1/2} \\
 & \dots \dots \dots \text{ (3)}
 \end{aligned}$$

**Development of Computer Program**

The computations involved in solving Equation 3 is both complex and tedious, especially when the optimum size of wheat thresher is to be determined for different types of threshers for various types and sizes of power sources. Therefore, a computer program\* (written in FORTRAN IV) was developed to select the least cost threshing system for different crop acreages. The least cost threshing system was selected by first determining the optimum size of wheat thresher for a given crop area and power source and then comparing the system cost of each threshing system. Selection procedure and program logic for selecting least cost threshing system is given in Fig. 5. In the computer program, the provision was made to compute the working hours required for custom work to make the cost of threshing at least equal to custom rate if the cost of threshing is more than the custom rate. Equation 4 was used to estimate the custom work, if required:

$$\begin{aligned}
 \text{WHRC} = & \left[ \text{AFC} - \text{AUC} \times \text{YC} \right. \\
 & \left. \times (\text{CRTH} - \text{OCTH}) \right] / \\
 & \left[ \text{CAPTH} \times (\text{CRTH} - \text{OCTH}) \right] \\
 & \dots \dots \dots \text{ (4)}
 \end{aligned}$$

- where
- AFC = annual fixed cost of thresher, Rs
  - CRTH = custom rate of thresh-

## Application of the Computer Program

To demonstrate the utility of the computer program, three types of threshers and 19 different power sources were considered which are commonly used in Punjab State. The relevant data, such as prices of threshers and power sources, fuel, oil and labour costs, were collected. The information such as life, annual use and repair and maintenance cost of the thresher, as well as of power sources, was taken from ISI Code (1979).

Based on these data, the results were obtained using the computer program.\* Table 1 indicates a portion of the output obtained with this program. The results pertain to the syndicator type of thresher for a farm growing 6 ha of wheat. Optimum wheat threshing systems for each type of power source are given, which include the following information:

- (1)PSN power source name
- (2)HPPS - size of power source, kW
- (3)CAPTH - optimum capacity (grain output) of thresher, t/h
- (4)PTH - price of thresher, Rs
- (5)FCTH - fixed cost of threshing, Rs/t
- (6)OCTH - operating cost of threshing, Rs/t
- (7)TCTH - timeliness cost of threshing, Rs/t
- (8)CTH - cost of threshing, Rs/t
- (9)AUTH - annual use of thresher, h
- (10)WHRC - working hours required for custom work to make the cost of threshing at least equal to custom rate, h
- (11)SHRS - system hours, h
- (12)SCOST - system cost, Rs

\* This program, named as OWTS, is available from the authors.

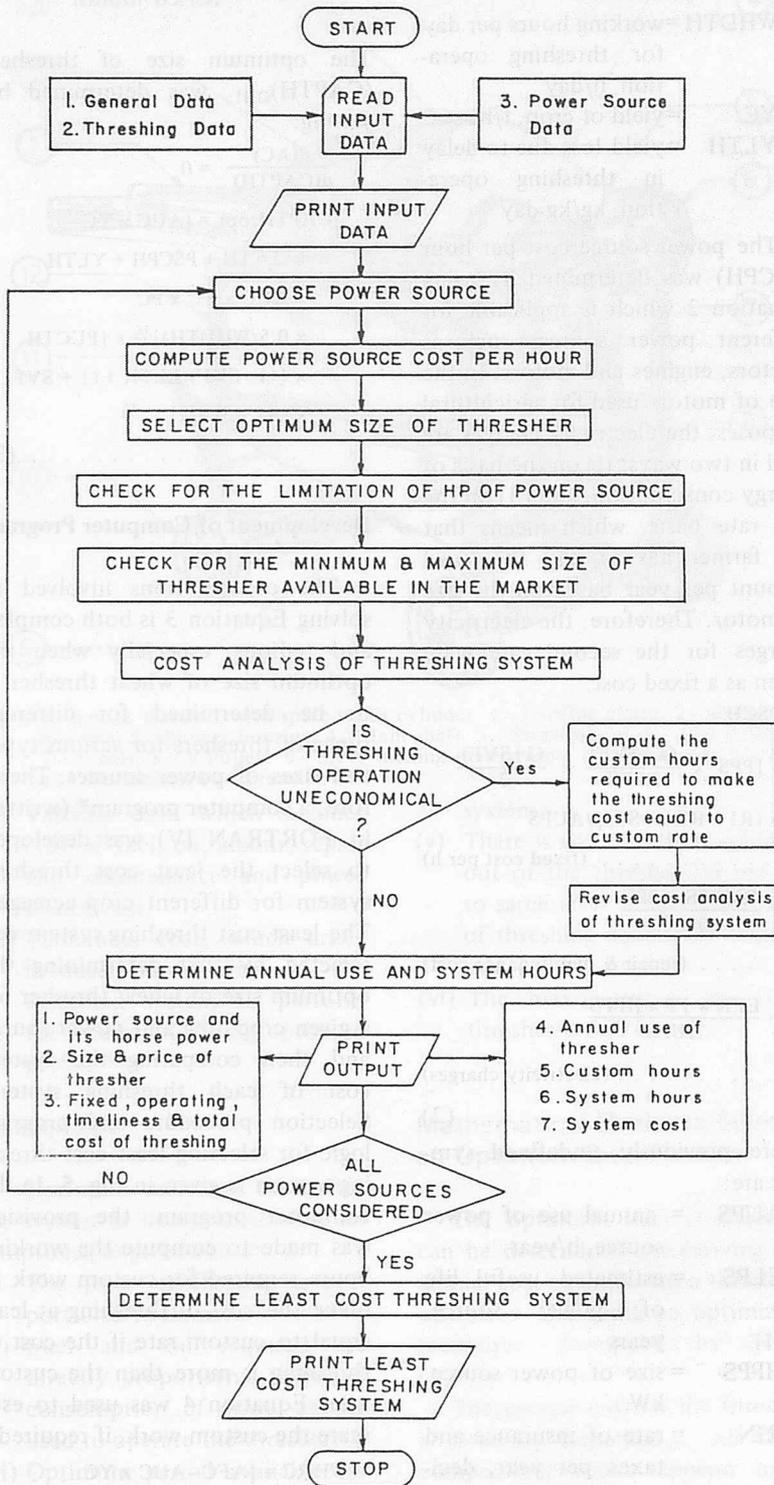


Fig. 5 Selection procedure and program logic for optimum selection of wheat threshing systems.

OCTH = operating cost of threshing, Rs/t

WHRC = working hours required for custom work, h

Table 1 A Portion of the Output Obtained with OWTS Program (YLTH = 0)

Thresher type = Syndicator			Optimum Wheat Threshing Systems						Area under crop = 6.0 ha			
System	PSN	HPPS	CAPTH	PTH	FCTH	OCTH	TCTH	CTH	AUTH	WHRC	SHRS	SCOST
1	Tractor	13.4	0.39	4498	40	66	0.0	106	54.2	0.0	54.2	2228.4
2	Tractor	18.6	0.43	4954	44	70	0.0	114	49.2	0.0	49.2	2398.7
3	Tractor	26.1	0.48	5568	50	76	0.0	126	43.7	0.0	43.7	2682.1
4	Tractor	33.6	0.49	5727	51	77	0.0	128	42.5	0.0	42.5	2687.5
5	Tractor	37.3	0.51	5912	53	79	0.0	132	41.2	0.0	41.2	2756.6
6	Engine	3.7	0.21	2449	22	47	0.0	69	99.5	0.0	99.5	1454.4
7	Engine	5.2	0.24	2852	25	45	0.0	70	86.3	0.0	86.3	1467.9
8	Engine	6.0	0.25	2910	26	46	0.0	72	83.7	0.0	83.7	1500.5
9	Engine	7.5	0.27	3148	28	48	0.0	76	77.4	0.0	77.4	1589.6
10	Engine	11.2	0.28	3212	29	48	0.0	77	75.8	0.0	75.8	1613.6
11	Engine	14.9	0.31	3568	32	51	0.0	83	68.3	0.0	68.3	1746.3
12	Engine	18.6	0.34	3891	35	54	0.0	89	62.6	0.0	62.6	1867.0
13	Motor	3.7	0.21	2449	22	33	0.0	55	99.5	0.0	99.5	1149.3
14	Motor	5.6	0.25	2925	26	31	0.0	57	83.3	0.0	83.3	1189.9
15	Motor	7.5	0.26	3052	27	32	0.0	59	79.8	0.0	79.8	1237.4
16	Motor	9.3	0.28	3216	29	33	0.0	62	75.7	0.0	75.7	1298.6
17	Motor	11.2	0.29	3338	30	34	0.0	64	73.0	0.0	73.0	1344.3
18	Motor	14.9	0.31	3565	32	36	0.0	68	68.3	0.0	68.3	1428.8
19	Motor	18.6	0.33	3827	34	39	0.0	73	63.7	0.0	63.7	1526.8

Note: Least cost threshing system is No. 3. System with annual use more than the maximum limit is not considered.

In addition to the above information, the output also identifies the least cost threshing system out of the various wheat threshing systems selected, depending upon the power source used on the farm. The computer output also identifies the systems in which the operating (variable) cost of threshing is more than the custom rate of threshing and thus it is uneconomical to own a thresher because in such a case no amount of custom work would be able to make the cost of threshing equal to the custom rate.

### Results and Discussion

The optimum size of thresher was determined for different crop areas and for various types and sizes of power sources (tractors, diesel engines and electric motors) commonly available in India. These results can be helpful directly in deciding the optimum size of thresher for the crop area and power source available with any farmer. As an example, the sizes of threshers for different sizes of diesel engines have been given in Fig. 6.

From the possible optimum combinations of thresher and power sources for a given crop area, the systems with least cost of

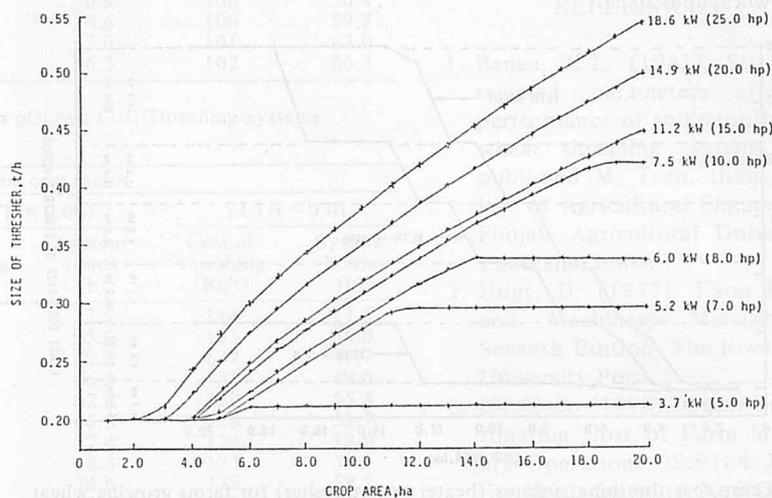


Fig. 6 Optimum size of engine-operated threshers (spike tooth type) for different crop areas.

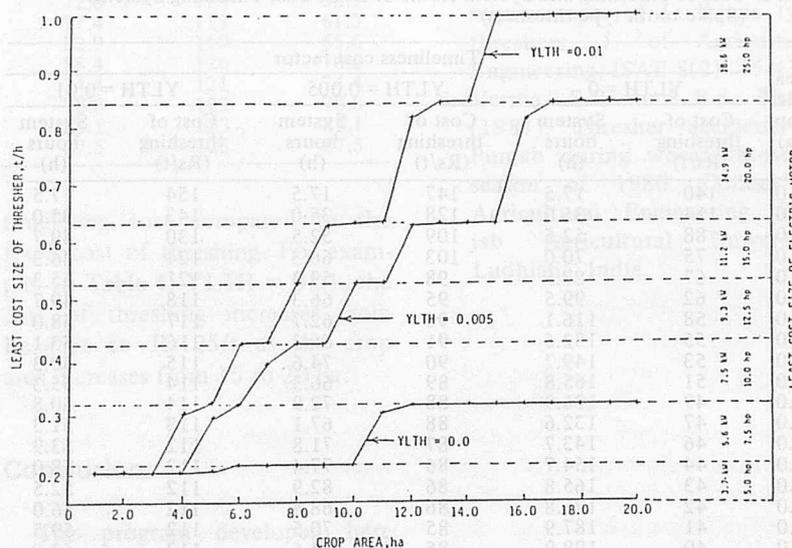


Fig. 7 Least cost threshing systems (spike tooth type thresher) for farms growing wheat up to 20 ha.

