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AMA

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EDITORIAL

Give Farners a Break

In most of the developing countries of the world, the vast majority of the population are farmers. Historically, most of these farmers are poor and are generally resigned to their fate, i.e., to live in want and poverty for the rest of their lives. Invariably, they inherited this fate from their forebears and, in all likelihood, their children will inherit the same fate—a vicious life cycle.

These are the farmers that need a break in life in order for that cycle of poverty from generation to generation to be broke. What is happening, however, is that they continue to be left behind precisely because they have not been given the opportunity to improve their lot. It is time that somebody, somehow give these farmers some opportunity to join the mainstream of their kind who have succeeded in their endeavor.

We, in the agricultural machinery business, have since been playing the role of exponents of progress in agricultural pursuits and welfare of famers through the use of farm machineries. But the gap between a poor farmer and a small tractor, for instance, is so wide that the former can never hope to utilize, much less own, the latter. And here is a situation wherein some opportunity may be provided that poor farmer: an opportunity from two alternatives.

Alternative I challenges agricultural banks to make soft loans to poor farmers to enable them to buy the tractor based on character of the farmers and the tractor itself as the collateral.

Alternative II, on the other hand, challenges the governments to promote the tractor shed or cooperative concept wherein farmer members of the shed or cooperative can use the tractor for some fee that is payable at harvest. Eventually, the farmers will be given the option to purchase these machineries on the assumption that their productivity will increase, hence enable them to buy second-hand tractors.

Step by faltering step, the farmers can appreciate their own potentials given this opportunity to mechanize their farming operations. This is why we ask the politicians, economists, bankers, engineers and landowners among us to join hands in finding ways and means of enabling the farmers to try and adapt either Alternative I or Alternative II. And we also ask our readers and co-editors to toy around with these ideas. Together, let us work in that direction. And together, someday soon, we might see the poor farmers getting the break that is long overdue.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
October, 1990

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol. 22, No. 2, Spring 1991

Development and Performance Evaluation of Bullock-drawn, Multi-purpose Hoe

by
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Abstract

Intercultivation of row-seeded crops is an essential farm operation done with the ultimate aim of increasing crop yields. Weeding, mulching, tilling and earthing are the main operations involved in the intercultivation. Conventionally different types of tools or implements are used to carry out these operations. The implements also very depending upon the row spacing. A multipurpose hoe is, therefore, designed and developed to suit to any row spacing between 300 to 450 mm and to perform any of the interculturing operations. This multipurpose hoe is tested in groundnut, sunflower, safflower and jowar in 1987 and 1988. A bullock pair can operate 2 to 4 hoes at a time. The weight of a hoe is 16 kg and the average draft required for a pair of hoes varies from 26 to 32 kg. The actual field capacity of a pair of hoes varies from 0.15 to 0.25 ha per hour. The hoe gives 35 mm maximum mulching depth, 75 mm maximum tilling depth and 50 to 80 mm earthing height (ridging crop rows). The hoe costs Rs. 350 per piece and a pair of hoes involves a cost of operation of Rs. 32 to 50 per ha depending upon row spacing and type of interculturing operation. It has shown a very good performance in all crops.

Introduction

Intercultivation of row-seeded crops is an essential farm operation done with any or all of the following objects:

1) Weeding consists of removal and disposal of unwanted plants which grow in a field with a cultivated crop competing with the crops for moisture and plant nutrients. Controlling weeds in cereals, pulses and oil seed crops is, therefore, very important for increasing the agricultural production.
2) Tilling is the stirring of 50 to 100 mm deep soil between the rows for earthing the root zone for better growth of roots.
3) Earthing is ridging of the soil to the base of the plants for additional support. In dry land areas due to earthing, shallow furrow is created between the plant rows. These furrows help in concentrating even small runoffs and help in conserving moisture.
4) Mulching is slicing and stirring of shallow (30-50 mm) top layer of soil such that this top layer of loose soil does not expose the moist subsurface and the evaporation rate is reduced. At times it also absorbs light showers of rain which would otherwise be lost by evaporation.

In India, a wide variety of hand tools, animal and tractor-drawn implements are available for interculturing row crops. However, they are mostly crop specific, row spacing specific or operation specific. This imposes restriction on their use and adaptability. The number of interculturing equipments required becomes large, e.g., a groundnut earthing hoe cannot be used for hoeing and earthing in other oil seed crops like sunflower and safflower or a cereal like jowar. Also, it cannot be used for creating shallow soil mulch as required in some crops in dry areas. So a multipurpose, multicrop, bullock-drawn interculturing equipment is a need of the Indian farmer. **Table 1** shows the row and plant spacing, intercultivation schedule and acreage of important oil seed and major cereal crops in Maharashtra (1987).

A suitable interculture equipment which will take care of the different row spacings of different crops (multicrop) and which will take care of different types of interculture operations (multipurpose) like weeding, tilling, earthing, mulching etc. would be

Table 1 Intercultivation Schedule of Major Corps, Maharashtra, 1987

Crops	Row × plant spacing (mm)	Intercultivation schedule	Area under crop 1000 ha
Groundnut (Kharif)		2 to 3 hoeings and 2 to 3 weedings	
Errect Semi-errect Spreading	300 × 100 375 × 150 450 × 150	At third hoeing deep tilling with earthing of the crop is recommended to encourage penetration of crop roots and proper aeration of root zone	736
Groundnut (Summer)			
Errect Spreading	300 × 150 450 × 150	3 hoeings, first 20 days after sowing, next two with 15 days interval. Third hoeing should accompany deep tilling and earthing of crop	61
Sunflower	450 to 600 × 225 to 300	Thining 15 days after sowing with first hoeing, next 2 hoeings at 15 days interval.	415
Safflower	450 × 200	Thinning + 2 hoeings + 1 or 2 weedings. First thinning and hoeing 20 days after sowing. Second hoeing with weeding 15 days after the first hoeing.	510
Sesame	300 × 150	2 hoeings with 2 to 3 weedings	224
Jowar (Kharif)	450 × 150	2 to 3 hoeings and 1 to 2 weedings within 35 days. Due to shortage of rains the soils crack loosening the roots causing lodging. Earthing up operation (50 to 80 mm) is recommended.	
Jowar (Rabi)	450 × 200	Thinning after 15 days and 2 hoeings. First at 20 days with blads or sweeps. Second and third deep tilling with shovels. Earthing operation is recommended at hitrd hoeing.	662
Wheat	Drilled at 225 row spacing	Three hoeings within 45 days. First hoeing shallow with blade or sweeps at 10-20 days. Second hoeing tilling deep with shovels at 28 to 30 days. Third at 30 to 40 days with small ridging plough to achieve earthing.	881

most suitable for all the major oilseed crops as well as major cereals. Such an equipment will have a wide scope of applicability as is obvious from the above table.

Materials and Methods

Keeping in view the planting geometry and the agronomical treatments required for better growth of the crops, a multicrop, multipurpose interculture equipment was designed and developed. It consists of the following components:

1) Main frame with clevis and ferrule
   a) Head piece (Tool bar)
   b) Tines with clamps
   c) Shovels
   d) Sweeps
2) Earthing device
3) Weed rake
4) Handle
5) Beam with hook

Main Frame with Clevis and Ferrule

The main frame is made of two 215-mm long MS flats (37.5 × 6 mm) welded 18 mm apart with an iron angle piece. The angle piece (50 × 25 × 6 mm) is also a component of the clamp that holds the tool bar. The main frame gives attachment to the clevis in the front and to the earthing equipment or weed rake at the rear. The clevis has a ferrule of 60 mm in length. It is a 50 mm dia pipe split into two pieces to facilitate fixing of beam by nut and bolt. On top of this main frame is welded a tool bar (head piece). This tool bar is made of two, 280 × 37.5 × 12.5 mm flats. Each flat has a rectangular groove of 16.2 × 5 mm size throughout its length. These two pieces slide on a MS square piece (75 × 16 × 16 mm) along the groove (one above and the other below the square piece). These three components can be locked together with a clamp on the main frame. This arrangement enables the change of length of the head piece from a minimum 225 mm to a maximum of 450 mm to suit varying row spacings of important crops.

Tines with Clamps

The tines with clamps can be attached at any desired spacing on the tool bar. Each tine is made of MS square bar of 300 × 16 × 16 mm and is given a shape at the end such that during operation in the field the soil cutting tool (either shovel or sweep) makes an angle of 22° with the horizontal (penetration angle).

Shovels

Shovels are double ended (two-point) reversible type. Each shovel is 100 mm in length and 35 mm in width. Thickness is 3 mm. Angle of approach is 35°. Three to five shovels can be used depending upon the requirement of crop row spacing.

Sweeps

The sweeps are for weeding and pulversing the top soil to shallow depths for creating mulch. They are used on tines instead of shovels. The length of each sweep is 200 mm with 3 mm thickness. Working width is 120 mm. Angles of approach and lift are 40° and 22°, respectively.

Earthing Device

This device is attached at the rear of the main frame. It has two trapezoidal wings of 3 mm MS sheet. Each wing is 200 mm in length. The height of the wing near the centre is 140 mm while at the end it is 100 mm. The wings can be opened as per requirement so as to suit the crop row spacing. The earthing device can be pressed in the soil to scrap the required quantity of soil by applying pressure on the handle. The device can be lifted to reduce the amount of soil being collected.

Weed Rake

The rake can be attached behind the main frame (in place of earthing equipment) to collect weeds removed by the sweeps in the front. It is made of 9 semicircular fingers fixed on a circular tool bar with a spacing of 50 mm. Each finger is of 6-mm MS rod bent in a half circle of 300 mm diameter. The tool bar is made of pipe on which the semicircular fingers are mounted is made from three pieces. The middle piece is 229 mm long made of 19 mm pipe and two end pieces, each of 133 mm length made of 16 mm pipe. The end pieces are inserted in the middle piece to form a total length of 400 mm. The weed rake with entire length can be used in the crop spacing of 450 mm. The end pieces can be removed when it is to be operated in a narrow row spacing up to 300 mm. During operation the unit can be lifted up separately to leave the heaps of weeds behind in the row which are collected manually afterwards.

Handle

The handle is made from MS pipe of 25 mm diameter, 2.3 mm thick and 750 mm long. A wooden piece at the top end on this handle facilitates holding and control of the implement.

Beam with Yoking Hook

A bamboo beam 3 m long is used for hitching the implement. At one end it is connected to the implement with the ferrule. At the other end a yoking hook is fixed on this beam for hitching the implement to the yoke.

Results and Discussions

This newly developed multipurpose multicrop hoe has been evaluated for its field performance in comparison with the local implements presently used in the area

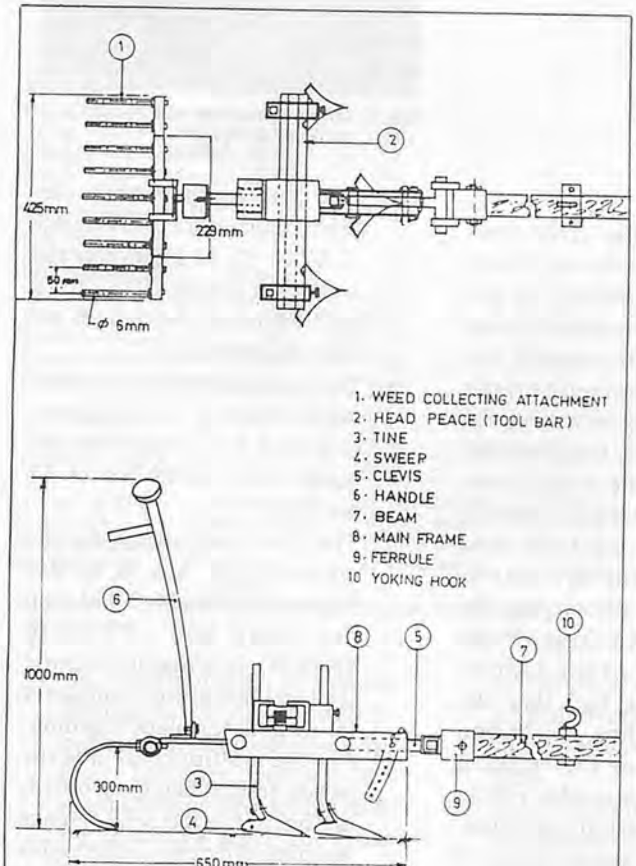

Fig. 1 Multipurpose hoe (sweeps + weed rake).