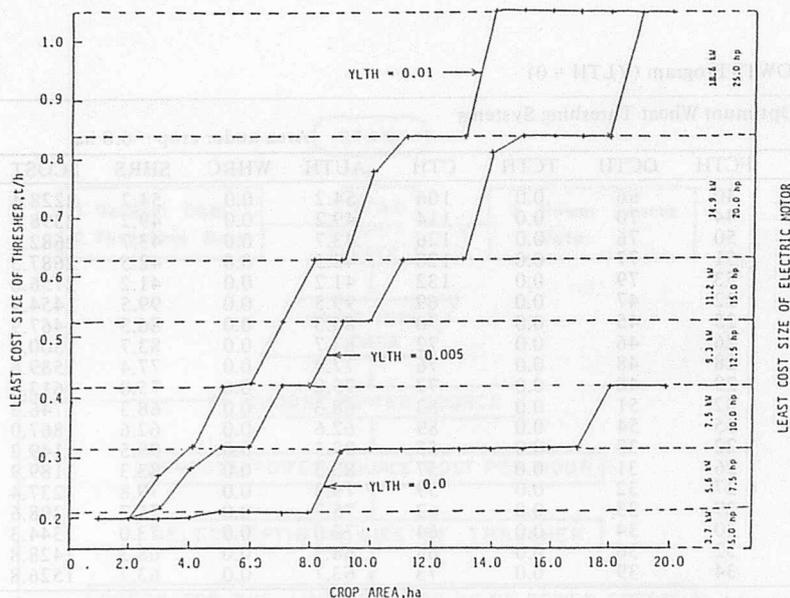


Fig. 8 Least cost threshing systems (syndicator type thresher) for farms growing wheat up to 20 ha.

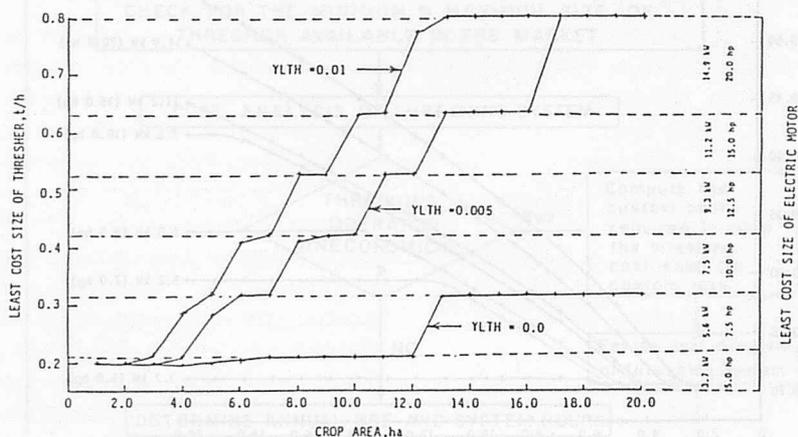


Fig. 9 Least cost threshing systems (beater type thresher) for farms growing wheat up to 20 ha.

Table 2 Cost of Threshing and System Hours of Least Cost Threshing Systems (Spike tooth type threshers)

Area under crop (ha)	Timeliness cost factor					
	YLTH = 0		YLTH = 0.005		YLTH = 0.01	
	Cost of threshing (Rs/t)	System hours (h)	Cost of threshing (Rs/t)	System hours (h)	Cost of threshing (Rs/t)	System hours (h)
1.0	140	17.5	147	17.5	154	17.5
2.0	114	35.0	128	35.0	143	35.0
3.0	88	52.5	109	52.5	130	49.7
4.0	75	70.0	103	66.3	124	46.3
5.0	67	87.5	98	59.3	121	55.3
6.0	62	99.5	95	66.3	118	49.7
7.0	58	116.1	93	62.7	117	58.0
8.0	55	132.6	91	66.3	116	53.1
9.0	53	149.2	90	74.6	115	50.3
10.0	51	165.8	89	66.3	114	55.3
11.0	49	126.9	88	72.9	114	60.8
12.0	47	132.6	88	67.1	113	51.3
13.0	46	143.7	87	71.8	112	53.9
14.0	44	154.7	86	77.4	112	58.0
15.0	43	165.8	86	82.9	112	52.5
16.0	42	176.8	86	68.8	112	56.0
17.0	41	187.9	85	70.5	112	59.5
18.0	40	198.9	85	74.6	112	63.0
19.0	40	210.0	84	78.8	112	66.5
20.0	39	221.1	84	82.9	113	70.0

threshing were selected. Figs. 7, 8 and 9 give the least cost threshing for spike tooth, syndicator and beater type threshers, respectively. The results are given at three levels of timeliness cost factor for farms growing wheat up to 20 ha. These can be helpful in selecting a least cost size of thresher, as well as power source for a given crop area. It was found that the least cost system was always from the electric motor-driven threshers. It is clearly demonstrated in these figures that with the increase in the timeliness cost factor, the size of the least cost thresher as well as the power source increases. This is because the increased size of thresher offsets the timeliness cost, which is higher in the case of small size threshers. These figures also show that with the increase in crop area, there is not always an increase in the size of least cost thresher. This can be attributed to three different constraints. Firstly, the least cost size of thresher for small farms is relatively small and hence the minimum size available in the market is to be selected, e.g., the least cost size of spike tooth type thresher (Fig. 7, YLTH = 0) for a crop area up to 5 ha has been taken as 0.2 t/h, the minimum size of thresher available in the market. Secondly, the least cost size of thresher is also limited by the available power from the power source, e.g., for crop areas of 12-20 ha (Fig. 7, YLTH=0) the least cost size of thresher has been taken as 0.32 t/h, which is limited by 5.6 kW of the electric motor. Lastly, for large crop areas and higher timeliness cost factor, the least cost size of thresher is limited by the maximum size available in the market, e.g., a thresher with a capacity of 1 t/h has been selected for crop areas varying from 15-20 ha (Fig. 7, YLTH = 0.01).

Tables 2, 3 and 4 give the cost of threshing and system hours (for least cost systems) at three levels of timeliness cost factor for spike

**Table 3** Cost of Threshing and System Hours of Least Cost Threshing System (Syndicator type thresher)

Area under crop (ha)	Timeliness cost factor					
	YLTH = 0		YLTH = 0.005		YLTH = 0.01	
	Cost of threshing (Rs/t)	System hours (h)	Cost of threshing (Rs/t)	System hours (h)	Cost of threshing (Rs/t)	System hours (h)
1.0	140	17.5	147	17.5	154	17.5
2.0	96	35.0	111	35.0	125	35.0
3.0	76	52.5	97	49.7	116	38.8
4.0	65	70.0	92	49.8	110	44.2
5.0	59	82.9	87	55.3	107	42.1
6.0	55	99.5	85	66.3	106	49.7
7.0	52	116.1	82	58.0	104	46.4
8.0	49	132.6	81	66.3	103	44.2
9.0	47	149.2	80	59.7	102	49.7
10.0	45	110.5	79	66.3	102	44.6
11.0	43	121.6	78	60.8	101	45.6
12.0	42	132.6	78	66.3	100	49.7
13.0	40	143.7	77	71.8	100	53.9
14.0	39	154.7	77	59.8	100	46.4
15.0	38	165.8	76	62.2	99	49.7
16.0	38	176.8	76	66.3	99	53.1
17.0	37	187.9	76	70.5	100	56.4
18.0	36	149.2	76	74.6	100	59.7
19.0	35	157.5	75	63.0	101	63.0
20.0	35	165.8	75	66.3	102	66.3

**Table 4** Cost of Threshing and System Hours of Least Cost Threshing Systems (Beater type threshers)

Area under crop (ha)	Timeliness cost factor					
	YLTH = 0		YLTH = 0.005		YLTH = 0.01	
	Cost of threshing (Rs/t)	System hours (h)	Cost of threshing (Rs/t)	System hours (h)	Cost of threshing (Rs/t)	System hours (h)
1.0	140	17.5	147	17.5	154	17.5
2.0	125	35.0	139	35.0	153	35.0
3.0	95	52.5	117	52.5	137	49.7
4.0	81	70.0	108	66.3	132	49.0
5.0	72	87.5	105	62.8	128	55.3
6.0	66	104.1	101	66.3	126	51.7
7.0	61	116.1	99	77.4	124	58.0
8.0	58	132.6	97	68.3	123	53.1
9.0	56	149.2	95	74.6	122	59.7
10.0	53	165.8	94	82.9	121	55.3
11.0	52	182.4	93	72.9	120	60.8
12.0	50	198.9	93	79.6	120	54.3
13.0	49	146.2	92	72.0	119	56.9
14.0	47	154.7	91	77.4	119	61.3
15.0	46	165.8	91	82.9	119	65.6
16.0	45	176.8	91	88.4	120	70.0
17.0	44	187.9	90	74.4	121	74.4
18.0	43	198.9	90	78.8	122	78.8
19.0	42	210.0	90	83.1	123	83.1
20.0	41	221.1	90	87.5	125	87.5

tooth, syndicator and beater type threshers, respectively. The results indicate that the cost of threshing generally decreases as the crop area increases from 1 to 20 ha. This may be due to a decrease in fixed cost of threshing (due to increased system hours) compared to the increase in the timeliness cost. However, in the case of large crop areas at higher timeliness cost factor, the cost of threshing may increase due to a relatively higher increase in

timeliness cost compared to the fixed cost of threshing. For example, in Table 4, YLTH = 0.01, the cost of threshing increases from Rs119/t to Rs125/t as the crop area increases from 15 to 20 ha.

### Conclusions

The program developed here can be used as a decision aid in determining the optimum size of

wheat thresher for a given crop area and power source used on a farm. It can also be used to select the least cost threshing system out of the various wheat threshing systems employed on the farms. It is expected that the program will be useful in establishing the basis for recommendations to the farmers by extension personnel. The program will also be helpful in determining whether the present systems of wheat threshing adopted by the farmers are the most appropriate.

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# Agricultural Mechanization Facilities in Sind, Pakistan

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## Introduction

Farm mechanization is an important step towards the development of agriculture and national prosperity. Delbert and Furguson (1,2) suggested that farm mechanization requires power machines, roads, education, training facilities, repair and land preparation facilities.

In Pakistan farm mechanization was introduced by the agriculture extension department which has provided the tractors at subsidised rates to the farmers. These tractors were mainly used to develop the land by levelling and deep plowing of virgin lands and installation of tubewells.

In the Nawabshah district, Sind, only the tillage implements are adopted by the farmers. Gradually they have become familiar with the use and benefits of other agricultural implements. Nowadays farm machines are used extensively because of the tremendous increase in sugarcane acreage and introduction of improved varieties of wheat and other crops.

Big landlords use tractors and implements such as moldboard plow, disc plow, disc harrow, leveler, ridger, seed drill, and thresher, to increase crop production. Agricultural machinery will not create any surplus labour problem in Nawabshah district as agriculture labour is in short supply. However, the farmers are slightly discouraged to use more agricultural machines due to the difficulties in obtaining credit for the purchase of tractors, non-availability of spare parts and lack of proper repair facilities. According to an estimate the number of tractors owned by the farmers in the district is about 480 units (4).

## Method of Study

The Nawabshah district was selected to study agricultural mechanization facilities. The survey of the whole district was made on the number of tractors, agricultural machinery, workshops, spare parts dealers, tubewells, credit facilities, P.O.L stations and other

related information for enhancing the pace of farm mechanization. Data was collected from the Revenue department, Agricultural Engineering department, Agricultural Extension department, agriculture-based industries and mills, machinery dealers and manufacturing companies and other sources through personal contacts.

The objective was to evaluate the extent of farm mechanization and standardization of farm tractors and machinery facilities available in the district. In this respect, therefore, data was also collected on land utilization, cropping pattern and available farm mechanization facilities.

## Results

Table 1 indicates the utilization of land in the district. The gross area was 1,853,440 acres and available agricultural land was 1,141,795 acres from which only 215,404 acres were cultivable. The ratio of cultivable land was so small due to lack of available sources. The

Table 1 Land Use in Nawabshah District

Item	Area (acres)
Gross area	1,853,440
Total agricultural land	1,141,795
Forests	75,022
Unassessed cultivable land	215,404
Unassessed uncultivable land	85,404
Area assessed for public purposes	110,448
Area assessed for non-agricultural purposes	109,862
Area leased out for 5 years	98,180
Area leased out for 10 years	6,220
Area covered by sand and river	8,365
Land available for disposal	3,220

cultivable area can easily be increased with the introduction of modern farm machines.

Table 2 presents the cropping pattern in the district during the past 14 years showing that wheat, cotton and oilseeds have been the main crops in the district. But, with the addition of one more sugar mill in 1968-69 the acreage under sugarcane increased to about 10 to 15 times more as compared to previous years. The total area under cultivation has increased by 81,572, 997,332 and 1,402,523 acres during 1960-61, 1968-69 and 1973-74, respectively due to the use of power machines and installation of tubewells.

Table 3 shows the distribution of government, semi-government and private agencies providing farm mechanization facilities in the district. There were 20 chain-type tractors in Agricultural Engineering department which were supplied to the farmers on hire basis for land development. Two private chain-type tractors were also owned by the farmers for their own work. There was a total of 510 wheel type tractors owned by farmers of the area. Many of these tractors were being utilized on hire basis too. There were only two private spare-parts dealers providing parts for Fiat and Belarus tractors and 12 private implement dealers. One well-established implement dealer was in Moro, 10 agricultural ma-

Table 2 Cropping Pattern in Nawabshah District

Crop	Total area (acres)		
	1960-61 <sup>a</sup>	1968-69 <sup>b</sup>	1973-74 <sup>c</sup>
Cotton	132,299	170,388	187,400
Sugarcane	28,937	48,583	572,360
Wheat	212,732	310,000	350,464
Jowar	71,476	72,551	62,500
Bajra	30,472	70,320	36,000
Oil seeds	179,074	200,000	74,869
Others	157,582	125,490	118,930
Total	812,572	997,332	1,402,523

a) Data for 1960-61 obtained from census report of district Nawabshah. b) Data for 1968-69 obtained from Agricultural Extension Dept. c) Data for 1973-74 obtained by personal survey from Revenue and Agriculture departments.

Table 3 Distribution of Farm Mechanization Facilities

Item	Ownership		Total
	Government	Private	
Tracklayer bulldozer	20 (8 out of order)	2	22
Wheel tractor	—	510	510
Spare parts dealer	—	2 (Fiat & Belarus)	2
Implement dealer	—	12	12
Implement manufacturing agencies	—	10	10
Repair workshop	1	11	12
Tractor and machinery servicing centres	—	134	134
P.O.L Station	1	45	46
Tubewell	1,196	450	1,646
Tubewell spare parts dealer	—	8	8
Tubewell boring agencies	1	10	11
Loan facilities	3	14	17

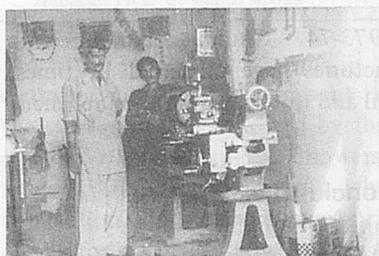


Fig. 1 A private workshop for repair and making of minor parts for tractors and machinery.



Fig. 2 A private tractor repair shop.

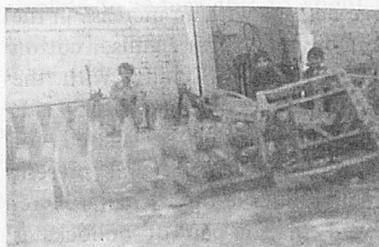


Fig. 3 A private repair shop for farm machinery.



Fig. 4 A tractor used for transport of farm materials.

chinery manufacturing agencies were in Nawabshah. There were 134 private small tractor machinery servicing centers working in the area and 45 private, 1 government

P.O.L stations supplied fuel to the tractors and vehicles, 1646 tubewells of which 1196 in North Rohri Project owned by the government and 450 others were

Table 4 Agricultural Mechanization Facilities

Town	Sugar mills	Cotton factories	Repair workshops	Tractor and machinery service stations	Tractor spare parts dealers	Implement dealers	Tubewell boring agencies	Agriculture extension centre	Total
Nawabshah	1	4	5	40	2	11	8	1	71
Daur	—	—	—	5	—	—	—	1	6
Bandhi	—	—	—	5	—	—	—	1	6
Sakrand	—	1	2	15	—	—	—	1	19
Kazi Ahmed	—	—	1	10	—	—	—	1	12
Kot-Laloo	—	—	1	5	—	—	—	1	7
Naushahro Feroze	—	1	—	8	—	—	1	1	11
Tharushah	—	1	—	3	—	—	—	1	5
Bhiria Road	—	1	1	5	—	—	—	1	8
Padiddan	—	1	—	4	—	—	—	1	6
Kandiario	—	1	—	3	—	—	1	1	6
Mehrabpur	—	1	—	3	—	—	1	1	6
Kotrikaber	—	—	—	3	—	—	—	1	4
Daulatpur	—	—	—	4	—	—	—	1	5
Jatoi	—	—	—	—	—	—	—	1	1
Halani	—	—	—	1	—	—	—	1	2
Moro	1	1	2	20	—	1	—	1	26
Total	2	12	12	134	2	12	11	17	301

Table 5 Distribution of Mills and Factories

Item	1960-61 <sup>a</sup>	1968-69 <sup>b</sup>	1973-74 <sup>c</sup>	Total
Sugar Mills	1	1	2	4
Cotton Factories	1	8	12	21
Oil Mills	—	2	3	5
Large Flour Mills	—	2	3	5
Small Flour Mills	200	350	500	1,050

a. Data for 1960-61 obtained from census report of District Nawabshah, 1961. b. Data for 1968-69 obtained from Agriculture Extension Department. c. Data for 1973-74 obtained by personal contacts from Revenue and Agriculture Departments.

privately owned. The private spare parts dealers were 8 and 11 tubewell boring agencies. Three agricultural development banks supplied loans to the growers for the purchase of tractors, implements tubewells, etc. There were 14 cotton factories and 2 sugar mills which released seasonal loans to the growers.

Table 4 shows the location of various facilities provided by different sectors and towns of the district. There were 17 agricultural extension headquarters in the district. The extension centers introduce modern cultural practices, improved seed and supply machinery and chemicals for insects and pest control.

Table 5 indicates the development in agriculture-based industries. There was only one sugar mill in the district during 1960-61 and the other was installed in

1973-74. Ginning and pressing factories have increased 12 times. Oil and flour mills were established.

### Conclusions

Farm mechanization is being adopted more and more in the district. Cash crops like sugarcane, cotton and oilseeds were grown on large acreage with an increase in the number of sugar mills, cotton factories and oil mills. With the adoption of mechanization aids more land could be spared for useful crops which is at present under fodder crops. Khan (3) reviewed that a pair of bullocks is recommended for the cultivation of 10 acres of land. This means that for available cultivable land in the Nawabshah district 21,540 pairs of bullocks are necessary and one acre of land is required for feeding

one pair of bullocks. Spare parts dealers, repair shops, service and P.O.L stations and loan facilities were scarce. The district is not linked properly with roads and railways for transport of agricultural products and farm supplies.

Roads, education, training, repair, land preparation facilities demonstrations, shows and reliable supply of inputs necessary for increasing production, including irrigation water, farm power and implements and credit facilities are desirable.

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# Comparison of USA and Japanese Agricultural Mechanization Models



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## Introduction

In mechanized agriculture US and Japanese farm machineries are generally regarded as the most advanced ones. Because of this impression agricultural mechanization experts are apt to advise the developing nations' administrators and strategists to utilize these models for ultimate development. The US models are recommended for large-scale tractorization and the Japanese models, for small-scale farming. **Table 1** compares agricultural mechanization status in both countries in order to provide guidelines for the developing countries to formulate their own agricultural mechanization strategies according to their priorities and needs.

## Agricultural Mechanization in the USA

A US farmer possessed about one tractor (approximately 30 kW) in the early 1960s. Twenty years later, the figure has doubled. American history considers 1830-50 as an agricultural development era because within this span of 20 years crop production methods underwent great changes. But the modern farm mechanization did not really evolve until the 19th

**Table 1** Comparison of Selected US and Japanese Agricultural Economics Parameters

Item	US	Japan
Total economically active population (%)	43.5	51.4
Population engaged in agriculture (%)	2.1	11.0
Land use for agriculture (%)	20.6	13.2
Per capita land available (ha)	0.85	0.02
Arable land/farm worker (ha)	85.7	0.8
Cultivated land/farm worker (ha)	84.0	0.6
Arable land utilization (%)	98.0	85.0
Percent irrigated land	10.0	50.0
Farm population/tractor	0.5	5.0
Available power/farm worker (kW)	60.0	6.0
Available mechanical power (kW)	0.7	9.4
Average yield of major crops (t/ha)	4.4	6.2

Source: 2, 6 and 8.

century when the development of the steel plow was followed by the advent of mechanical mowers, reapers, threshers, and later, the application of steam engine primarily for stationary power (7).

In 1830, 136 man-h of labor were required to farm one ha of wheat but mechanization made it possible to reduce this to about 4 man-h/ha. Presently, all farm operations, like tilling, planting, cultivating, milking cows, feed metering, egg gathering, and several other similar jobs are performed mechanically. Efficient and optimum use of farm machinery-cum-worker has been achieved about two decades ago and at present effort is being concentrated to further make these operations precise.

The important achievements in the US agricultural mechanization scheme from the beginning of the present century are illustrated in

## Fig. 1.

The US farm mechanization achieved the present level with the innovative aptitude of the farmers and the small local manufacturers. Government agencies and educational institutions devoted their time and efforts mainly toward basic research which was of an immediate use to the farmers. So, necessity being the mother of invention, US farmers at their own pioneered in agricultural mechanization breakthroughs. Of course, the government stability and protectionism further provided the base for such developmental process. The strong voice of the farmers also helped change several legislations in their favor.

A historic invention was made by a Virginia farmer, Cyrus Hall McCormick, who developed the first reaper in 1831. This invention could have marked the era of the

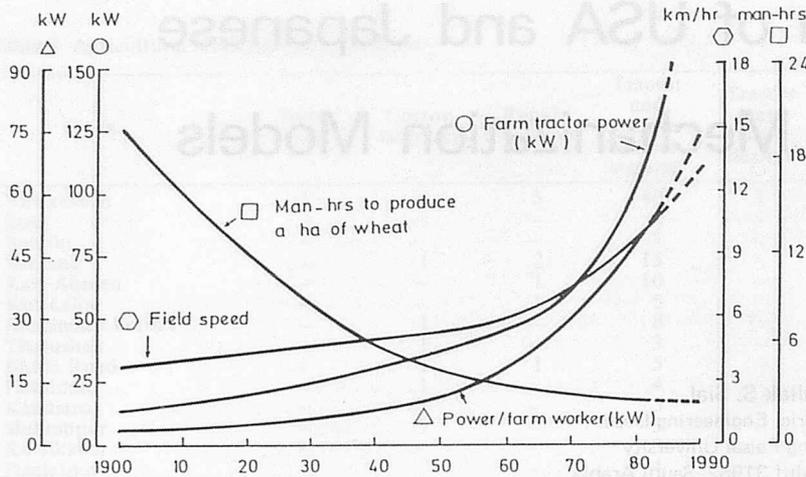


Fig. 1 Agricultural mechanization development and its achievements in the U.S.A.

start of mechanization but unfortunately its significance was realized only about a century later. This conceptual reaper actually set in motion the process of farm mechanization which ultimately changed the economy of the entire world as well as the sociological destiny of millions yet to be born (7).