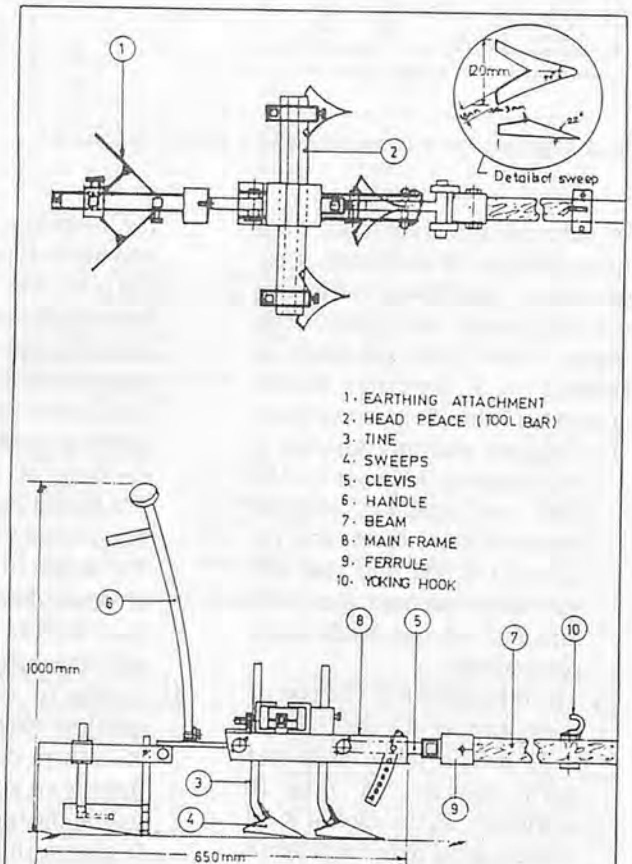

Fig. 2 Multipurpose hoe (sweeps + earthing attachment).

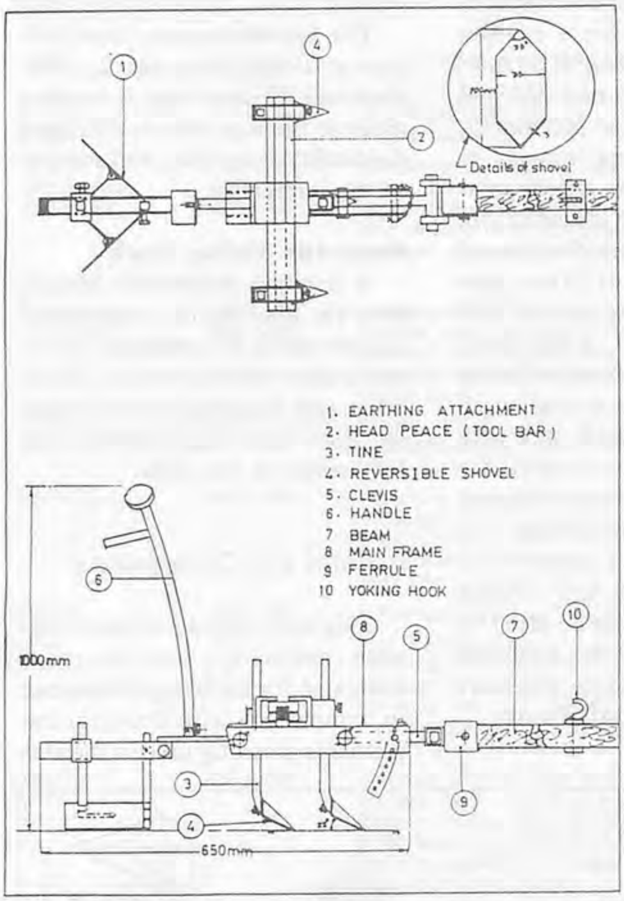

Fig. 3 Multipurpose hoe (reversible shovel + earthing attachment).

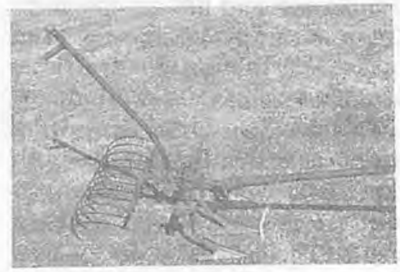

Fig. 4 Multipurpose hoe with sweeps and weed rake attachment.

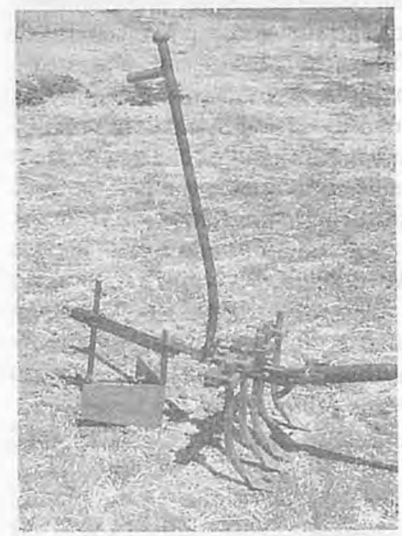

Fig. 5 Multipurpose hoe with shovels and earthing device.

for interculture. The trials were taken in major oil seed crops, i.e., groundnut, sunflower, safflower and the cereal rabi-jowar. The results of the trials are given in **Tables 2** to **5**. Referring to the summary **(Table 6)** it is seen that:

1) The same multipurpose hoe is adaptable to 300 mm to 450 mm row spacing whereas separate local hoes are required for 300 mm and 450 mm row spacings, i.e., 225 mm and 360 mm blade hoes, respectively.
2) The tilling depth in the case of multipurpose hoe with sweeps is 35 mm in jowar crop and with shovels 75 mm in safflower. In the case of local blade hoe the maximum depth of tilling is 35 mm.
3) The local hoe is not designed for earthing the crop rows and hence it pushes very little soil (30 mm height) to the base of the crop plants which is inadequate to support the crop plants. The multipurpose hoe is provided with a special earthing device, that does the earthing of the crop rows. The height obtained is seen to range from 51 mm to 80 mm. The height of the earthing can be controlled by varying the load on the earthing device with the help of the handle.
4) Inspite of the fact that the multipurpose hoe, in addition to tilling, does the earthing there is no appreciable reduction in the speed of operation. It shows the speed range of 2.6 to 3.3 as against 2.8 to 3.1 km/h of the local hoe.
5) The multipurpose hoe required little more draft (range 27.82 to 32.10 kgf) than the local hoe (range 20.3 to 26 kgf). However, both hoes are light to operate.
6) The multipurpose hoe shows more effective field capacity (1.21 to 1.87 ha/day) than the local hoe (0.99 to 1.41 ha/day).
7) The field efficiency of the multipurpose hoe is always higher (68.45 to 86.57%) than the local hoe (59.43 to 69.60%). It is mainly because the local hoe always consumes lot of time for blade cleaning.
8) For the multipurpose hoe the weeds besides being uprooted, are burried effectively. Hence weeding efficiency observed is more, (75 to 88.75%) than local hoe (62.5 to 85%).

Table 2 Comparative Performance of Multipurpose Hoe and Local Blade Hoe

Item		Multipurpose* hoe	Local blade hoe
Date of trial		1.8.87	1.8.87
Plot size	$(m)^2$	170 × 20	170 × 20
No. of hoes used		2	2
Tilling depth obtained	(mm)	72	35
Earthing height obtained	(mm)	75	30
Width of operation	(mm)	600	600
(width of implements)	(mm)	(400)	(400)
Speed of operation	(km/h)	3.3	3.1
Av. draft	(Kgf)	27.8	20.3
Duration of test	(h)	2.25	2.75
Eff. field capacity	(ha/day)	1.21	0.99
Theo, field capacity	(ha/day)	1.58	1.49
Field efficiency	(%)	76.58	66.44
Weeding efficiency	(%)	79.09	71.82
Damage percentage	(%)	3.67	8.54
Power requirement per ha.			
Machine-h		13.24	16.18
Man-h		13.24	16.18
Bullock-h		13.24	16.18
Cost of operation	(Rs/h)	50.43	56.71

1) Place of trial : College farm
2) Soil type : Medium black
3) Moisture content: 14%
4) Crop (variety) : Groundnut (JL-24)
5) Age of Crop : 42 days
6) Row Spacing : 300 mm
7) Crop height : 140 mm
8) Weed height : 85 mm

*Multipurpose hoe with 3 shovels at 100 mm spacing and earthing device 200 mm open.

Table 3 Comparative Performance of Multipurpose Hoe and Local Blade Hoe

Item		Multipurpose* hoe	Local blade hoe
Date of trial		10.12.87	10.12.87
Plot size	$(m)^2$	254 × 21	254 × 21
No. of hoes used		2	2
Tilling depth obtained	(mm)	75	32
Earthing height obtained	(mm)	80	30
Width of operation	(mm)	900	900
(width of implement)	(mm)	(700)	(700)
Speed of operation	(km/h)	3.1	2.95
Av. draft	(Kgf)	29.7	21.8
Duration of test	(h)	2.80	3.38
Eff. field capacity	(ha/day)	1.52	1.26
Theo, field capacity	(ha/day)	2.23	2.12
Field efficiency	(%)	68.16	59.43
Weeding efficiency	(%)	80.11	76.14
Damage percentage	(%)	5.52	6.85
Power requirement per ha.			
Machine-h		10.50	12.67
Man-h		10.50	12.67
Bullock-h		10.50	12.67
Cost of operation	(Rs/h)	40.00	44.40

1) Place of trial : College farm
2) Soil type : Medium black
3) Moisture content : 16%
4) Crop (variety) : Safflower (Bhima)
5) Age of Crop : 30 days
6) Row Spacing : 450 mm
7) Crop height : 150 mm
8) Weed height : 60 mm

*Multipurpose hoe with 4 shovels at 116 mm spacing and earthing device 350 mm open.

Table 4 Comparative Performance of Multipurpose Hoe and Local Blade Hoe

Item		Multipurpose* hoe	Local blade hoe
Date of trial		18.1.88	18.1.88
Plot size	$(m)^2$	37 × 19	37 × 19
No. of hoes used		2	2
Tilling depth obtained	(mm)	69	29
Earthing height obtained	(mm)	78	30
Width of operation	(mm)	900	900
(width of implement)	(mm)	(700)	(700)
Speed of operation	(km/h)	3.0	2.8
Av. draft	(Kgf)	32.1	26
Duration of test	(h)	0.3	0.4
Eff. field capacity	(ha/day)	1.87	1.41
Theo, field capacity	(ha/day)	2.16	2.02
Field efficiency	(%)	66.57	69.60
Weeding efficiency	(%)	75	62.5
Damage percentage	(%)	7.27	10.90
Power requirement per ha.			
Machine-h		8.53	11.38
Man-h		8.53	11.38
Bullock-h		8.53	11.38
Cost of operation	(Rs/h)	32.52	39.87

1) Place of trial : Pathology farm
2) Soil type : Medium black
3) Moisture content : 13%
4) Crop variety : Sunflower (moden)
5) Age of Crop : 30 days
6) Row Spacing : 450 mm
7) Crop height : 100 mm
8) Weed height : 45 mm

*Multipurpose hoe with 4 shovels at 116 mm spacing and earthing device 350 mm open.

Table 5 Comparative Performance of Multipurpose Hoe and Local Blade Hoe

Item		Multipurpose* hoe	Local blade hoe
Date of trial		2.1.88	2.1.88
Plot size	$(m)^2$	80 × 30	80 × 30
No. of hoes used		2	2
Tilling depth obtained	(mm)	35	30
Earthing height obtained	(mm)	51	30
Width of operation	(mm)	900	900
(width of implement)	(mm)	(720)	(700)
Speed of operation	(km/h)	2.6	2.8
Av. draft	(Kgf)	28.20	22
Duration of test	(h)	1.28	1.58
Eff. field capacity	(ha/day)	1.50	1.22
Theo, field capacity	(ha/day)	1.87	2.01
Field efficiency	(%)	80.21	60.70
Weeding efficiency	(%)	88.75	85
Damage percentage	(%)	7.1	5.1
Power requirement per ha.			
Machine-h		10.67	13.17
Man-h		10.67	13.17
Bullock-h		10.67	13.67
Cost of operation	(Rs/h)	36.22	50.16

1) Place of trial : College farm
2) Soil type : Medium black
3) Moisture content : 14%
4) Crop (variety) : Jowar (M-35)
5) Age of Crop : 35 days
6) Row Spacing : 450 mm
7) Crop height : 240 mm
8) Weed height : 80 mm

*Multipurpose hoe with 3 sweeps at 120 mm spacing and earthing device 360 mm open.

9) The percentage of plant damage is not accountable in both cases. The multipurpose hoe, however, shows less plant damage percentage than the local hoe when the front unit is with shovels. In jowar crop when sweeps are mounted the plant damage is seen to be little more in multipurpose hoe compared to local blade hoe.
10) As far as cost of operation is concerned the multipurpose hoe (shovels + earthing unit) does not show much benefit in oilseeds, though it is always less than the local hoe. For the multipurpose hoe the cost of operation ranges from Rs. 32.52 to 50.43 per ha. In the case of local hoe it is Rs. 39.87 to 56.71 per ha. The improved hoe, however,

Table 6 Summary Result of Performance Evaluation Trials of Multipurpose Hoe vs Local Hoe

Item		Groundnut		Sunflower		Safflower		Jowar		Range	
		M	L	M	L	M	L	M*	L	M	L
Row spacing	(mm)	300	300	450	450	450	450	450	450	300 to 450	300 to 450
Tilling depth	(mm)	72	35	69	29	75	32	35	30	35 to 75	29 to 35
Earthing height	(mm)	75	30	78	30	80	30	51	30	51 to 80	30
Speed	(km/h)	3.3	3.1	3.0	2.8	3.1	2.95	2.6	2.8	2.6 to 3.3	2.8 to 3.1
Draft	(kgf)	27.8	20.3	32.1	26.0	29.7	21.8	20.2	22.0	27.82 to 32.10	20.3 to 26
Eff. Field capacity	(ha/day)	1.21	0.99	1.87	1.41	1.52	1.26	1.50	1.22	1.21 to 1.87	0.99 to 1.41
Field efficiency	(%)	76.58	66.44	86.57	69.60	68.16	59.43	80.21	60.70	68.16 to 86.57	59.43 to 69.60
Weeding efficiency	(%)	79.09	71.82	75.00	62.50	80.11	76.14	88.75	85.00	75 to 88.75	62.5 to 85
Plant damage	(%)	3.67	8.54	7.27	10.90	5.52	6.85	7.1	5.1	3.67 to 7.27	5.1 to 10.9
Cost of operation	(Rs/ha)	50.43	56.71	32.52	39.87	40.00	44.40	36.22	50.16	32.22 to 50.43	39.87 to 56.71

* Multipurpose hoe with sweeps on.

shows little more saving in jowar crop. It required Rs. 36.22 as against Rs. 50.16 per ha of the local hoe. The quality of operation of the multipurpose hoe was very much appreciated by farmers and crop specialists.

Conclusions

i) The multipurpose hoe is adaptable to any row spacing between 225 mm and 450 mm. The soil working tools can have any gradual increase in spacing, e.g., in safflower the spacing is 116 mm to suit to the crop growth.
ii) Desired depth of operation can be achieved by changing the soil working tools, angles of penetration and the pressure on the handle.
iii) The multipurpose hoe is suitable for the earthing operation in row crops like groundnut and jowar.
iv) The multipurpose hoe is light to handle and to operate. The draft requirement causes no exertion on the part of the bullocks. The field capacity is quite high.
v) The multipurpose hoe is an efficient interculture equipment for weeding, tilling and earthing operations.
vi) From the point of view of the function performed the multipurpose hoe involved less cost of operation compared to local implements.
vii) The quality of operation is superior and the multipurpose hoe had no problems during operation.

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Bullock-drawn Roller-type Mould Board Plough for Heavy Soils

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Abstract

A bullock-drawn mould board plough with two, three and four rollers were developed and tested in black soils of eastern parts of Orissa, Inida. The performance of these ploughs were compared with the conventional mould board plough. The ploughs with three rollers performed better with least draft, higher field capacity and to the utmost satisfaction of the farmers in the State.

Introduction

The State of Orissa has a total area of 15.57 million ha of which 6.56 million ha are under cultivation. This area is distributed over 3.57 million farm holdings. The average size of land holding is 1.6 ha and about 75.7% of farmers have holdings measuring less than 1.99 ha. Because of the small and fragmented landholding and unfavourable economic and social conditions of the farmers, the tillage operations are performed with the help of bullock-drawn ploughs. In some parts of the State tractors and power tillers are used by big-time farmers either owning them or by hiring them. In the Government farms and by the farmers on co-operative basis, tractors and power tillers are used but by and large the bullock-drawn poughs are used by the farmers.

The bullock-drawn ploughs available in the State of Orissa can be categorised as wooden *deshi* plough, Bose plough, iron plough manufactured at the Implement Factory of the State Department of Agriculture and the iron plough manufactured in the College of Agricultural Engineering and Technology (**Figs. 1a and 1b**). The wooden deshi ploughs are gradually replaced by the iron ploughs. Every year more than 12,000 implement factory ploughs and 10 000 Bose ploughs are sold to farmers. The wooden country plough is locally made. Neither it gives qualitative performance nor inverts and pulverises the soil for better tilth. It very often leaves unploughed land in between two strips and the effective field capacity is also low. The iron ploughs give better inversion and pulverization in the coastal soils of the

Fig. 1a Bose plough, implement factory plough, wooden deshi plough.

Fig. 1b C.A.E.T. mould board plough.

State which mainly comprises of sandy loam soils and loamy soils.

Some parts of the western districts of the State have black-heavy soils of medium to heavy texture whereas some parts of the coastal districts have clay loam and clay soils. The tillage operations in these soils pose the problem of improper inversion, poor scouring, higher draft, bad tilth and above all, frequent breakage of the cast iron plough.

Keeping these problems in view, bullock-drawn mould board ploughs with two, three and four rollers were developed at the College of Agricultural Engineering and Technology and were tested. The objective was to reduce the draft and to increase the percentage of inversion of the heavy soil.

Development of the Plough

The conventional mould board plough of 15 cm width developed at the College of Agricultural Engineering and Technology has been modified for this purpose. The central portion of the plough was removed by gas cutting. The curvature, shape and size were kept similar to that of the smooth mould board surface. Out of 460 cm^2 of mould board area, 93.5 cm^2, 127.5 cm^2 and 161.5 cm^2 of area were removed for two, three and our roller ploughs, respectively. The rollers were of 8 cm length and 2.5 cm diameter. These rollers were fitted on the mould board over the fixed steel rod of 1 cm diameter. These rods were fixed at both ends in the groove by arc welding and the rollers were fitted to obtain the curvature with rollers instead of a solid surface. The total surface area with two, three and four rollers mould boards were reduced to 406.5 cm^2, 396 cm^2 and 383.5 cm^2, respectively (**Fig. 2**).

Fig. 2 Two roller, three roller and four roller ploughs.

Fig. 3 Operation of designed plough.

Methodology

The field test was conducted with smooth surface mould board (conventional) plough as well as with 3-roller type mould board ploughs according to Bureau of Indian Standard, test code NO. IS: 6288-1971 (**Fig. 3**). The performance characteristics of these ploughs are shown in **Table 1**. The performance tests of the ploughs were undertaken in June, 1988. In three different fields and at three different levels of moisture content, tillage operation was done to compare the performance. The moisture content and mean soil clod sizes were determined in the laboratory, the depth of cut and draft were measured and time taken to plough a particular strip of land was noted during the test. Three different plough men were engaged for the test in three fields.

Result and Discussions

The stickiness of the heavy soil which poses the problem of improper inversion in the conventional mould board surface was overcome by putting the rollers in the mould board. These rollers not only reduce the soil metal contact area but also help in moving the soil by rolling action and reduce the frictional forces and the draft requirement. It is observed (**Table 1**) that the draft requirement of all three roller type mould board

Table 1 Performance Characteristics of the Conventional and Roller Mould Board Ploughs

Type of plough	Moisture content %	Depth of cut cm	Draft kg	Unit draft kg/cm^2	Speed of ploughing km/h	Horse-power t	Draft power kW	Field capacity ha/h	Specific energy requirement kW-h/ha	Mean clod size dia, mm
Conventional	9.61	7.3	52.5	0.47	2.183	0.42	0.35	0.032	10.93	21.0
2-Roller		7.4	50.8	0.45	2.214	0.41	0.35	0.033	10.60	19.1
3-Roller		7.5	48.5	0.43	2.521	0.45	0.37	0.037	10.00	15.7
4-Roller		7.6	50.9	0.44	2.395	0.45	0.37	0.035	10.57	17.5
Conventional	10.60	8.3	51.2	0.41	2.112	0.40	0.33	0.031	10.64	17.3
2-Roller		8.3	48.3	0.38	2.104	0.37	0.31	0.031	10.00	17.0
3-Roller		8.6	47.5	0.36	2.334	0.41	0.34	0.035	9.71	15.2
4-Roller		8.5	48.7	0.38	2.225	0.40	0.33	0.033	10.00	16.0
Conventional	11.85	9.8	49.2	0.33	2.067	0.37	0.31	0.031	10.00	17.6
2-Roller		9.6	46.5	0.35	2.169	0.38	0.31	0.032	9.68	17.0
3-Roller		10.0	44.4	0.29	2.253	0.37	0.30	0.033	9.09	16.1
4-Roller		9.9	45.9	0.31	2.157	0.36	0.30	0.032	9.37	16.9

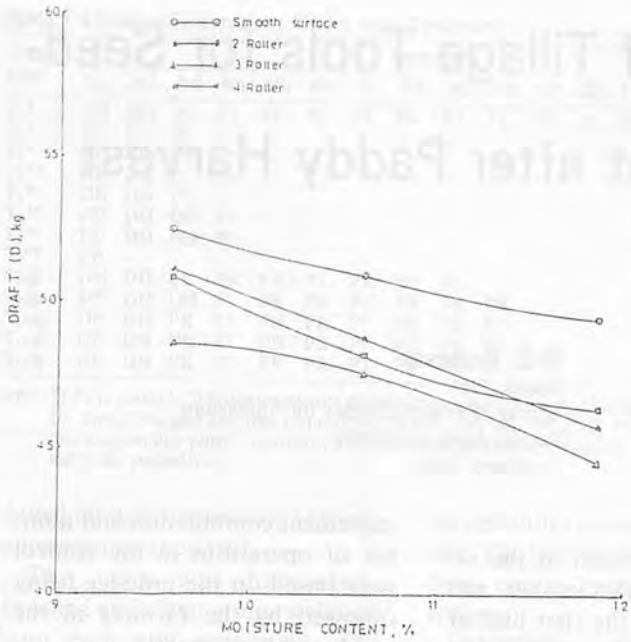

Fig. 4 Relationship between draft and moisture content for the smooth surface and roller mould board ploughs.