A Red River Valley farmer wanted a large tractor and there was none available, so he designed and built his own. It created interest among other farmers and he made a few more and ultimately formed a company after his name, Steiger Tractor Co. Now it makes tractors under its name as well as for other manufacturing companies. The airflow planter which is now made by International Harvester Company was invented by an Iowa farmer. Similarly, a number of years ago, some farmers with the help of a few small local equipment manufacturers designed a mechanism to help unload forage wagons easily. More recently, farmers with the help of insurance and electric utility companies added to the National Electric Code of Article 547, Agricultural Buildings. All these examples reflect the US farmer's level of technical thinking which has contributed toward the present state of me-

chanized agriculture.

### Agricultural Mechanization in Japan

Analogue to the US farm mechanization development process, the pioneers of the Japanese agricultural machinery industry were the farmers, local carpenters, and smiths, i.e., the improvement of traditional equipment (local rural inventories). This was followed by the transfer of some designs from abroad and finally the local modifications of the foreign farm machines (generally Swiss and Ameri-

can) and the mass production of better quality machines (4).

Like the American McCormick T. Hirobe was the Japanese pioneer of farm machinery research and development. Mr. Hirobe was the chief engineer of National Agricultural Experiment Station in 1911 (4). Japanese treat 1912-1925 as "dawn of agricultural mechanization" because of the introduction of powered farm implements. But farm mechanization grew rapidly in the post-war Japan because of the need to cope with diminishing labor force. Also, the process was stimulated by the strong demand for labor in other industries, as the latter drew workers from the land they had raised fixed-wage rates (3). Farm mechanization in Japan was thus motivated by a complex mixture of urban 'pull' and rural 'push'.

Mechanization demonstrated the capacity of farmers themselves to modify institutions and practices, where necessary, to make use of new technology. For example, cooperative farming made some kind of mechanization possible in the country. Of course, the present cooperative farming systems are vastly different from those originally set up. Farmers have made continuous rational modifications

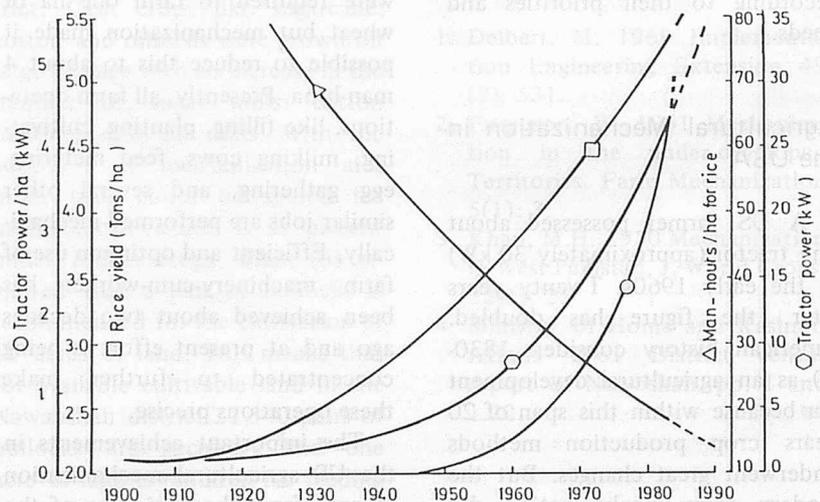


Fig. 2 Agricultural mechanization development and its achievements in Japan.

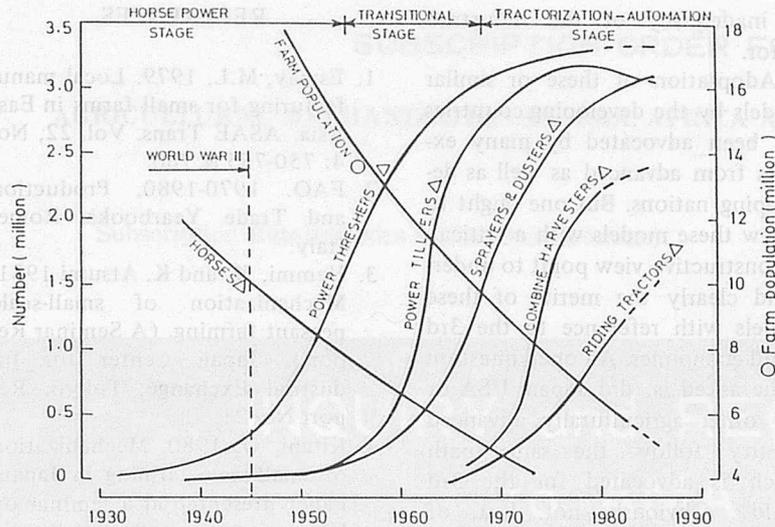


Fig. 3 Diffusion process of farm machinery into Japanese agriculture.

to facilitate mechanization and to accomplish other goals of the family enterprises.

The Japanese government played a vital role in this whole mechanization process by funding programs as those of land consolidation, drainage and irrigation, loan grants, and various other incentives.

The diffusion process of farm machinery into Japanese agriculture is shown in Figs 2 and 3.

### US vs Japanese Agriculture

The two models can be compared from every possible angle to establish pros and cons of each in relevance to their adaptability in developing nations. However, an average aggregate yield of major crops per ha has been plotted against an effective power per ha for the period 1965-1980 in Fig. 4 for both countries to judge the level of input - output per ha.

American agriculture has been often pointed to as the world's most successful model in both production and productivity in terms of per unit of labor. It also has been labelled as a highly capital- and energy-intensive, or in other words, technology intensive and terribly wasteful. But from Fig. 4

the Japanese model is more energy-intensive. Obviously, some variations in the two models are due to the geographic differences.

The Japanese obtain about 40% higher yield/ha than US with almost 100% more power input. The rate of increase of US farm output over the period of 15 years has been 3.5 times more efficient (slope comparison in Fig. 4).

In both countries, some increased production must be credited to advances in non-engineering phase of agricultural technology such as high yielding varieties, more effective use of fertilizer, irrigation and drainage practices, plant protection, and improved cultural practices. If the Japanese higher yield/ha is attributed to the high dose of energy input/area the US multifold rate of yield increase can be credited to the optimal and effective use of mechanical power input/area as well as the other non-engineering inputs.

Unlike the US mechanization approach to farm scale expansion, the Japanese concentrate on small and medium sized farm mechanization depending on the national requirements. The high government subsidization and guaranteed price of rice (Japanese staple food) to farmers at a level three to four

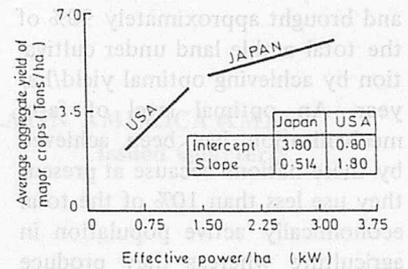


Fig. 4 Input-output/ha between 1965-80.

times the world market helped stimulate higher total production levels of rice each year, in bringing the rice production beyond the point of self-sufficiency in 1969 (1). It was a bitter experience for Japanese because of strong emphasis on a single crop, so they had to decelerate rice production and diversify to other crops.

The US did not import agricultural mechanization technology but rather developed her own as the need arose. But the US did import the capacity - farming oriented European who migrated to the US in search of better opportunities brought with them the agricultural know-how. This constituted a major step towards the agricultural development process. Of course, it took decades under the continuous government patronage to reach the present level of production. This certainly did not happen overnight.

The Japanese, on the other hand, imported the material to help start the farm mechanization program. They imported machinery, implements and designs. They never used the imported equipment as such: rather they modified them extensively to suit the local requirements. Once the suitability (adaptability) of a machine was established, then they produce it in bulk for distribution among the farmers on credit. This helped initiate the technical know-how in the country as well as use the national talent and material.

These nations have followed extensive as well intensive agricultural mechanization techniques

and brought approximately 90% of the total arable land under cultivation by achieving optimal yield/ha/year. An optimal level of farm mechanization has been achieved by these nations because at present they use less than 10% of the total economically active population in agriculture whereas they produce more than what they can actually consume.

These nations made parallel advancement in the industrial sector as well which absorbed the labor force freed from farms due to mechanization.

### Lessons to be Learned

Broadly speaking, both models are good but only under their own circumstances. Transplantation of these models into socio-economic setups dissimilar to their own will result in catastrophe. Even the simple interchange of these models will not prove feasible. Above all, experimentation of these models into other socio-economic structures during the past decades has shown very limited success. Then, why are these models repeatedly advocated to prove prosperous for the 3rd world economies where capital is scarce and labor is cheap and the agriculturally feed labor cannot be effectively utilized due

to inadequacy of the industrial sector.

Adoption of these or similar models by the developing countries has been advocated by many experts from advanced as well as developing nations. But one ought to review these models with a critically-constructive view point to understand clearly the merits of these models with reference to the 3rd world economies. An open question to be asked is: did Japan, USA or any other agriculturally advanced country follow the same path which is advocated for the 3rd world? Obviously not. But, of course, the course these nations followed to achieve present level of production is worth considering for the developing nations.

In both models, role of 'stable' governments have been very significant — providing long and easy term loans and subsidies to farmers and various other incentives and encouraging local manufacturing. Factors like farmers' education, timely weather forecasts, extension services, genetic improvement of the crop varieties, proper crop rotation, government protectionism and dissemination of research findings of one place to the farmers of the other areas helped motivate the farmers to achieve their highest level of production.

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Pakistan

## Introduction

Pakistan has primarily been following an import-based agricultural mechanization strategy with major emphasis on introducing medium size (34-45 kW) tractors from the western countries. Consequently a severe foreign exchange drain is being incurred in mechanizing Pakistan agriculture. Since foreign exchange limitation is expected to continue for a long time, the country has reoriented its mechanization strategy towards indigenously produced farm equipment. The expected production during the Sixth Five Year Plan (1983-88) in the agriculture sector would not be possible without large scale modernisation. For this purpose, large scale introduction of medium size (34 kW) and small size (below 22 kW) tractors will be necessary. Five plants for medium size tractors have already been sanctioned and 2 plants for small tractors are proposed to be set up.

## Objective

The study was undertaken to fulfill the following objectives:

- i) To determine the local production of agricultural machinery; and
- ii) To highlight problem areas in the agricultural machinery manufacturing industry like financing, marketing, availability of raw materials, and manpower.

## Materials and Methods

Data were obtained through interviews with agricultural machinery and implements manufacturers in December, 1984. They were classified as small, medium and large on the basis of investment.<sup>2</sup> The assets (including land and building) of small manufacturers are limited to Rs.5 million whereas the medium manufacturers have assets of more than 5 million. The large manufacturers exceeded the preceding limits. A proportionate random sample of 46 firms (about 10%) of the total firms were

drawn using random sampling technique, out of which 40, 5 and 1 were small, medium and large, respectively. The interviews with manufacturers were carried out in local language for better communication and interpretation.

## Results and Discussion

There are five makes of tractors which are being locally assembled or manufactured in the country. These are Massey Ferguson, Fiat, IMT, Belarus and Ford. The farm implements/machines currently manufactured in the country are: cultivators, scraper, rear blade, land levellers, border discs, ditchers, moldboard ploughs, disc ploughs, disc harrows (imported discs), seed-cum-fertilizer drills, cotton/maize planters, potato planters, manually and power-operated knapsack sprayers, tractor-mounted sprayers, reapers windrowers, cutter binders, combines and threshers.

The major centres of farm machinery manufacturers are marked in Fig. 1. These manufacturers

Table 1 Sale of Locally Manufactured and Imported Farm Machines/Implements

Item	Origin	Local content (%)	Unit price (Rs)	Quantity sold* (1983-84)
<b>Tractors</b>				
Belarus MTZ-50 (41 kW)	USSR	35	105 720	870
Fiat-480 (37 kW)	Italy	11	104 710	8 869
Fiat-640 (48 kW)	Italy	—	139 900	1 628
Ford-4610 (46 kW)	UK	—	126 000	3 113
Ford-3610 (37 kW)	UK	—	97 500	—
IMT-560 (48 kW)	Yugoslavia	—	96 600	560
IMT-540 (39 kW)	Yugoslavia	40	76 400	560
MF-265 (46 kW)	UK	—	115 000	1 992
F-240 (37 kW)	UK	40	88 000	11 640
MF-210 (19 kW)	Japan	—	57 000	300
<b>Power tillers</b>				
Dung-fong (3 kW)	China	—	24 300	100
<b>Land development implements</b>				
Front blade	Pakistan	100	4 900	100
Rear blade	Pakistan	100	1 900	270
Land leveller	Pakistan	100	2 700	200
Cultivator	Pakistan	100	3 200	38 950
Cultivator	UK	Nil	8 000	60
<b>Planting implements</b>				
Seed drill	Pakistan	100	4 200	1 940
Seed drill	Denmark	nil	12 000	22
Maize and cotton planter	Pakistan	100	5 000	618
Groundnut planter	Pakistan	100	3 900	14
Ridger	Pakistan	100	3 700	414
Ridger	UK	60	7 500	26
Post hole digger	UK	nil	16 250	15
Potato planter	Pakistan	100	3 500	107
<b>Weeding and hoeing implements</b>				
Bar harrow	Pakistan	100	2 600	180
<b>Sprayers and broadcasters</b>				
Power sprayer	Pakistan	100	11 000	177
Power sprayer	Italy	nil	15 000	3
Scraper	Pakistan	100	11 000	170
Plank (iron)	Pakistan	100	1 100	20
Border disc	Pakistan	100	4 100	164
Border disc	UK	60	5 000	20
Ditcher	Pakistan	100	3 000	71
<b>Primary tillage implements</b>				
Moldboard plough	Pakistan	100	4 400	250
Disc plough	Spain	60	17 000	43
Chisel plough	Pakistan	100	3 600	520
Chisel plough	Spain	nil	8 000	25
Rotary cultivator	Italy	nil	15 000	25
Rotary cultivator	Yugoslavia	nil	16 000	250
Rotary cultivator	West-Germany	nil	12 000	240
Sub-soiler	Pakistan	100	1 800	55
<b>Secondary tillage implements</b>				
Disc harrow	Spain	60	4 500	175
Disc harrow	Yugoslavia	nil	7 100	50
Disc harrow	Australia	nil	11 000	15
Wheelbarrow sprayer	Pakistan	90	3 500	10
<b>Harvesting machinery</b>				
Reaper-windrower	Pakistan	100	14 000	1 500
Combine harvester	Denmark	nil	115 000	33
Potato digger	Pakistan	100	5 700	19
Groundnut digger	Pakistan	100	3 500	155
<b>Threshing machinery</b>				
Wheat thresher	Pakistan	100	16 500	25 000
Multicrop thresher	Pakistan	100	21 000	16
Sunflower thresher	Pakistan	100	11 000	63
Maize sheller	Pakistan	100	4 000	80
<b>Handling and haulage machine</b>				
Trolley	Pakistan	100	11 000	12 800
<b>Others</b>				
Cane crusher	Pakistan	100	1 900	15 000
Chaff cutter	Pakistan	100	600	40 000
Manure spreader	UK	nil	196-967	1
Grain dryer	USA	nil	140-000	7
Sugar extractor	Pakistan	100	1 200	10
P.T.O. pulley	Pakistan	100	950	—
Pump	Pakistan	100	2 500	3 300
Diesel engine (high speed)	China	60	8 500	802

\* The sales figures for imported items are actual, while those for locally-produced items are projected from a survey of 40 firms, carried out by the Farm Machinery Institute.

1. BAHAWALPUR.
2. DASKA.
3. FAISALABAD.
4. GUJRANWALA.
5. LAHORE.
6. MIAN CHANNU.
7. RAHEEM YAR KHAN.

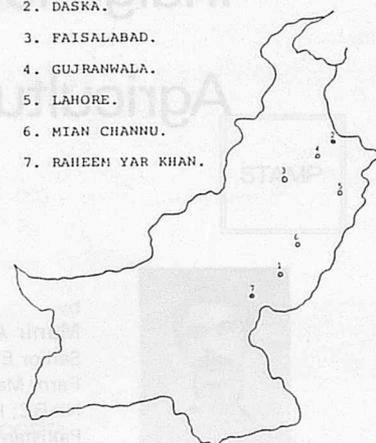


Fig. 1 Major farm machinery manufacturing centres in Pakistan.

have the capability of making all types of farm machines, provided the proper materials are readily available, Table 1 shows the 1983-84 estimated sales value of both locally manufactured and imported farm machines, and gives an idea of the contribution of local farm machinery manufacturing industry in the country's economy.

The Government provides several incentives to the farm machinery manufacturers such as exemptions from income tax, refund of custom duty paid on the import of raw materials and permission of importing workshop machines, etc. These incentives have helped in rapid expansion of the local farm machinery manufacturing industry in the past decade.

The farm machinery manufacturing capability of the country is not fully utilized. Some areas require strengthening or improvements.<sup>3</sup> The research and development facility (R&D) was almost non-existent in the country. There were only a few large farm machinery manufacturers which have separate R&D sections in their premises, whereas the rest of the manufacturers did not have even a single person on their staff, who could read a drawing, or consult a reference book or a guide on design. Besides, the majority of small and medium

units had unqualified foremen in their workshops. The percentage of trained foremen in small and medium units were only 17.5 and 25, respectively. This was one of the factors responsible for the poor quality of locally produced agricultural machines/implements. Foremen supervised all types of operation such as machining, drilling, welding, fitting, etc. There was an acute need to train them in reading/understanding engineering drawings and other aspects of manufacturing techniques.

The purchasing and storing of raw materials and parts is a very important activity in a manufacturing concern. This activity is to be managed in such a way that financial resources of the industry are not strained and the manufacturing process does not slow down. Majority of small (83%) and medium (50%) manufacturers were unable to purchase raw materials in bulk quantity or at wholesale price. Most of the manufacturers purchased raw materials from the local market and Government concession for allowing duty-free material cannot be utilized. These factors resulted in low quality and high cost of locally-produced farm machines/implements. In addition, the storage space is often very poorly arranged and record was about non-existent. Hence, it was difficult to trace the required materials and parts.

The manufacturing machines and the buildings of most of farm machinery manufacturer were obsolete. To update these facilities requires capital and in many cases no outlet for the sale of used machinery, furniture, etc. were available. The approved plans for constructing a modern manufacturing facility incorporating safety features, use of local materials, etc. were not available. The workers of farm machinery industry were working under unsafe conditions with inefficient machines. This

activity was poorly managed by the local farm machinery manufacturers.

The marketing sector is completely ignored by this industry. The field demonstrations of various locally-manufactured machines was being handled by research institutes in the country. Similarly, the demand surveys of farm machines were also being conducted by the research institutes. As a matter of fact such activities should be undertaken by a farm machinery manufacturers' association. The majority of small (97.5%) units sold their products directly to the farmers while the medium (50%) and large (100%) used dealer networks for marketing their products. The average number of dealers of small, medium and large manufacturers were 6,8 and 45, respectively.

The Agricultural Development Bank of Pakistan (ADBP), the Industrial Development Bank of Pakistan (IDBP), the Pakistan Industrial Credit and Investment Corporation (PICIC) and most of the commercial banks provide loans to the manufacturers. The rate of interest of these financial institutions varies from 11 to 15%. The manufacturers generally consider this too high. Besides this, the procedure for obtaining the loans is quite lengthy and complicated. All credit institutions require a feasibility study from the manufacturers to ascertain the profitability of the business venture, so that loan recovery is certain. Such studies cannot be prepared by the manufacturer due to low educational standards of the majority of them. They also could not hire a consultant. In the absence of a feasibility report, the credit institutions provide credit against collateral and usually, the manufacturers could not arrange collateral to match the required credit.

#### Agricultural Mechanization Promotion

There are three universities in the country awarding B.Sc. degree in agricultural engineering. They turn out about 100 graduates annually. Today only one university has started a M.Sc. programme in agricultural engineering. Two universities are offering B.Sc. degree in agricultural mechanics; they turn out approximately 25 graduates annually. There are three institutes in the country awarding diploma in auto and farm machinery, and approximately 50 persons qualify each year. There are three agricultural machinery research institutes in the country. All of them have been established in the recent past (less than 10 years). These are the Farm Machinery Institute (FMI), Islamabad, the Agricultural Mechanization Research Institute (AMRI), Multan and the Agricultural Mechanization Research Cell (AMRC), Hyderabad. The FMI coordinates the activities in agricultural mechanization research, and is the focal point of national and international cooperation. In addition, four testing sub-stations, one in each province, have been established by the FMI with the assistance of the World Bank.

There are a dozen institutions in the country which offer vocational training and turn out tractor mechanics, operators and technicians. Three large farm machinery manufacturers have the necessary short-term training. Only a few farm machinery manufacturers maintain a dealer network on nation-wide basis. They provide after-sale service, repair and spare parts through their dealers. The rest of the manufacturers do not maintain any dealer network, hence they cannot render service or repair facility. The service usually is provided by a local workshop, often run by unqualified mechanics, poorly equipped and built. Therefore, most often the service is unsatisfactory, and hence make the farmers unhappy.

The agricultural mechanization extension activities fall in the two categories, viz, industrial extension and agricultural extension. Industrial extension is aimed at manufacturers and is carried out by research institutes. The FMI enjoys great respect and good relations with the farm machinery manufacturers in the country. Help and guidance is provided in manufacturing and field testing of farm machines. In many cases help in design improvement, workshop layout, store reorganization and staff training has been provided by the Farm Machinery Institute.

Agricultural extension in farm mechanization is rather poorly staffed and organized. As a matter of fact, this activity is the responsibility of provincial governments. The FMI and provincial institutes are playing their role through demonstration, field days, news letters, radio and TV programmes.

#### Conclusions and Recommendations

1. Majority of the farm machinery manufacturers were small and were not in a position to export

their commodities.

2. In order to expand production, export of agricultural machinery should be considered. The Agricultural Machinery Manufacturers Association should try to promote joint marketing efforts for exports.
3. Small scale manufacturers complained about high interest rates and difficult loan procedures. Hence, state-owned banks should provide loan on low interest rate and simplify their loan procedure so that small manufacturers could be benefited.
4. Small and medium-scale manufacturers should purchase prior tested raw material for better quality of their products.
5. The Ministry of Industry and Production, in collaboration with Farm Machinery Institute (FMI) and NARC should assist local manufacturers in the preparation of workshop layout, setting up of Pakistan line, etc.
6. The Research and Development Institute should be strengthened in design and manufacturing techniques so that it can assist the local industry in a proper way.

#### REFERENCES

1. (1983), The Sixth Five Year Plan (1983-88), Planning Commission, Government of Pakistan.
2. (1983), A Hand Book of Agricultural Machinery Manufacturers in Pakistan published by Farm Machinery Institute, Pakistan Agricultural Research Council, Islamabad.
3. Ahmad, S. Iqbal (1984), Agricultural mechanization and agricultural machinery manufacturing in Pakistan, Proceeding of the 2nd International Conference, on Agricultural Machinery Industry in developing countries, Amsterdam, January 23-26. ■■

## ABSTRACTS

*Automation on Farm – A Review:* A.C. Srivastava, Scientist, Indian Institute of Sugarcane Research, Lucknow, India.