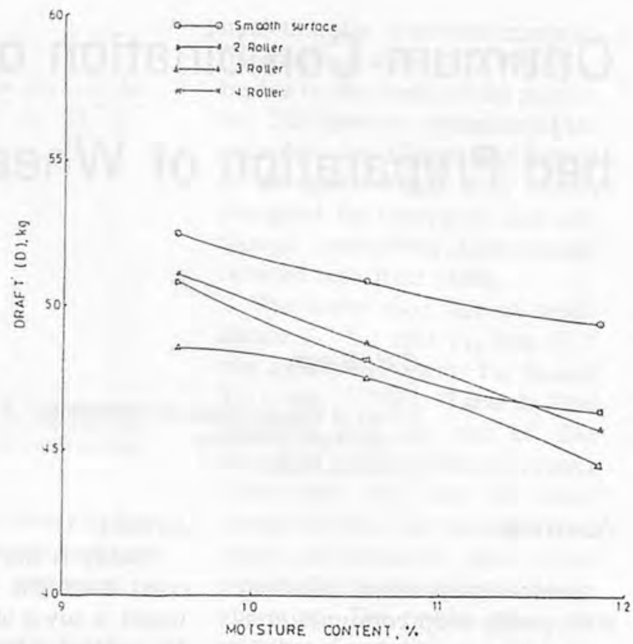

Fig. 5 Relationship between moisture content and mean clod size diameter for smooth surface and roller mould board ploughs.

ploughs is less in comparison to the conventional mould board ploughs at all levels of moisture content. From among the roller type ploughs it is seen that the mould board plough having 3 rollers performs better (Figs. 4 and 5), so far as draft requirement, field capacity and inversion of soil is concerned in comparison to two and four roller ploughs. For the 4-roller plough, though the surface area is further reduced it poses the problem of clogging of soil. As the moisture content increases from 9.61 to 11.85%, the draft requirement decreases for all the roller type ploughs. The mean clod size for 3-roller plough is minimum at 10.60% moisture content. Though the field capacity is great at 9.61% moisture content and draft requirement is less at 11.85% moisture content, the 10.60% moisture content is taken to be ideal as at this level, the inversion and pulverization yield minimum clod sizes.

Conclusion

During the primary tillage operation in heavy soils the soil inversion is a major problem. This can be solved by substituting a 3-roller mould board in place of plain mould board. The overall performance of 3-reller mould board plough was satisfactory for bullock-drawn ploughs. Therefore, the use of 3-roller bullock-drawn mould board plough in heavy soils of Orissa as a primary tillage implement is recommended.

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Optimum Combination of Tillage Tools for Seed-bed Preparation of Wheat after Paddy Harvest

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Abstract

Seedbed preparation for wheat after paddy crop consumes considerable amount of energy. To reduce the energy expenditure for seedbed preparation, several combinations of existing tillage machines were studied. Clod size distribution, crop yield, total energy, time and cost of seedbed preparation were studied for all the machine systems. The combination of disc harrow, cultivator and plank gave the minimum average clod size in all the trials. However, the grain yield was high when chisel plough or rotary cultivator and pulverizing roller were used in combination with other equipment. Combination of disc harrow, pulverising roller and plank was optimum from net energy and economic returns point of view.

Introduction

Paddy is one of the major *kharif* crops of Punjab state. Production, productivity and area planted to this crop has increased manifold during the last two decades.The cultural practices followed in Punjab require puddled field for transplanting paddy. This leaves soil manipulation in this condition is a big problem for the farmers.

Paddy is harvested in the second fortnight of October and wheat is sown in the first half of November (Anon., 1987 and 1978a). There is hardly 15 days' time available between harvest of paddy and timely sowing of wheat. This puts great pressure on the farmers for expediting seedbed preparation in paddy-wheat rotation. The energy input, time and cost for seedbed preparation for wheat in the paddy soils is tremendous. Delayed sowing and poor quality seedbed affecting proper seed germination result in lower grain yield.

Keeping these problems in view, a study was undertaken with the specific objective of expediting seedbed preparation after paddy harvest.

Materials and Methods

The experiments were conducted for three years. A total of 12 treatments with one control were included in the study. The treatments comprised of one or combination of more than one implement selected from field cultivator, chisel plough, disc harrow, disc plough, field cultivator with pulverizing roller, rotavator and plank. **Table 1** gives details of operations for each treatment. The implement combination and number of operations in the control were based on the practice being followed by the farmers in the paddy growing areas.

Clod size distribution, time and fuel consumption after seedbed preparation and grain yield were recorded. Clod size distribution was determined by sieving a representative area (20cm x 20cm) of the tilled sooil. The sieve set was well shaken and the weight of the material retained on each sieve was recorded. The size of the biggest clod in the top sieve (second major dimension) was also recorded. The sieve set consisted of sieves with square openings of 38.1, 25.4, 19.0, 12.7, 9.5, and 4.8 mm and pan. The following expression was used to calculate mean mass diameter (MMD):

$$MMD = (\sum_{I} (M(I) \times (D(I-1) + D(I))/2)/\sum_{I} M(I) \quad \text{.............. (1)}$$

where,

M(I) = mass of the soil retained on I'th sieve from top, kg

D(I) = size of the I'th sieve, mm

D(0) = size (second major dimension) of the largest clod on top sieve, mm

Time and fuel consumption for each operation were determined separately in a plot of approximately 0.4 ha. The fuel consumption was measured by topping method. The time of operation in-

Table 1 Details of Operations Under each Treatment

Treatment	Operations															
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th
T_0*	DH	DH	P1	P1	FC	P1	P1	FC	P1	P1	FC	P1	P1	FC	P1	P1
T_1*	RO	RO	P1													
T_2*	DH	RO	P1													
T_3**	DP	RO	P1													
T_4**	DH	DH	P1													
T_5**	CP	DH	DH	P1												
T_6**	DP	DH	DH	P1												
T_7**	CP															
T_8@	DH	DH	P1	PR	PR	P1	PR	RP	P1							
T_9@	DP	DH	DH	P1	PR	PR	P1	PR	PR	P1						
T_{10}@	DP	DH	PR	P1	PR	PR	P1	PR	PR	P1						
T_{11}@	CP	DH	DH	P1	PR	PR	P1	PR	PR	P1						
T_{12}@	CP	DH	PR	P1	PR	PR	P1	PR	PR	P1						

Note: 1) T_0 is control; 2) Experiments for the treatments marked as *, ** and @ were conducted for three, two and one year respectively; 3) DH, DP, RO, FC, CP, P1 and PR stands for disc harrow, disc plogh, rotavotor, field cultivator, palnker and field cultivator with pulverising roller respectively.

cluded all such losses which are encountered in the field.

The crop was harvested, threshed and clean grains weighed from each plot separately. The quantity of fertilizer, fuel, chemicals, seed and water and implements used for post-seedbed operations were the same for all plots. The total energy input (EI) and average power requirements (AP) for seedbed preparation were computed by using the following equations:

$$EI = 1.96 \times H + 56.31 \times FC \quad \text{.......................... (2)}$$

$$AP = (0.05 \times H + FC/SEC)/T \quad \text{.......................... (3)}$$

where,

EI = Energy input for seedbed preparation, MJ

H = Total human labour input for seedbed preparation, man-h

FC = Total fuel consumed for seedbed preparation, l

SFC = Specific fuel consumption for tractor, 1/kWh

T = Total time for seedbed preparation, h

The specific fuel consumption for the tractor was 339g/kWh. The cost of seedbed preparation was computed by assuming prevalent price of equipment, life, labour charges, interest on investment, depreciation, shelter, etc (Anon., 1979a). The costs for insurance and taxes were not accounted for as these are not levied on agricultural machinery in Punjab. The benefit from a treatment over control was computed as follows:

$$BNET(I) = C(O) - C(I) + P \times (Y(I) - Y(O)) \quad \text{............ (4)}$$

where,

BNET = Benefit from I'th treatment, Rs/ha

C(O) = Cost of seedbed preparation with control, Rs/ha

C(I) = Cost of seedbed preparation with I'th treatment, Rs/ha

Y(I) = Wheat yield in I'th treatment, kg/ha

Y(O) = Wheat yield in control, kg/ha

P = Sale price of wheat, Rs/kg

Results and Discussion

Average Clod Size

The average clod size was used as indirect index for soil tilth. The minimum average clod size was obtained for control (12.1 mm) and maximum was for T_4(29.3 mm) i.e., two times disc harrow and planking. When, with this treatment (T_4), pulverising roller was combined resulting into T_8 treatment, the average clod size decreased from 29 to 14 mm (**Table 2**).

In the treatments involving the combination of rotavator with disc harrow (T_2) and disc plough (T_3), the average clod size was lower (16 mm) than the treatment comprising rotavator alone (T_1). This may be due to the speed of the rotavator. The speed of operation of the rotavator was highest and lowest in the plots which were earlier ploughed by rotavator and disc plough, respectively. Lower speed resulted into finer clods.

The mean clod size in treatments T_5, T_{11} and T_{12} was 19.1 mm and in treatments T_6, T_9 and T_{10} it was 17.7 mm (**Table 2**). This indicates that the use of disc plough as primary tillage tool gave lower clod size than the chisel plough as the disc plough does more pulverisation than chisel plough during the primary tillage operation. The reuslts also indicate that if one disc harrow operaiton is replaced by pulverising roller, the average clod size increased from 17 mm (T_9 and T_{10}) to 19 mm (T_{11} and T_{12}). This means two operations of disc harrow are necessary if pulverising roller is to be used after disc harrow.

The average clod size (17 mm) in the treatments having different combinations of disc harrow and disc plough with rotavator (T_1, T_2 and T_3) was observed to be smaller than the average clod size (20 mm) in the treatments having different combinations of disc plough, chisel plough and pulverising roller with disc harrow (T_4, T_5, T_9, T_{10}, T_{11} and T_{12}) as the rotavator sliced the soil into finger particles. But the average clod size (19 mm) for the treatment having rotavator alone (T_1) was higher than in the treatment having disc harrow (14 mm) in combination with pulverising roller (T_3). The use of pulverising roller in treatments T_4 and T_5, resulting into new treatments T_9 and T_{11} also decreased the average clod size (**Table 2**).

Crop Yield

The grain yield recorded under all the machine systems is given in **Table 2**. During all the *rabi* sea-

Table 2 Average Clod Size, Time, Fuel Consumed, Cost, Energy and Average Power Input for Seedbed Preparation and Average Yield & Benefit of Using Different Tillage Machinery Conbinations for Sowing Wheat after Paddy Harvest

Treatment	Average clod size	For complete seedbed preparation					Average yeild	Benefit
		Time,	Fuel consumption,	Cost	Energy input	Average power input		
	mm	h/ha	1/ha	Rs/ha	MJ/ha	kW	kg/ha	Rs/ha
T_0	12.1	16.0	40.0	436.8	2306	7.46	1370	—
T_1	19.0	5.7	21.5	166.9	1224	11.19	1710	646.01
T_2	15.8	5.2	18.5	151.3	1055	10.56	2200	1203.94
T_3	16.1	10.4	33.0	310.9	1882	9.42	1680	468.80
T_4	29.3	4.7	15.5	75.7	884	9.79	1280	261.28
T_5	18.9	9.7	30.5	214.8	1739	9.33	1300	144.32
T_6	18.2	11.9	37.0	294.1	2109	9.23	1400	175.70
T_7	*	5.0	15.0	139.1	854	8.90	1880	861.96
T_8	14.1	11.1	29.7	298.9	1702	7.96	2800	1720.42
T_9	15.0	18.3	51.2	517.3	2926	8.31	2430	1032.50
T_{10}	19.3	17.5	47.0	493.4	2688	7.98	2070	717.96
T_{11}	18.9	16.1	44.7	438.0	2556	8.25	2670	1437.44
T_{12}	19.5	15.3	40.5	414.1	2318	7.87	1880	586.96

Note: * Means data were not recorded as the clods were of very large size.

sons the grain yield obtained in the control (T_0), in general, was less than other treatments except in one year where treatment T_4 gave the lowest yield.