This paper reviews many phases of the work related to automation on farm around the world. Recent advancement in the electronic field makes the automation a little easier than before. A remote controlled device is thus coming up as a possibility for sugarbeet thinning, tomato-sorting, potato grading, apple-bruise detecting unit and, above all, for a driverless tractor operation.

*Radiation and Energy Balances from Standard Meteorological Observations in Bangladesh:* Md. Shahid Ullah Talukder, Assistant Prof., Dept. of Irrigation and Water Management, Bangladesh Agricultural University, Mymensingh, Bangladesh

There is limited information available in Bangladesh on radiation and energy balances at the surface as affected by climatic conditions. Estimation of radiation and energy balances are, therefore, needed for water balance studies, irrigation planning, scheduling and management, and other practices related to efficient utilization of available water resources. Major climatological data like temperature, relative humidity, wind speed, rainfall and sunshine hours for a period of 5 years from eight different but evenly distributed locations in Bangladesh were collected and computed for determining radiation and energy balances at the surface. The objectives of this study were to determine the radiation and energy balances at the surface at various locations in Bangladesh.

Components of radiation and energy balance equations were assessed. About 75 to 80 % of the net radiation received at the surface is used for latent heat of evapotranspiration and the rest is used for soil heat flux and sensible heat flux. Sensible heat flux towards the surface is an important source of energy for evapotranspiration while advected energy utilized for evapotranspiration was relatively small.

*Tractive Performance of Three Agricultural Tractors:* J.G. Shebi, Agric. Engineer, Ministry of Agric. and Natural Res., Kaunda, Nigeria. K.C. Oni, Senior Lecturer, University of Ilorin, Nigeria. F.G. Braide, Senior Lecturer, Ahmadu Bello Univ., Nigeria.

Tractor power, tractor speed and tractor tire

inflation pressure with different tillage implements were investigated, including the influence of the above parameters on travel reduction, drawbar pull, soil resistance to cone penetrometer pressure and soil bulk density. Measured drawbar pull was found to be consistently higher than estimated drawbar pull. The higher values of measured drawbar pull was probably due to the change in soil properties from point to point. Travel reduction decreased from 11.2 to 3.5% while estimated drawbar pull increased from 0.72 to 1.42 kN when the tractor power was increased from 19 to 47 kW.

Increasing the tire inflation pressure from 83 to 110 kPa increased travel reduction from 12.6 to 13.4% while the estimated drawbar pull decreased from 1.25 to 1.11 kN for a given tractor. The measured drawbar pull was found to decrease from 2.21 to 1.37 kN.

*Experimental Processing of Coffee Harvested by Plastic Nets:* A.D. Sharma, Asst. Prof., Univ. of Puerto Rico, Mayaguez. C.J. Torres, Administrator (Retired). E.J. Ravalo, Assoc. Prof., Univ. of Puerto Rico, Mayaguez.

Coffee berries harvested using plastic nets were cleaned, pulped, and dried to determine the output-input ratio of dried coffee bean yield to the material collected. The coffee berry recovery ranged from 20 to 27% depending on the prevailing weather conditions. The method of harvesting coffee by plastic nets has been adopted by some growers in Puerto Rico during the last 15 years, although it still lacks the mass appeal for various reasons.

*Stabilization of Rice Bran by Steaming and Conduction Drying in a PHTC—Continuous Rice Bran Stabilizer, Part II:* A. Chakraverty, Asst. Prof., Indian Institute of Technology, Kharagpur. D.S.K. Devadattam, Research Scholar, ditto.

A continuous rice bran stabilizer of 30 kg/h capacity consisting of a horizontal steam jacketed screw conveyor and a steam jacketed cylindrical dryer has been developed and tested. Results of the studies on open steaming of rice bran for 1.5, 3.0, 5.0 and 7.5 min followed by conduction drying at 120°C for 10 min on stabilization of rice bran show that open steaming for 5 min followed by conduction drying at 120°C for 10 min are optimal for stabilization of rice bran in the above

stabilizer. Bran thus treated could be stored in sealed polyethylene bags for 60 days at 20-38°C and 50-88% relative humidity with free fatty acids (FFA) below 8%. The regression equations, developed for a drying surface temperature of 120°C for 20 min treatment, relating FFA content to heat treatment period, storage period and type of packaging material, are in fairly good agreement with the experimental data.

**Effect of Seeding Methods on Plant Emergence:** P.D. Gupta, Agric. Engineer. D.T. Anderson, Former Canadian Principal Adviser, All India Coordinated Research Project for Dryland Agriculture, Santoshnagar, Hyderabad, India.

The paper deals with the effect of six different seeding methods using bullock-drawn machinery at three soil moisture conditions on early and maximum plant emergence of jowar seed. The overall performance has been evaluated by combined analysis to find out a method for maximum field emergence efficiency suited for seeding under receding and optimum moisture conditions of dryland. The pora method and single row developed planter were given 54.4% and 56.8% actual field emergence as compared to others.

**Effect of Seed and Fertilizer Placement on Plant Emergence:** P.D. Gupta, Agric. Engineer. U.M.B. Rao, Scientist, Central Research Institute for Dryland Agriculture, Hyderabad, India.

The experiment was conducted to find out the effect of placement of nitrogenous fertilizer on plant emergence of jowar crop under dryland conditions.

Four different methods of placement (side, band, below and mixture) have been studied with the help of bullock pair, country plough and bamboo pora tube. The quantity of nitrogenous fertilizer which can be safely mixed with the seed during seeding in broad and narrow furrow opener has also been evaluated.

**Water Loss Reduction in Conveyance System Using newly Fabricated Low-cost Canal Sections:** Md. Abdul Hamid, Scientific Officer, Institute of Nuclear Agriculture, Mymensingh. A. Khair, Asst. Prof., Bangladesh Agric. Univ., Mymensingh.

Cement, sand, khoa and ash (burnt rice husks) were used to fabricate low-cost precast portable irrigation canal sections. It was found that the seepage rate through the sections made of these materials in different proportions and thicknesses, with capacity ranging from 0.0283-0.0566 m<sup>3</sup>/sec. were very much less in comparison to seepage losses through unlined canals in the field. The seepage rate through the cement-sand precast section in the ratio of 1:4 with a thickness of 2.54 cm ranged from 0.0059-0.0015 m<sup>3</sup>/m<sup>2</sup>/day and its construction cost was 1.27 U.S. dollar per running meter. The seepage rate through the cement-sand-khoa precast section in the ratio of 1:4:8 with a thickness of 5.08 cm ranged from 0.0057-0.00035 m<sup>3</sup>/m<sup>2</sup>/day and its construction cost was 1.4 U.S. dollar per running meter. While through cement-ash-sand-khoa section in the ratio of 1:2:4:8 with a thickness of 5.08 cm ranged from 0.0054-0.0010 m<sup>3</sup>/m<sup>2</sup>/day and its construction cost was 1.27 U.S. dollar per running meter. ■

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**"Farming Ready to Enter  
the Technological Era"**

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There is a lot of new technology waiting for farmers in the U.S.A., Europe and elsewhere in the world. That is the overview conclusion of the Royal Agricultural Society of England's International Symposium on Farm Electronics and Computing held at Stratford-upon-Avon in England on October 20-25, 1985 where delegates gathered from 30 different countries to compare notes.

The electronic engineer has had a benign and productive influence on the question of field and barn machinery — both in control systems and quality assessment and this is only beginning. On its way too is the application of robotics to farming — the fully automated milking shed is now in sight.

Farm uptake of microcomputers is not very different between countries. Apart from bureau services only a minority — say 5% of farmers are fully into micros in business planning terms. A big role was seen for micros in data capture — common examples being feed allocations, milk recording, and so on. Even bigger breakthroughs will come when work on electronic identification of livestock comes about: a chip implant or tag could not only identify the animal from birth to slaughter but capture essential growth and health data as well. Whilst France has pushed ahead with Mini-tel an electronic I.T. system for its farmers, there is a general view that as far as electronic and computing is concerned a lot of technology is looking for a market. Progress on uptake by farmers is slow: the critical criteria

being the provision of relevant information and friendly hardware — with easy access.

The electronics engineer is pioneering a benign revolution in farming worldwide — but delegates all recognised the need for their work and its implications to be better understood. As scientists they do respond to the market — but there is need for those who fund research budgets in the public sector to be more understanding of the opportunities offered by electronics and computing — both of which herald the change from an era of industrial society to a technological one — and farming is not likely to be far behind.

Symposium Chairman and organiser George Jackson, the Royal Agricultural Society of England's senior agricultural technologist, welcomed the message which delegates put forward: there is immense scientific competence and know how: "the market and society must respond if we are to maintain agricultural progress and release scarce resources for other productive uses."

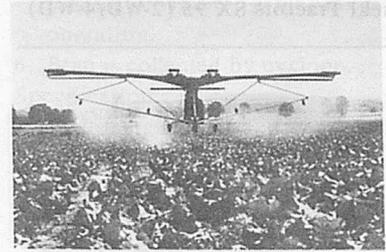
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**International Aircraft Corporation  
supplies light utility aircraft and  
crop treatment systems**

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The development and increased usage of ultra-low-volume crop treatment with controlled droplet applicators and vegetable oil as the chemical carrier has created a need for an efficient and accurate spray vehicle.

The most important breakthrough in ultra-low-volume ag crop spraying is the replacement of water with vegetable oil as the chemical carrier. One of the great-



est advantages of vegetable oil over water is that the oil does not evaporate. Small water droplets will evaporate in seconds leaving chemical particles floating in the atmosphere. Vegetable oil, by effectively eliminating evaporation can help to dramatically reduce drift.

Additionally, vegetable oil will spread over a leaf area up to 16 times greater than a water droplet. This effect decreases the amount of chemical needed and increases the area of leaf covered. Hairy-leaved plants or insects are no barrier to the chemical carrying oil droplet.

The synergistic combination of controlled droplet application, the replacement of water with vegetable oil, and the ability of the AG-7 aircraft to fly and spray crops under 48.3 mph (the upward speed limit of accurate spraying) results in a viable and economical solution to growers' crop treatment problems.

International Aircraft Corporation provides the aircraft and technology to allow growers to cut chemical application costs to less than 40 cents per acre. Costs may be reduced to as little as 9 cents per acre when spraying at 200 feet for applications such as mosquito control or tree spraying.

An information package is available free of charge from: International Aircraft Corporation, N34 W28341 Taylors Woods Road, Pewaukee, WI 53072, U.S.A. ■■

## NEW PRODUCTS

### Iseki Tractors SX 95 (2-WD/4-WD)



#### Features:

**Power**— Engine is specially designed for large tractors. Unequalled low-speed torque. Tough and maintenance-free. Outstanding durability.

**Comfort**— Human engineered full floating cab. Shuttle change levers. Flat floor-deck.

**Operability**— Wide range speeds. Tilting, telescoping steering wheel.

**Field work**— Dependable, high-traction 4-wd. Independent 2-speed PTO. Integral power steering. Wet-type multi-disc brake.

**Versatility**— High-power 3-point linkage. Triple attachment control.

#### Specifications:

Dimension (L x H x Tread):

4265 x 2695 x 1410 mm

Weight: w/ROPS 3600 kg

Engine: Water-cooled, 4-cycle diesel, 95HP/2200 rpm.

Speed: 12-forward, 4-reverse.

For further information contact: Iseki & Co., Ltd. Foreign Affairs Div. 3-6, Kioi-cho, Chiyoda-ku, Tokyo, 102 Japan

### Kubota M8030F/D Tractor, 4-WD

#### Features:

1. Designed with direct-injection



engines to assure easy start-up, while also providing stingy fuel consumption.