The average wheat yield in treatments T_1, T_2 and T_3 was 1700, 2200 and 1680 kg/ha, respectively. This shows that combination of disc plough with rotavator (T_2) gave better yield than the rotavator alone (T_3) or combination of rotavator with disc harrow. This may be due to the fact that the mean mass diameter of the clods being less in T_2 treatment than in T_1 or T_3 treatments resulting in better seed soil contact and germination.

The mean wheat yield for treatments T_6, T_9 and T_{10} was 1970 kg/h. It was 1950kg/ha for T_5, T_{11} and T_{12} treatments. The difference in these two sets of treatment was in primary tillage only. The disc plough was used as primary tillage implement in the former set and chisel plough in the latter set. Hence, the use of disc or chisel plough for primary tillage operation gave almost the same yield due to similar depth of ploughing in the two primary tillage tools. The mean yield for treatments T_4 and T_8 was 2040 kg/ha and for treatments T_5, T_6, T_9 and T_{11} it was 1950 kg/ha. Either disc or chisel plough was used as primary tillage tool in the latter set of treatments whereas these implements were not used in the former set. Thus, additional use of disc or chisel plough for primary tillage did not show any advantage. Instead the grain yield was 4% less. The difference was not significant. This shows that deep ploughing by chisel or disc plough does not improve the crop output in this situation.

The treatment T_8 (2800 kg/ha) gave very good grain yield in comparison to treatment T_4 (1280 kg/ha). Also, treatments T_9 and T_{11} gave better yield than treatments T_5 and T_6. The mean yields for treatments T_4, T_5 and T_6 was 1330 kg/ha and for treatments T_8, T_9 and T_{12} 2630 kg/ha. The difference in these two sets of treatment was only in the additional use of pulverising roller (four times) and plank (two times) which existed in the latter set. Hence additional use of pulverising roller and plank helped in almost doubling the grain yield. It gave good compact seedbed below the point of action of its pulverising member and loose seedbed above that point. If the seed is placed at the point of action of pulverising member it will have good water uptake from below and air availability from above. This might have helped in increasing germination and plant growth and hence, better grain yield.

The mean yield for treatments T_9 and T_{11} was 2550 kg/ha and for treatments T_{10} and T_{12} 1980 kg/ha. One disc harrow operation was replaced with operation of pulverising roller in the latter set. This means the extra use of pulverising roller in place of disc harrow does not help in increasing the yield. Rather it decreased the yield by 22%.

The treatment T_7 gave better yield than T_0, T_1, T_3, T_4, T_5 and T_6. In this system (T_7) only the chisel plough was used and the seed was dropped in the furrow opened by the chisel plough.

Energy Requirements

Table 2 gives the energy requirements of different treatments for seedbed preparation. The energy requirements for deep ploughing by chiesel plough (T_7) is almost similar to those of two operations of disc harrow (T_4), but the average power requirements were 10% more for disc harrow (T_4), than the chisel plough (T_7). Addition of chisel and disc plough in the treatment T8 forming treatments T_{11} and T_9, increased the energy requirements by 50% and 72%, respectively. The average power requirement for treatments T_9 and T_{11} were almost similar and were 4% more than T_8 treatment. Similarly, the addition of disc or chiesel plough in treatment T_4 resulting into treatments T_6 and T_5, respectively, increased the energy requirements by 139% and 96%. Almost for every treatment except T_9, T_{10}, T_{11} and T_{12} the energy input was lower than the control, i.e., T_0. Hence, treatments T_1 to T_8 can save energy over control (T_0) to an extent of 9% to 63%, respectively. If the common method of seedbed preparation used by the farmers (T_0) is replaced by any of the treatments from T_1 to T_8, 9% to 63%

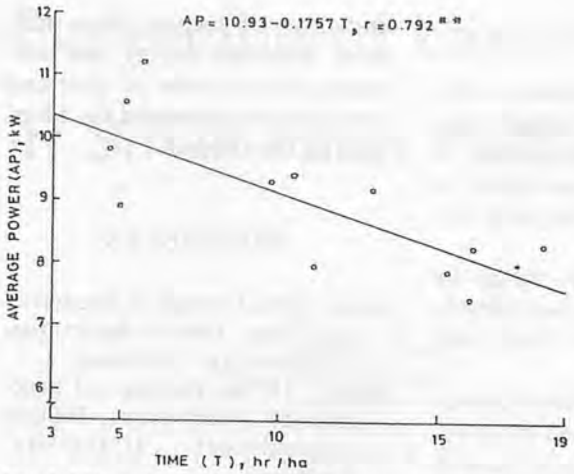

Fig. 1 Effect of total time on average power input for seedbed preparation for sowing wheat after paddy.

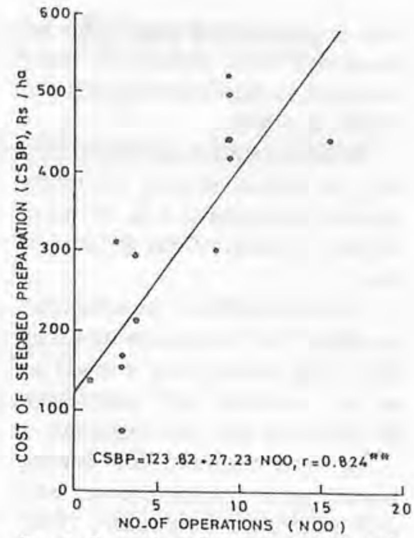

Fig. 2 Cost of seedbed preparation and number of operations.

energy and 26% to 70% time can be saved. However, if the usual method of seedbed preparation is replaced by treatments T_9 to T_{12}, then 0.5 to 27% extra energy is requireed. The average power requirements for seedbed preparation decreased with an increase in time spent for seedbed preparation (**Fig. 1**). The following relationship between average power and total time was developed:

$$AP = 10.93 - 0.1757 \times T, \quad r = 0.792^{**} \quad \ldots\ldots\ldots\ldots (5)$$

where,

AP = Average power requirements for seedbed preparation, kW

T = Total time for seedbed prepation, h/ha

Cost of Seedbed Preparation

The cost of preparing seedbed of one hectare with treatments is given in **Table 2.** The minimum cost of seedbed preparation was for treatment T_4 (comprising disc harrow and plank) and maximum cost was for treatment T_9 (comprising disc plough, disc harrow, pulverising roller and plank). The cost of seedbed preparation increased with the increase in number of operations (**Fig. 2**). The following equation between cost of seedbed preparation (CSBP) and number of operations was developed:

$$CSBP = 123.82 + 27.232 \times N00, \quad r = 0.824^{*} \quad \ldots\ldots\ldots\ldots (6)$$

where,

CSBP = Cost of seedbed preparation, Rs/ha

NOO = Number of operations

Benefit

Benefit was computed over control treatment according to equation 4 and is givevn in **Table 2**. The benefit was maximum for treatment T_3 and minimum for T_5. The addition of disc and chisel plough in treatment T_4 decreased in benefit from Rs 261 per ha to Rs 144-175.7 per ha. Thus, the addition of chisel or disc plough does not add to the benefit. Similar result was also obtained on comparing benefits for treatment T_8, T_9 and T_{10}. This might be due to either increase in cost of seedbed preparation or decrease in grain yield or both by addition of disc or chisel plough.

The benefit in treatments T_1 and T_2 was Rs 646 and 1204 per ha, respectively. This means replacing one operation of rotavator with disc harrow almost doubled the benefit. However, replacing one operation of rotavator with disc plough reduced the benefit by about 27%.

The benefits in treatment T_8, T_9 and T_{11} were 6.6, 5.9 and 10 times the benefit in treatments T_4, T_5 and T_6, respectively. This indicates that addition of four operations of pulverising roller increased the benefit. This was mainly due to increase in wheat yields by the addition of pulverising roller.

The replacement of one operation of disc harrow with pulverising roller (T_9 V/S T_{10} and T_{11} V/S T_{12}) reduced the benefit by 30% to 60%. This was primarily due to reduction in yield (**Table 2**).

Optimum Implement Combination

Energy input, yield and cost of seedbed preparation were the main criteria for the selection of optimum combination of tillage tools. Under actual conditions the time required to complete seedbed preparation will be reflected through timeliness cost. The combined effect of timeliness cost, yield and cost of seedbed preparation is reflected in the returns. The first and second optimization attempt was made from net economic and energy return parameters, respectively. The following assumptions were made to calculate net returns:

1) 80% of the total cultivated

area is under wheat crop. This assumption was based on data reported in the literature (Anon., 1979b & 1980).

2) The optimum period available for wheat sowing including seedbed preparation is 25 days (Anon., 1978 & 1978a) @ 10 h per day.

3) About 80% of the total time is utilised for the completion of the job. This assumption is made so as to account for unforeseen breakdowns and interruptions.

4) Time required for sowing wheat with tractor-drawn seed drill is 3.5 h per ha (Anon., 1978, 1979 & 1980).

5) One week delay reduces wheat yield by 10.0% (Anon., 1978 and Singh et al., 1971).

6) Optimum time available for wheat sowing is proportionately distributed among the area under wheat after paddy and non-paddy crops.

7) The sale price of wheat is taken as Rs 110.68 per quintal as was prevalent in the market.

Two computer programmes in FORTRAN-4X language were made to maximize the net economic returns and net energy returns by accounting for yield loss due to delayed sowing in case the time required fit seedbed preparation and sowing exceeds the permissible time limit. The programme was run for area under paddy crop varying from 10% to 100% and farm size from 1 ha to 100 ha. Treatment T_8 gave maximum net economic and energy returns irrespective of farm size and percent area under paddy. Hence, the combination of disc harrow, pulverising roller and planker was optimum and is recommended.

Conclusions

1) Combining rotavator with disc harrow or disc plough was useful in comparison to using it alone. The benefit was higher in the former case and the yield was higher in the latter.

2) The use of disc plough in place of chisel plough was beneficial as it gives finer clods and higher yields.

3) Combining pulverising roller with disc harrow helped in reducing clod size and in increasing yields and benefit.

4) The use of disc or chisel plough as primary tillage tool with disc harrow or disc harrow and pulverising roller combination decreased the benefit. However, wheat yield was not affected by this addition. Hence, disc or chisel plough may not be used with disc harrow or its combination with pulverising roller.

5) The average power requirements for seedbed preparation decreased linearly with the increase in time required to complete the seedbed preparation.

6) The cost of seedbed preparation increased linearly with the increase in number of operations for seedbed preparation.

7) The two operations of disc harrow, four of pulverising roller and three of planker were optimum from net energy and economic returns point of view and hence are recommended for adoption by the farmers.

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AMA Vol. 22, No. 1, P69., The author should appear as follows:

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Evaluation of Land Preparation Methods in Small Farm Holdings in Northern Sudan

by

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Abstract

Decision on suitable levels of technology is an important issue in developing countries which are faced by foreign currency problems. This paper attempts to evaluate suitable land preparation methods in Aliab, an irrigation scheme in Northern Sudan. Technical and economic criteria are followed in the evaluation which is based on a survey carried out in the scheme in the season of 1984/85. The trade-off between the use of machinery and animal-draught power is discussed.

Introduction

The question of what level of technology to be adopted in agricultural production is of utmost importance, especially in developing countries which are often faced by foreign exchange constraints and have to consider the trade-off between capital and labor use. This statement applies largely to the use of machinery on small farms. Although mechanization is believed to solve labor scarcity problems, increase labor-efficiency, and alleviate farm drudgery, animal-draught technology have many advantages on account of its availability, acquaintance of farmers to its use, low levels of risk associated with its application and availability of room for improving its present performance. However, such aspects should be examined within the context of resource availability and other economic circumstances specific to a particular situation.