2. Wet disc brakes; creep speeds; hydraulic draft, position and combination implement control; power steering; front differential lock with a new automatic system; and SAE Category I and II 3-point hitch.

3. Operator comfort and ease of operation.

#### Specifications:

Dimension (L x W):

3820 x 2070 mm

Weight: 2780 kg

Speeds: 16 forward/4 reverse

Engine: water-cooled, 4 cylinder, diesel, 81hp

For further information contact: Kubota, Ltd.

2-47, Shikitsuhigashi 1-chome, Naniwa-ku, Osaka 556-91, Japan

2. Safety measures — all the power transmission parts are covered.
3. Compact body has a low center of gravity.
4. Wide range of attachments for variety of soil works.
5. Suitable speeds can be selected by one-touch operation of buttons for various operations.

#### Specifications:

1. Chassis

Dimension (L x W x H):

1460 x 605 x 890 mm

Gear shifting: 2 forward, 1 reverse

Standard tire: 3.50-7

PTO shaft: low 629/high

1095 rpm

2. Engine

Model: G500B-14, aircooling, 4-cycle

Displacement: 185 cc

Max. output: 5 PS/2000 rpm

Fuel tank capacity: 3000 cc

Starting system: recoil starter attached with automatic pressure reducer

For further information contact: Mametora Agric. Machinery Co., Ltd. 9-37, Nishi-2 chome, Okegawa-shi, Saitama-ken, Japan

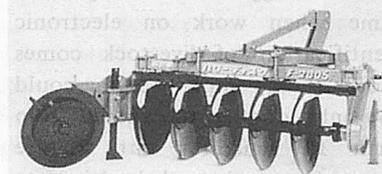
### Mametora Power Tiller MC-500D, New "To-ne"



#### Features:

1. Electronic engine is provided — low noise and one-touch starting.

### Hinimoto Power Disc F-2805



#### Features:

If blade shape discs are rotated with a 3 to 5 times increase over that of the speed of the tractor tires, the discs slip and cut into even hard soils, smoothly penetrating even the deepest layers.

## NEW PRODUCTS

The slip creates a strong thrust to facilitate the tractor driving force. The slip also creates a positive effect in terms of deep plowing by deeply cutting through the soil by rotation. The rotation of the blade's concave portion naturally causes the plowed and cut soil spattering to both sides.

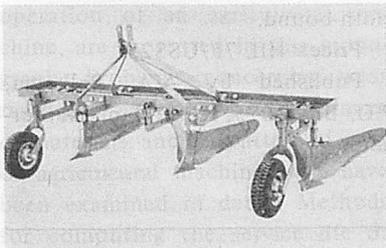
### Specification:

Dimension (L x W x H):  
2740 x 1960 x 1285 mm  
Weight: 630 kg  
Disc blade diam.: 710 mm  
Disc blade angle: 25-35°  
Rear wheel diam.: 710 mm  
No. of discs: 5  
Plowing depth: 150-300 mm  
Plowing width: 1430-1590 mm  
Working speed: 3-5 km/h  
Applicable tractor: 45-70 PS  
3-Point hitch: Category I or II

For further information contact:

Toyosha Co., Ltd.  
55, Joshoji-16, Kadoma-shi,  
Osaka 571, Japan

### Sukigara Triple-row Ridger Model TCR-M



### Features:

1. Frame is usable for ridging and cultivating works.
2. Leading wheels help to ensure uniform ridging depth.
3. Frame has high clearance — no damage occurs to the crop.
4. Ridgers and other operating

parts can be replaced easily.

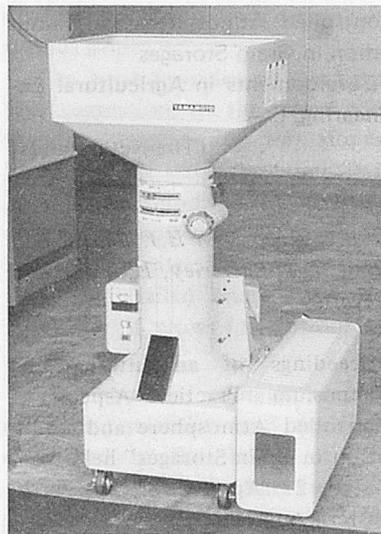
### Specification:

Dimension (L x W x H):  
972 x 2162 x 885 mm  
Weight: 72 kg  
Row width: 480-780 mm  
Working speed: 3-5 km/h  
Power required: 15-20 hp  
Efficiency: 0.4-0.8 acre/h  
Category: 0(Large) or 1  
Application: Furrowing, ridging, and cultivating.

For further information contact:

Sukigara Agricultural Machinery Co., Ltd. Yahagi-cho, Okazaki-city, Aichi, 444 Japan

### Yamamoto Rice Whitener Model VP-75



### Features:

1. Rate of whitening is adjustable.
2. Low temperature operation ensures good taste of the finished rice.
3. Even the unmaturred grains are whitened.
4. Uniform pressure in the milling chamber results in a high yield ratio.

5. Rice does not remain in the milling chamber after milling operation.

6. Bran is collected by cyclone.

### Specification:

Whitening system: vertical type, one-pass

Dimension (H x W x L):  
1075 x 430 x 620 mm  
Weight: 41 kg  
Required power: 0.75 kW  
Electric mains: 3 phase 200 V, 50/60 Hz  
Efficiency: 60 kg/h  
Revolution: 680 RPM  
Hopper capacity: 30 kg

For further information contact:

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## BOOK REVIEW

Proceedings of the Annual Convention of the Indian Society of Agricultural Engineers, October, 1985

(India)

Vol. 1 Farm Machinery and Power  
Vol. 2 Soil and Water Engineering  
Vol. 3 Process, Food and Dairy Engineering  
Vol. 4 Energy in Agriculture

Each volume costs US\$20 plus surface mail postage 6. Whole set of 4 volumes containing 141 good quality papers costs US\$80 plus 20 and Abstract of all the 255 papers presented US\$5 plus 3.

The orders may be sent to Mr. N. S.L. Srivastava, Project Coordinator (DAP) and Convener Silver Jubilee Convention of ISAE 1985, Central Institute of Agricultural Engineering, Nabi Bagh, Berasia Road, Bhopal 462018, India

Directory of Agricultural Machinery and Manufacturers

(India)

Compiled by G. Singh and K.C. Bhardwaj

The majority of farmers of Asia, Africa and Latin America, who are small land holders, cannot afford large powerful machinery. They need appropriate technology to suit their economic status as well small land holdings. There is a considerable demand throughout these continents for the simple but efficient agricultural equipment comprising manually-operated, animal-drawn and small power-operated machines. But no publications have been brought out so far to provide these informations.

Hopefully the publication full of illustrations, specifications, performance and cost data will bring awareness of improved agricultural machine among the readers. It is expected that the farmers, extension workers, implements dealers, exporters, manufacturers and the researchers would benefit from this publication. At the present juncture when mechanization has been progressing fast, publication will bridge the gap between the improved agriculture and traditional farming.

Size: 23.5 cm x 18 cm, 245 pp, soft cover

Price: US\$15.00

Published by Central Institute of Agricultural Engineering, Nabi Bagh, Berasia Road, Bhopal-462018 (M.P.), India

Controlled Atmosphere and Fumigation in Grain Storages  
—Developments in Agricultural Engineering, 5 —

(The Netherlands)

by B.E. Ripp with H.J. Banks, E.J. Bond, D.J. Calverley, E.G. Jay and S. Navarro

Proceedings of an International Symposium "Practical Aspects of Controlled Atmosphere and Fumigation in Grain Storages" held from 11 to 22 April 1983 in Perth, Western Australia

This volume deals with the practical aspects of the technology of controlled atmosphere and fumigation in grain storages. It contains much valuable information for engineers, entomologists, pest control officers, managers, and all involved in grain handling, storage, transport, and quality control.

Size: 25 x 17 cm, 798p, hard cover

Price: US\$109.50/Dfl. 285.00

Published by Elsevier Science Publishers, P.O. Box 211, 100 AE Amsterdam, The Netherlands

Agricultural Machines — Theory of Operation, Computation of Controlling Parameters and the Conditions of Operation

[Russian Translations Series, 31]  
(Netherlands)

by N.I. Klenin, I.F. Popov, V.A. Sakunin

The authors describe the various working parts of agricultural machines in relation to their interaction with the material being processed. A substantial portion of the book has been devoted to the study of the operating processes. The setting of mechanisms to optimum operation has been described in light of the properties and conditions of the material to be processed.

The authors have selectively elaborated the details necessary for engineers and technicians to help them understand and resolve practical engineering problems.

Size: 24 cm x 16 cm, 650 pp, cloth-bound.

Price: Hfl. 75/US\$25

Published by A.A. Balkema, P.O. Box 1675, Rotterdam, Netherlands

Digging of Soils by Earthmovers with Powered Parts

[Russian Translation Series, 32]  
(Netherlands)

by V.K. Rudnev

This book describes the design

## BOOK REVIEW

features and operation of earthmovers with powered parts. The prospects for the production of such machines are discussed on the basis of feasibility studies and generalized techno-economic evaluation.

The problems in planning and conducting investigation of digging processes using such machines have been explained in light of models and actual field trials. Design methods have also been presented for these machines.

This monograph will be of interest to engineers and researchers engaged in the production and operation of earthmovers.

Size: 24 cm x 16 cm, cloth, 146 pp

Price: Hfl. 55/US\$20.00

Published by A.A. Balkema

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Wear of Agricultural Machine Parts  
[Russian Translation Series, 36]  
(Netherlands)

*edited by M.M. Severnev*

Results of theoretical as well as experimental investigations on the wearing-out capability and corrosiveness of a medium, during the operation of an agricultural machine, are presented in this monograph. Problems concerning wear resistance and corrosion resistance of materials, and the pattern of wear of agricultural machine parts have been examined in detail. Methods for computing the service life of agricultural machine parts have been suggested.

Recommendations are offered for increasing the durability of parts.

The monograph is intended for scientists, engineers and technicians who are engaged in designing, manufacturing, operating and repair of

agricultural machines.

Size: 24 cm x 16 cm, 271 pp, cloth

Price: Hfl. 55/US\$19.50

Published by A.A. Balkema

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Operation of Soil-Working Implements in Hilly Regions

[Russian Translations Series, 37]

(Netherlands)

*by Kh. A. Khachatryan*

This book is in three parts. Part I deals with the problems of equilibrium of soil-working implements in conditions of hilly regions. Part II deals with the actual process of soil-working depending on topographic features. Part III is devoted to the study of resistance to the traction of soil-working implements on various slopes.

The book provides various practical suggestions on the use of soil-working implements on slopes. Based on the data presented, it is possible to modify the existing designs of soil-working machines and implements. The author provides a detailed analysis of the mounting of plows for working on slopes.

The book is recommended to engineers, scientists and designers engaged in the design of soil-working machines for hilly regions.

Size: 24 cm x 16 cm 239 pp cloth

Price: Hfl. 70/US\$25

Published by A.A. Balkema

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Soil Physics and Rice  
(Philippines)

With a world demand for rice

that is expected to grow by an annual 3% for the next 15 yr, it is essential that improved soil and water management methods be developed and adopted for rice-lands, both to increase food production and to avoid soil erosion and degradation.

These issues and problems were addressed in the Workshop on Physical Aspects of Soil Management in Rice-based Cropping Systems at IRRI 10-14 Dec. 1984. It was attended by 55 participants from 21 countries and by several IRRI staff members.

The proceedings include 26 papers, 19 poster abstracts, and recommendations for future research, training, and coordination of programs.

Participants concluded that there is significant potential to develop practical technologies that will increase food production from lowland rice-based cropping systems. Essential to these increases will be applied research on those physical aspects of soil management that now limit food production.

Size: 23 cm x 25 cm, 436 pp, soft cover.