Recently, opinions have been differing and controversial as to what level of mechanization would be appropriate for Government schemes in Northern Sudan. These schemes are run by the Northern Agricultural Production Corporation (NAPC). With the incoming of two rehabilitation projects, one from International Fund for Agricultural Development (IFAD) and the other from Overseas Development Association (ODA), the Corporation has felt an urgent need to find answers to questions regarding suitable levels of mechanization to be adopted in its schemes.

The objective of this paper is to investigate the economic aspects of land preparation methods in Aliab Government's Scheme in Northern Sudan, as far as the level of technology is concerned.

Northern Sudan is characterized by its desert and semi-desert climate where total annual rainfall hardly exceeds 100 mm. Cropping is confined to a relatively narrow strip of fertile soils along the Nile banks, predominantly under irrigation. Different modes of agricultural production exist in the region, the most dominant being private, governmental and cooperatives. Crop combinations mostly comprise trees and annual crops. The most important tree crops are date palms, citrus and mangoes. Annual cropping is in the form of different mixes of cereals (wheat and sorghum), food legumes (faba bean, phaseolus, chickpea and lupin), vegetable crops (mainly onions), different types of spices, in addition to some fodders, especially lucerne and sorghum. Generally, a three-course rotation is followed : damira-winter-summer crops. However, the summer phase is now largely replaced by a fallow period. The most important constraints faced in the region are transport bottlenecks, shortages of spare parts for pumps, fuel and agricultural inputs such as machinery, improved seeds, fertilizers and pesticides. There is high dependence on family labor and animal draught power and the use of agricultural machinery is limited.

The NAPC runs 14 schemes with a total cultivable area of about 22000 ha where trees occupy 6000 ha and annual crops occupy 16000 ha. Aliab, which is one of the schemes run by the NAPC, was established in 1942. It lies on the eastern bank of the Nile about 20 kilometers south of El Damar, capital of the Northern Region. It has an area of about 2 100 ha cultivated by some 500 farmers with holdings of 4 ha each. The crops grown are mainly sorghum, faba bean and some lucerne, in addition to permanent gardens. The responsibility of the NAPC is to provide irrigation water (pumped from the Nile) and collect water charges. They may also provide machinery for land preparation, but on a very limited scale. At the time of the study the scheme's administration had only two tractors, one plough, a ridger and a leveler.

Sampling and Data Collection

A survey was conducted in the scheme for the season 1985/86 using a structured farmer questionnaire and a sample of 41 farmers. The sampled farmers were those who participated in on-farm trials that were conducted over several seasons in the scheme to test production factors of early sowing, frequent watering and pest control (ICARDA, 1985). The sample was distributed geographically over the scheme where its southern, central and northern sections were represented by 19, 10 and 12 farmers, respectively. The respondent farmers were interviewed twice. The first was in late October and early November during land preparation and planting of the main winter crop, faba bean. The second was in April after crop harvesting. The questionnaire covered topics of land preparation methods, their costs and farmers' opinions about their effectiveness and problems associated with their use.

Results and Discussion

Available Power

According to the survey results, the types of tractors and farm implements available in the scheme's area are shown in **Table 1**.

According to these figures, the average gross area served by a tractor with its implements amounts to about 191 ha. Most of the machinery is privately owned and has high mobility within different neighboring producing areas.

Moreover, most of the farmers (75%) owned a pair of trained oxen for land preparation while 5% keep only cows for milk. The draft cattle used in the scheme and in the region is the zebu type. Their weight ranges between 350 to 400 kg and they supply an average tractive effort of 3 565 Newton, thus considered well suited to work.

Usually, a pair of oxen is used. The common type of harness is the withers or double neck yokes. These are held in position by two wooden sticks inserted vertically close to both sides of each animal's neck **(Fig. 1)**. Swing plows are commonly used in the region. these are either locally manufactured or imported from India. The earth scoop is also a common implement.

Land Preparation Methods

The main tillage operations for faba bean, and most of the other crops, are one or two ploughings, one or two leveling operations, ridging after hand broadcasting of seeds and opening of field canals.

Although farmers keep draught animals, most of them used tractors hired from the private sector for the first ploughing and first leveling operations with frequencies of 85% and 76%, respectively **(Fig. 2)**. Those who did a

Table 1 Available Tractors and Farm Implements in Aliab Scheme, 1985/86

Type	Number
Tractors 70-80 HP	9
Tractors 50 HP	2
Disc plow with 3 discs	9
Disc plow with 2 discs	2
Scraper	11

Fig. 1 Use of animal-draught power in land preparation in Northern Sudan.

second ploughing or a second leveling depended mostly on their animal draught power. Farmers keep draught animals mainly to supplement and improve tractor operations. After the first tractor ploughing, the land is left with big clods. Animal ploughing is then performed in order to break such clods and prepare a fine seedbed. This is followed by the first leveling done by tractors, Animals are then used for a second cut-and-fill leveling operation which evens out depressions and highpoints left by tractor wheels. Ridging was , and is usually, done by draught animals (in 71% of the cases). In the season under consideration, however, tractor ridging was introduced on about one-fifth of the farms, mostly by government machinery.

Field observations and measurements done during the survey showed that the tractor ploughing depth ranged between 10 and 15 cm compared to a range of 9 to 11 cm by animal draught. For ridging, the two methods differ with respect to the ridge depth. It was 20 cm with tractors and variable with the animal-drawn plough, ranging between 13 and 20 cm. However, the ridge width was

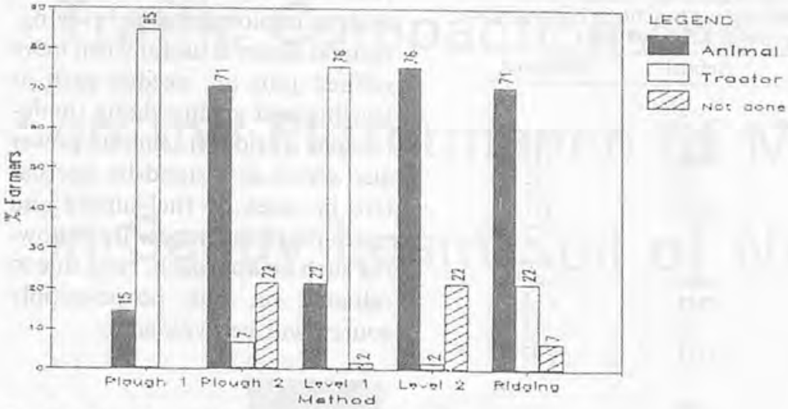

Fig. 2 Land preparation methods, Aliab Scheme.

similar with the two methods ranging between 67 and 70 cm.

Farmers' Opinions on Land Preparation Methods

Opinions on the most suitable land preparation methods differed considerably among farmers. Although 46% were content with the methods they already follow, opinions of the rest varied between additional needs for tractor operations and more intensive use of animal power (**Table 2**). About 20% of the farmers expressed by some way or another the need for machine operations. This was further reflected by the response of farmers to the nature of problems faced in land preparation. As much as 44% related problems to the scarcity of machinery (**Fig. 3**).

Cost of Land Preparation Methods

Table 3 shows the costs of land preparation operations according to the methods used. Tractors were more expensive than animal power in all operations except for ridging where figures were similar. If all operations were to be done by tractors, they would cost LS 381.418 per ha on average, which would be LS 88.755 more than with animal power.

It should, however, be taken into consideration that the recorded animal-power costs were mostly estimates given by farmers as to what would these costs be if they were to hire these services. This is due to the fact that most farmers used their own animals. Opportunity costs of animal use seems to be higher. Animal keeping poses a demand on the valuable land factor where many farmers mentioned that they allocate part of their area (about 0.2 ha) to fodder devoted to draught animals, in addition to sorghum residues and purchased concentrates. Most of farmers mentioned that they face increasing difficulties in keeping their animals. On the other hand, draught animals have more "flow value" than just providing land preparation services. Trained oxen fetch much higher prices than untrained ones. Even though few farmers mentioned keeping dairy cows, training oxen through use on these farms brings additional income. These items are difficult to evaluate but nevertheless should be taken into consideration.

Table 2 Farmers' Opinions About the Most Suitable Land Preparation Method in Aliab Scheme, 1985/86, %

Method	Response
Current method	46
Geneal use of tractors	12
Early additional tractor ploughing	5
Tractor ridging	3
More intensive use of animals	5
Prefer animal ridging	3
Presowing irrigation	2
No answer	24
Total	100

Table 3 Costs of Different Land Preparation Methods at Aliab Scheme, 1985/86 (in LS/ha)*

Operation	Costs By	
	Animals	Tractor
First ploughing	57.518	77.588
Second ploughing	46.410	63.467**
First levelling	74.044	86.337
Second levelling	75.922	114.240***
Ridging	39.146	40.163
Total	293.040	381.795

* One US Dollar = 4.5 Sudanese pounds (LS).
** only 3 farmers. *** only one farmer.

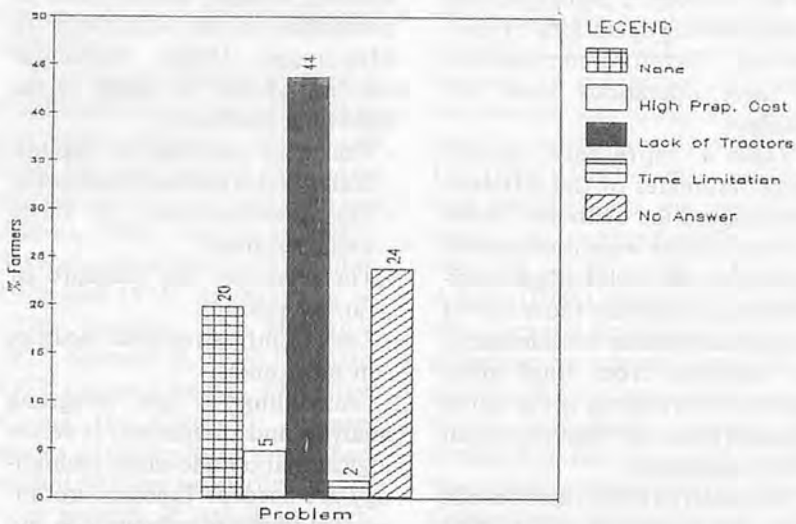

Fig. 3 Land preparation problems, Aliab Scheme.

Table 4 Partial Budget of Animal Versus Tractor Use in Different Tillage Operations. (Yield in kg/ha; gross benefits, variable costs and net benefits in LS/ha. Gross benefits were calculated with grain field price of LS 1.909/kg)

Operation/Item	Tractor	Animal	Difference
First ploughing:			
No. of farmers	29	5	
Average yield	1680	1495	185
Gross benefits	3207	2854	353
Variable costs	79	57	22
Net benefits	3128	2797	331
First levelling:			
No. of farmers	27	7	
Average yield	1645	1690	−45
Gross benefits	3140	3225	−85
Variable costs	86	74	12
Net benefits	3054	3151	−97
Ridging:			
No. of farmers	7	24	
Average yield	1827	1578	249
Gross benefits	3475	3013	462
Variable costs	40	38	2
Net benefits	3435	2975	460

Benefits of Land Preparation Methods

Obviously, costs alone are not useful in evaluating different methods without the consideration of their effects on crop yields and thus benefits. **Table 4** shows the cost, yield and benefit comparisons of tractor versus animal input for different operations.

Three operations have been considered in the evaluation based on the availability of information on their input by both tractors and animals. These are first ploughing, first leveling and ridging, in spite of the low number of farmers who do these operations by either of the two methods. Only few farmers did the second ploughing and second leveling operations by tractors and, therefore comparisons on these operations were not justified.

Table 4 represents partial budget estimates of the different land preparation methods. Yields and crop prices were those stated by farmers. In such budgets variable costs, which are those due to the operation under consideration, are deducted from total gross benefits. The interest is not in the resulting total net benefits, but in their comparison.

Net benefits with tractor use in both first ploughing and ridging were considerably higher than with animal power while the reverse is true for leveling. Actually, most farmers prefer draught-animal use in leveling since they have a better control over the leveling operation. Increases in net benefits with tractor ploughing and ridging averaged LS 331 and LS 460 per ha while an average loss of LS 97 per ha were incurred with tractor leveling.

Discussion

A number of major problems limit the use of modern agricultural mechanization and thus provide a certain amount of scope for keeping draught animals and its promotion in this area (refer to Munzinger, 1982). Particular mention should be made to the following problems:

- The acute shortage of capital, both at farm and national levels.
- The predominance of fairly small holdings.
- The relatively low standard of farmer training.
- Lack of infrastructural facilities in most areas.

According to the foregoing analysis and discussion, it seems logical that both levels of technology are needed. Tractors are important for more arduous jobs and especially for ones where a higher field capacity could be achieved such as in ploughing and ridging. Animal power is useful when more refined jobs are needed such as leveling and green ridging (maintenance of ridges). Animal power also serves as a stand-by alternative in cases of fuel-supply and spare-parts shortages. By following such an approach, risks due to reliance on one power-supply source will be avoided.

Recommendations

Both animal power and tractorization are needed in Northern Sudan. Their availability and enhancement of efficiency should be given due consideration. This could be achieved by the following:

A) For animal power:
- Improvement of the available implements and encouragement of their local manufacturing.
- Better training of operators and oxen.
- Provision of better veterinary services.

B) For tractorization:
- Supply of fuel and spare parts.
- Betterment of maintenance facilities.
- Training of the manpower involved in operation and maintenance.

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Traffic Compaction and Tillage Effects on the Performance of Maize in Sandy Loam Soil of Nigeria

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Abstract

The effects of repeated traffic of a 45-kW agricultural tractor on a maize cropped farmland subjected to different tillage treatments were investigated. The experimental design was comprised of three tractor passes, 0, 5 and 10, and, five tillage methods, disk ploughing followed by disk harrowing (DPH), deep strip tilling (STD), shallow strip tilling (STS), paraploughing (PP) and no tillage (NT), respectively.

Results show that soil dry bulk density increased with depth up to 10 cm soil and was significantly influenced by tillage methods and compaction levels. Soil resistance to cone penetration increased with soil depth and was higher for no tillage (NT) than other tillage methods for all compaction levels. Root length density varied exponentially with soil depth and showed a greater root exploration at shallow depth than at greater depth. Its effect was significant at $P \leq 0.05$.

Effects of depth of seed placement, seedling emergence, plant height and kernel yield of maize were not statistically significant at $P \leq 0.05$ for all tillage methods and all compaction levels.

Introduction

Soil tilling is the most intensive of all processes involved in crop production. In Nigeria, soil cultivation is performed indiscriminately, with little or no regard for the resulting effects on soil degradation and crop performance. These effects are further compounded by repeated passages of agricultural machinery during the production cycle of any crop. The exact number of passes of agricultural tractors during this produciton cycle has not been firmly established but can be assumed to vary between 8 and 10 passes for a fully mechanized operation.

Continuous passage of agricultural tractors over farm lands does not only compact the plough layer but has marked effect also on crop growth and yield (Oni and Adeoti, 1986; Negi et al, 1980). Several researchers (Chancellor, 1971 and 1976; Raghavan et al, 1976; Voorhees and Hendrick, 1977; Soane et al, 1979; Dunham, 1982; Oni and Adeoti, 1986) have studied the effects of repeated passes of agricultural machinery on soil physical properties and on crop growth. It has been established that repeated passes of agricultural tractors on farm lands can lead to reduced infiltration rates, poor soil aeration, reduced root exploration, reduced crop yield and soil erosion, particularly for soils with low vegetative cover (Barnes et al, 1971; Erickson, et al, 1974; Raghavan, et al, 1976; Soane, et al, 1979; Oni and Adeoti, 1986).

Lal, 1977 inferred that maize root penetration was greater in conventionally tilled soil (ploughed and harrowed) than under no-till condition. Under no-till condition, it was observed that root exploration concentrated more at the surface than for conventionally tilled soil (ploughing to a depth of 20 cm followed by harrowing). In subsurface soil, root exploration was lower for no-till than for conventionally tilled soil. Lal (1977) further inferred that root proliferation was generally better for conventionally tilled than for no-till system. Oni and Adeoti (1986) showed that there was a general decrease in root exploration for cotton grown in a loamy soil as the number of passes of agricultural tractors increased but that root proliferation was greater at shallow depth. Root density was sampled using soil core samplers with samples taken

Table 1 Physical and Chemical Characteristics of the Sandy Loam Soil Profile

Depth	Physical composition (%, w/w)			pH	Chemical composition (m.eq. $100g^{-1}$)						Organic C (%, w/w)	N (%, w/w)	Available P (ppm)
cm	Sand	Silt	Clay		Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	Acidity	Total			
0-10	68.2	16.6	15.2	6.6	3.2	1.28	0.39	0.09	0.04	5.00	1.30	0.11	5.25
10-36	80.2	4.6	15.2	6.5	1.0	1.24	0.10	0.09	0.06	2.49	0.45	0.04	0.53
36-48	80.2	4.6	15.2	6.8	0.6	0.20	0.11	0.06	0.05	1.02	0.33	0.03	1.22
48-84	48.2	4.6	45.2	6.0	3.0	0.60	0.24	0.13	0.11	4.08	0.49	0.04	1.93
84-116	47.2	9.6	43.2	6.1	3.6	0.72	0.25	0.13	0.05	4.75	0.27	0.02	0.00

at a distance of 10-15 cm from the base of maize plant. The length of root segments per unit volume of soil was determined.

Daynard and Ketcheson (1982) and Oni and Adeoti (1986) studied the influence of soil type and tillage methods on the performance of maize and cotton, respectively. Tillage practices that enhanced the proportion of fine soil aggregate were found to significantly influence crop production.

The objectives of this investigation were to study (a) the extent to which five tillage methods could relieve differently compacted sandy loam soil of the Southern Guinea savannah vegetation zone of Nigeria and (b) the effects of the treatment combinations on the growth and yield of maize.

Materials and Methods

This investigation was conducted at the tillage research experimental site located on the main campus of the University of Ilorin in Kwara State (04°29′E, 08°26′N) in the Southern Guinea savannah vegatation zone of West Africa. The land is gently sloping. The texture of the surface soil is sandy loam, varying progressively to loamy sand and sandy clay loam in the subsurface horizons. This implies that water infiltration rate is faster in the surface horizons. The soil profile distribution of sand and slit particlels as well as the exchangeable cations indicate truncation, a younger soil having been deposited over an older, in-situ profile. The pedon belongs to the order Alfisol. The physical and chemical composition of the soil is presented in **Table 1**. There was no known recent record of cultivation on the land.

The land was initially ploughed to a depth of 40 to 50 cm followed by an application of 200 kg/ha of superphosphate (15-15-15 of N-P-K) and then disk-harrowed. A split-plot statistical design, comprising three compaction levels (tractor passes) and five tillage methods was laid out on the land with each treatment combination replicated three times. There were nine blocks with five plots per block and each plot size was 3 × 10 m. The five tillage methods were randomly assigned.

The three compaction levels were 0, 5 and 10 wheel-to-wheel passes of a 45-kW agricultural tractor at a contact inflation pressure of about 95 kPa applied to the rear tyres while that for the front tyres was about 160 kPa. The tractor was driven over the experimental plots until the desired number of tractor passes was achieved and was followed by the tillage treatments.

The five tillage treatments comprised of disk ploughing to a depth of 25 cm followed by disk harrowing (DPH), deep strip tilling to a depth of 20 to 25 cm using a spring-tined chisel plough (STD), shallow strip tilling (STS) to an average depth of 15 cm using a p.t.o. driven rotavator but with its blades spaced in conformity with the desired row spacing for maize, paraploughing (PP) to a depth of 25 cm using a half-V-blade sweep and a no-tillage (NT).

Maize seeds were planted using a rolling injection planter at a between-the-row spacing of 50 cm and a within-the-row spacing of 25 cm. Following planting operation, a pre-emergence herbicide was applied. This consisted of a mixture of Gexaprim, Dual and Gramoxone at a rate of 0.25 + 0.35 liter/ha. At about 4 weeks after planting, Calcium Ammonium Nitrate (CAN) containing about 20% nitrogen was applied at a rate of 200 kg/ha to boost the growth and ear yield of the maize crop. Seedling emergence count was also conducted about this period.

The soil bulk density, root length density, the soil resistance to cone penetration and plant height measurements were conducted at 75 days after planting at a near field capacity condition of the sandy loam soil. This was when the soil pores were fully saturated. The root length density was determined using the procedure described by Oni and Adeoti (1986) and taking soil samples at two locations, at a lateral distance of 10 to 15 cm from the base of the maize plants.

At the end of the growing season, the maize ears were harvested by hand and shelled. The kernel weight was determined for each tillage method.

Results and Discussions

Depth of Seed Placement

There was no significant effect of the tillage methods and compaction levels on depth of seed placement as shown in **Table 2**. For all compaction levels and all tillage methods, the depth of seed placement averaged 4.17 cm. The

Table 2 Summary of Statistical Analysis of Variance for the Measured Soil and Plant Parameters

Parameter	Variate	DF	F-values[a]	Standard Error (SE)
Depth of seed Placement (cm)	Total	36		
	Tillage Methods (TM)	4	0.942 ns	0.573
	Tillage Methods Comp. Levels (TM x CL)	8	0.476 ns	0.762
	Residual	24		
Seedling emergence (cm)	Total	36		
	Tillage Methods (TM)	4	2.282 ns	1.540
	TM x CL	8	0.643 ns	3.092
	Residual	24		
Soil dry builk density (g/cm^3)	Total	163		
	TM	4	1.505 ns	0.029
	CL	2	7.524*	0.026
	TM x CL	8	0.681	0.057
	Residual	147		
Soil resistance to Cone penetrometer pressure (kPa)	Total	126		
	TM	4	9.455*	62.100
	CL	2	5.081*	58.420
	TM x CL	8	2.986*	87.800
	Residual	110		
Root length density (cm. cm^{-3})	Total	163		
	TM	4	5.802*	0.039
	CL	2	1.821 ns	0.0215
	TM x CL	8	0.405 ns	0.069
	Residual	147		
Plant height (cm)	Total	36		
	TM	4	1.087 ns	1.562
	CL	2	0.007 ns	2.915
	TM x CL	8	1.470 ns	1.626
	Residual	20		
Kernel yield (kg)	Total	36		
	TM	4	0.450 ns	0.262
	CL	2	0.229 ns	1.966
	TM x CL	8	0.745 ns	2.394
	Residual	20		

a:* Statistically significant at $P \leq 0.05$; ns not stastically significant at $P \leq 0.05$

Table 3 Treatment Means of Measured Soil Properties and Parameters of Maize

Tillage teatments	Measurements*		
	Dry bulk density (g/cm^3)	Cone pressure (kPa)	Root length density (cm/cm^3)
Disk ploughed-disk harrowed (DPH)	1.238 a	693 b	112 cd
Deep strip tilled (STD)	1.352 bc	838 ab	97 bc
Shallow strip tilled (STS)	1.330 bc	938 bc	79 ab
Paraploughed (PP)	1.296 b	558 a	67 ab
No tillage (NT)	1.268 b	1 037 cd	55 a

* Means with the same letter are not significantly different at $P \leq 0.05$ using Duncan's new multiple-range test.