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

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Journal of Philippine Development  
[First Semester 1985, No. 1]  
(Philippines)

This special issue features most of the papers presented during the Seminar-Workshop on "The Consequences of Small Farm Mechanization on Production, Employment and Incomes in the Philippines" held on 1-2 December 1983 at the Development Academy of the

## BOOK REVIEW

Philippines in Tagaytay City.

The workshop attempted to look into the effects of small farm mechanization in areas where it has been adopted.

In addition, the workshop also addressed the question of institutionalizing the process of mechanization. It found out that (1) the demand for farm machineries was induced by changes in the demand and supply for agricultural products and in the prices of inputs and outputs which make up the agricultural production system; and (2) the management of a mechanization strategy involved a longrun commitment and that there was a need for the right mix of capable leaders, adequate resources and policies which were flexible and responsive to changing need and economic conditions and uniquely tailored to the needs of the rural poor.

Size: 23 cm x 15 cm, 248 pp, paper cover.

Published by Philippine Institute for Development Studies, NEDA sa Makati Building, 106 Amorsolo Street, Legaspi Village, Philippines.

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### Modelling the Impact of Small Farm Mechanization

[PIDS Monograph Series No.5]  
(Philippines)

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The papers contained in this monograph were designed to examine the impact of agricultural engineering technologies on production, employment and rural incomes. The first three focus on macro issues; a fourth addresses the choice of technique question at the farm level. The two general equilibrium models from the Philippines (Ahammed and Herdt) and from Indonesia (Ahammed and Duff), examine the effects of alternative

mechanization policies on output, use of labor, total income and income distribution by farm and income group. This class of model measures both the direct and indirect impact of technological change and explicitly quantifies the multiplied effects of the consumption/production linkages between various sectors of the economy. These general equilibrium models are valuable tools in assessing the impact of various policy options.

Each model is part of a study of the Consequences of Small Farm Mechanization on Production, Employment and Income in Selected Countries of Asia sponsored by the International Rice Research Institute in collaboration with research institutions in Indonesia, Thailand and the Philippines. The Philippine Institute for Development Studies has taken the lead in communicating the results of this research to development practitioners. Financial support for the study and publication of these results has been provided by the United States Agency for International Development.

Size: 23 cm x 15 cm, 109 pp, paper cover

Published by Philippine Institute for Development Studies, NEDA sa Makati Building, 106 Amorsolo Street, Legaspi Village, Makati, Philippines

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### Small Farm Mechanization for Developing Countries (U.K.)

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by Peter Crossley and John Kilgour  
with a chapter by J. Morris

This book has been written by two agricultural engineers, with very useful assistance (in Chapter 8)

from an agricultural economist. We have all been involved with the problems of small farm mechanization for a number of years. Our aim has been to use engineering and economics respectively as tools to tackle the particular problems of agriculture in the small farms sector of developing countries. The aim is continued in this book, which should be regarded as an aid to making and implementing the basic decisions relating to power in agricultural mechanization.

Since ours is a physical world, the application of physical science (or engineering) to the solution of its problems will always be necessary and relevant. But so, too, are considerations of economics and people. Even if the engineering is 'right' there is no guarantee that a machine or system will be regarded as socially acceptable or be economically viable. This point is often made and is a very valid one. The argument is favour of tackling the engineering, however, is that a machine must be able to perform its basic functions before it can even begin to be regarded as economically or socially acceptable. That is why we have endeavoured to show here how engineering principles and techniques can be applied to the particular problems of smallholder mechanization.

Size: 23.5 cm x 16 cm, 269 pp, hard cover.

Price: US\$39.95

Published by John Wiley & Sons, Inc. Export Sales Dept.  
605 Third Avenue  
New York, N.Y. 10158  
U.S.A.

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### Tools for Agriculture — A Buyer's Guide to Appropriate Equipment (U.K.)

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## BOOK REVIEW

*Introduction by Ian Carruthers*

Today there is a growing demand for information on technology alternatives on the level of small-scale farming. More and more, agricultural implements, tools and items of equipment have shifted into the centre of attention.

Information on such subjects is, however, hard to get: if you want to buy a 90-hp tractor you can find the appropriate information almost everywhere in the world, but if you look for simple, small-scale equipment you are lost. In fact, the earlier editions to *Tools for Agriculture* were almost the only source of external information GATE was able to rely on in answering questions about low-cost agricultural equipment and where it can be obtained. But catalogues like *Tools for Agriculture* are not just things to lean back on. They are like tools themselves, and from time to time they need sharpening up and renewing on the basis of experience.

ITDG proposed to produce a new catalogue, to be improved in a number of ways.

- to contain the most factual and most reliable information on manufacturers of small-scale equipment worldwide;
- to collect information from Third World countries in order to establish direct south-to-south trade relations — instead of technical hardware to place the actual user in the centre of attention by actually helping him or her to obtain suitable equipment (introductions to each topic, cross-referencing etc.) rather than just identifying it.

Size: 29 cm x 21 cm, 264 pp, paper cover.

Price: £15.00

Published by Intermediate Technology Publications, 9 King Street,

London WC2E 8HW, U.K.

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Fuelwood Consumption and Deforestation in African Countries  
(U.S.A.)

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*by Dennis Anderson and Robert Fishwick*

The paper reviews recent reports on the level and growth of fuelwood consumption in Africa, and on the ecological, economic and possible micro-climatic effects of deforestation. It then reviews the economic and operational aspects of policies open to governments (i) to encourage fuelwood conservation, (ii) to facilitate the substitution of commercial energy for fuelwood, where desirable on grounds of relative costs, (iii) in developing the 'traditional' functions of the forestry services in maintaining the forest reserves and undertaking plantings in watersheds and shelterbelts, and (iv) in promoting the practice of agro-forestry, i.e., the planting and maintenance of trees in copses and around farms by the farm families themselves.

Size: 27 x 21 cm, 52p, paper cover

Published by World Bank Publications, P.O. Box 37525  
Washington, D.C. 20013, U.S.A.

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Agricultural Mechanization — A Comparative Historical Perspective  
(U.S.A.)

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*by Hans P. Binswanger*

This paper provides a detailed comparative historical review of the patterns of agricultural mechaniza-

tion by operation, emphasizing the similarities and differences in the patterns of adoption across developed and developing countries. The first section re-emphasizes the major conclusion of the induced innovation literature that the growth contribution of mechanization depends on the factor endowments of the economy in terms of land and labor, and on non-agricultural labor demand. Mechanization contributes most to growth where land is abundant and labor is scarce.

The second section shows the remarkable similarity in the early mechanization experiences of the developed and developing countries. New mechanical power sources were first used on power intensive operations such as processing, pumping, transport and tillage, while mechanization of control intensive operations came much later and usually in association with high wages. This specialization of new power sources leads, in the early stages of adoption, to the coexistence of the new and the old power source. Such coexistence was commonly observed in the developed world, with the new power source being used only on operations where it had a high comparative advantage. The control intensive operations were shifted to mechanical power sources only after massive wage rate rises, and such shifts should not be expected in the developing world in the absence of rising wages.

Size: 27 x 21 cm, 80p, paper cover

Published by World Bank Publications, P.O. Box 37525  
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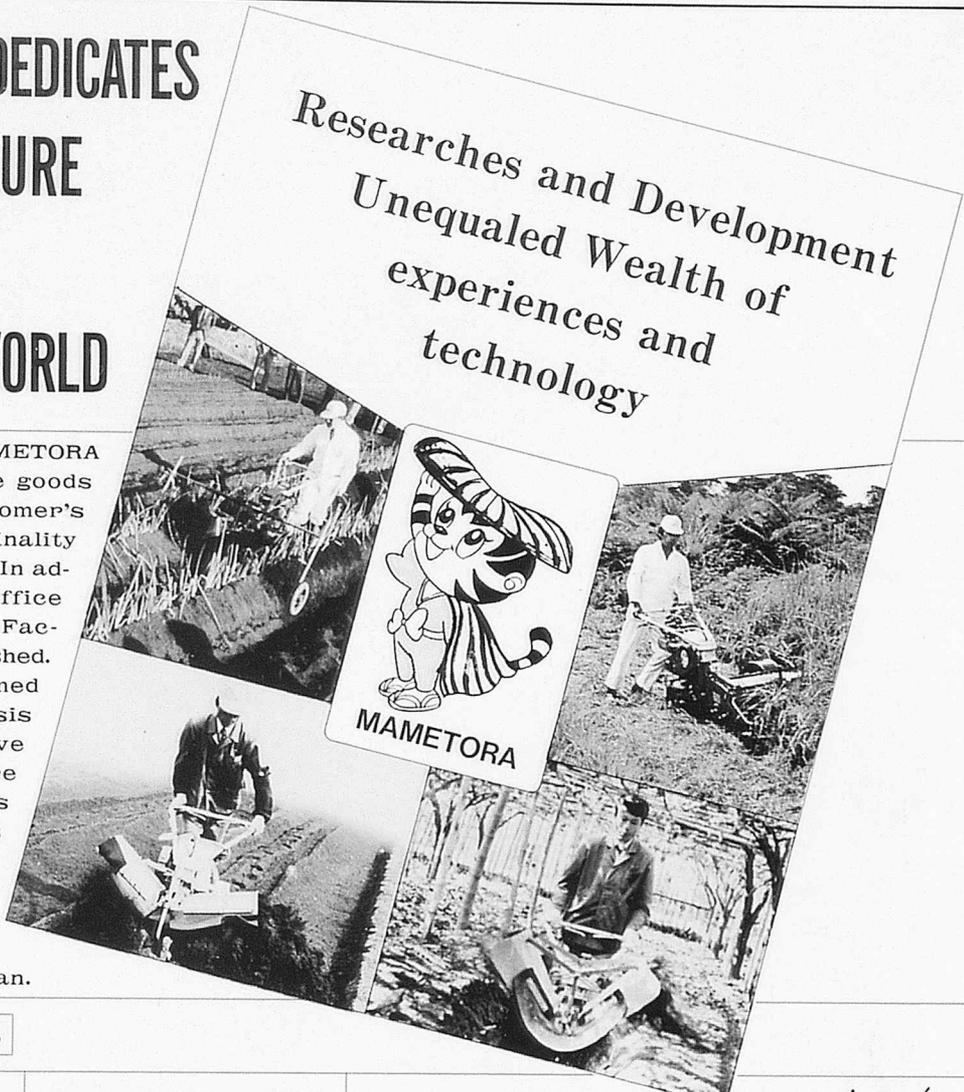
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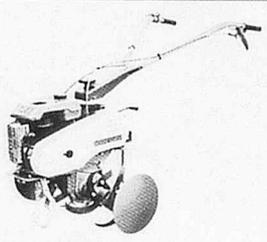
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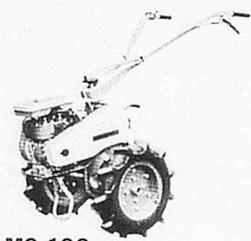
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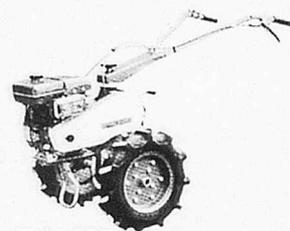
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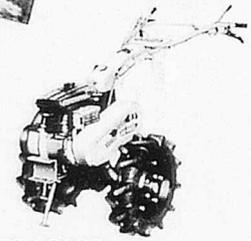
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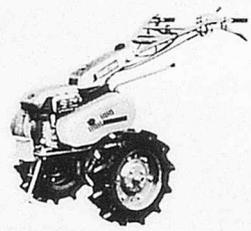
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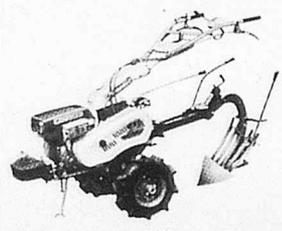
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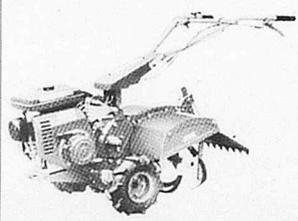
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