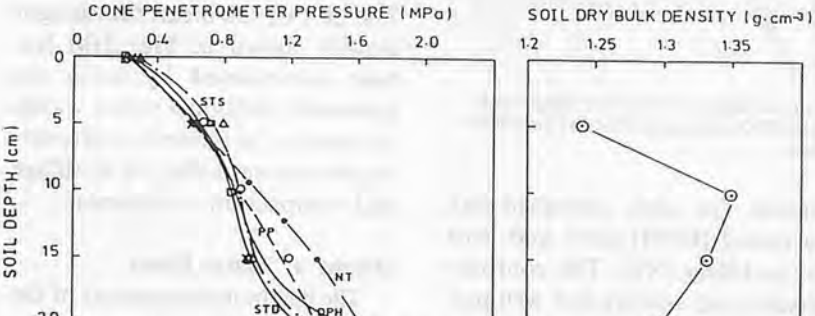

Fig. 1 Cone penetrometer and soil dry bulk density variation with soil depth at near field capacity state for the sandy loam soil. DPH-disk ploughed-disk harrowed, STD-deep strip tilled, STS-shallow strip tilled, PP-paraploughed, NT-no tillage.

maximum depth was observed for disk ploughed-disk harrowed system while the no-tillage system gave the least depth.

Maize Seedling Emergence

The tillage methods, the compaction levels and interaction of these treatments did not show any significant effect on seedling emergence when tested at $P \leq 0.05$ as shown in **Table 2**. Disk ploughing followed by disk harrowing (DPH), however, had the lowest seedling emergence count while the no-tillage (NT) had the heighest.

Soil Dry Bulk Density

For all tillage treatments and compaction levels, there was an increase of dry bulk density with soil depth, from zero to 10 cm, beyond which there was a slight decrease as shown in **Fig. 1(b)**. The interaction of tillage methods with compaction levels was significant at $P \leq 0.05$ as shown in **Tables 2** and 3.

Soil Resistance to Cone Penetrometer Pressure

The tillage methods, compaction levels and interaction of tillage methods with compaction levels gave significant effects of soil resistance to the penetration of a 30 degree, 130 mm^2 base area hand-held cone penetrometer. The results further show an increase of these values with soil depth and a good correlation with soil dry bulk density as illustrated in **Fig. 2**. **Fig. 1(a)** shows that cone pressure was highest for no tillage (NT) than for other tillage treaetments particulars at soil depth greater than 10 cm. Each data point is an average of several readings at a specified depth range.

Root Length Density

The effects of root length density of maize plant was significant at $P \leq 0.05$ for the tillage methods. **Fig. 3** shows root length den-

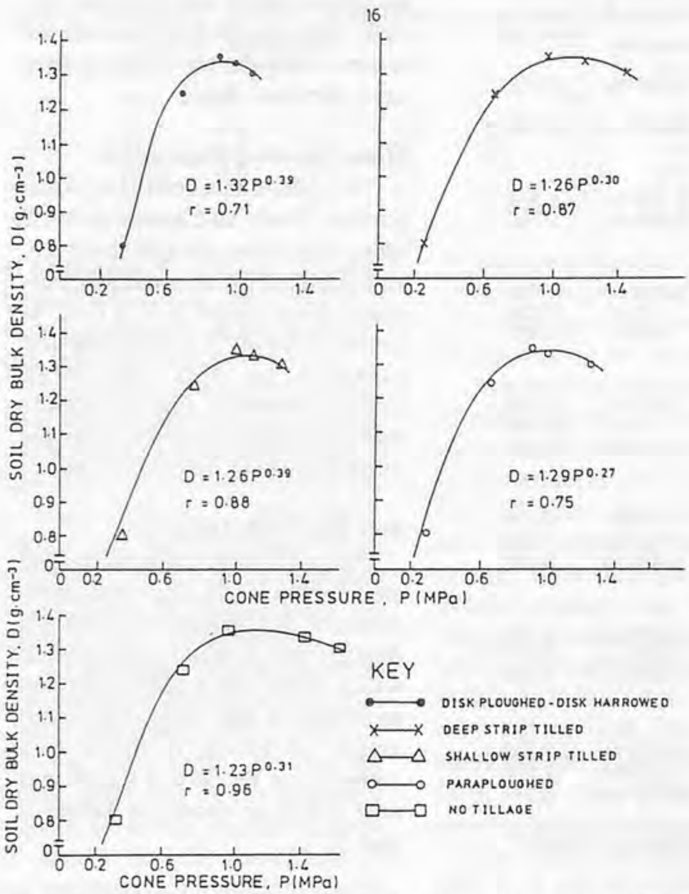

Fig. 2 Relationship between soil resistance to cone pressure and soil dry bulk density for a sandy loam soil.

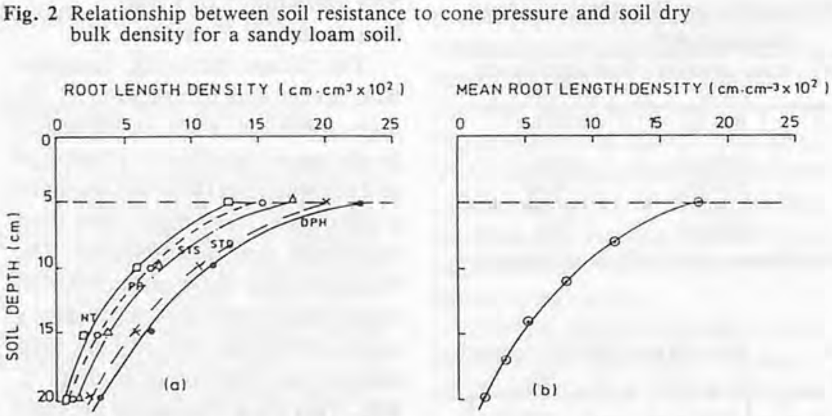

Fig. 3 Relationship between root length density and soil depth for the five tillage treatments: DHP = disk ploughed-disk harrowed; STD-deep strip tilled; STS-shallow strip tilled; PP-paraploughed; NT-no tillage.

sity and mean root length density variations with soil depth and is a measure of the extent of root exploration as depth was increased. The figure further reveals extensive root exploration at shallow depth. **Table 3** shows that the treatment means, using Duncan's new multiple-range test, was highest for disk ploughed-disk harrowed (DPH) plots and least for no-tillage (NT). This confirms greater root activity in a well pulverized soil.

The mean root length density curve in **Fig. 3 (b)** was obtained by generating additional values from the root length density values using a polynomial curve fitting technique (Carnahan et al, 1969).

The governing general equation is:

$$P_n(x) = \sum_{i=1}^{n} L_i(x) f(x_i) \quad \ldots (1)$$

where,

$$L_i(x) = \prod_{\substack{j=1 \\ j \neq i}}^{n} \frac{(x - x_j)}{(x_i - x_j)},$$

$$i = 1, 2, \ldots\ldots, n \quad \ldots (2)$$

and x = soil depth

The expanded form for the polynomial of degree 3 becomes:

$$P_3(x) = L_1(x)f(x_1) + L_2(x)f(x_2) + L_3(x)f(x_3) + L(x)f(x_4)$$

where

$f(x_i) = F_i$
= depth function values

The shortened form of this polynomial becomes:

$$P_3(x) = A_1x^3 + A_2x^2 + A_3x + A_4$$

The coefficients were computed in terms of the function values. The resulting polynomial for the mean root length density is:

$$P_3(x) = (-4.93 \times 10^{-5})x^3 + (2.50 \times 10^3)x^2 - (4.71 \times 10^{-2})x + 0.356$$

The plot of the mean root length density shown in **Fig. 3 (b)** has been smoothened by using the generated additional values within the range of soil depth, representing the average value for all tillage and compaction treatments.

Height of Maize Plant

The height measurements of the maize plants did not have any significant effects for tillage methods and compaction levels at $P \leq 0.05$ as shown in **Table 3**. This implies that soon after crop establishment, shoot development was probably governed more by factors other than tillage and compaction treatments under the conditions investigated.

Maize Kernel Yield

Results show that maize kernel yield was not significantly influenced by tillage and compaction treatments at $P \leq 0.05$ as shown in **Table 2**.

Conclusions

The response of maize to tillage and compaction treatments were investigated for a sandy loam soil in terms of depth of seed placement, seedling emergence, soil dry bulk density, cone pressure, root length density, plant height and kernel yield. Results showed that maize crop performance can be quantified in terms of soil dry bulk density, cone pressure and root length density measurements. Effects of treatment combinations on seed placement depth, seedling emergence, plant height and kernel yield were not significant at $P \leq 0.05$.

The performance of the maize crop was governed more by the tillage methods than by compaction levels for each measured parameter. More research work is required to further confirm these observations under conditions investigated.

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Standardization and Quality Control of Centrifugal Pumps

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Abstract

Centrifugal pumps operated by electric motor or engine for lifting water are popular and are the major source of energy consumption in agriculture. A testing of three new centrifugal pumps of 100 × 75 mm size showed that head, discharge, pump efficiency and power input varied from 0 to +15.2%. −2.5% to +33.3%, −2.5% to +109% and −20.3% to +11.3%, respectively, as compared to duty point values declared by the manufacturer. Hardware improvement through quality material and modern manufacturing techniques can improve operational efficiency of centrifugal pumps and savings in energy substantially.

Introduction

Land and water are the basic requirements for agriculture. The total agricultural production from a gross area of 165 million ha in India is currently about 150 million t which is to be raised to about 250 million t by the year 2001. The recognition of ground water as an important irrigation source is not new which is the major consumer of direct commercial energy. Despite large scale development, nearly two-thirds of the potential still remains untapped in India leaving Haryana, Punjab and Delhi. Thus, demand for commercial energy to raise additional 100 million t production will compel to design and use energy efficient water lifting devices. However, it is well known that centrigufal pumps are most commonly used as water lifting devices for irrigation purposes. There are about nine million pump sets in the country (Anonymous, 1988). Each pump set is estimated to provide irrigation for two hectares. On this basis, 18 million ha can be irrigated with ground water, contributing for at least 36 million of food grains (Anonymons, 1988). Correlation between the commercial energy inputs and agricultural productivity shows that the demand for commercial energy in the agricultural sector is likely to increase rapidly during the next 15-20 years. On the other hand, global availability of conventional energy resources are expected to diminish sharply by the turn of the century (Pathak and Bining, 1984). The combination of these two factors, namely; the increasing demand for commercial energy inputs and the probability of serious restrictions on commercial energy supply in the near future will force to pay more attention towards efficient utilisation of energy in agricultural production.

It has been reported that savings to the extent of 30% energy can be effected with energy-efficient pump-sets, which is possible through general improvement in lift-irrigation hardware (Anonymous, 1988). Thus there is an urgent need to launch a massive quality improvement programme to spread the concept of energy-efficient pump sets. For this, the operating range of different centrifugal pumps needs to be specified for proper selection, as different pumps of the same size exhibit maximum efficiency at different total heads and discharge. Moreover, before a pump is accepted by the purchaser, it should be tested to make sure that it meets the guaranteed head, capacity and efficiency.

The inter-relation of capacity, head, power and pump efficiency are best shown graphically and these curves are called characteristic curves (Church and Lal, 1973). It is usual to plot head, power and efficiency against capacity at specified speed. A pump should be selected that will give a high efficiency for a wide range of discharge valves. However, the pump will give the best performance when operating against the head and capacity corresponding to the inter-section point of head and efficiency. The characteristic curves and the duty points are supplied by the manufacturer. Characteristic curves differ in shape and magnitude depending upon the size, type of impeller and overall design of the pump. In view of this, a testing and evaluation of a few selected pumps of different make was undertaken to varify the duty points (characteristic values) declared by the manufacturer with the observed values and inter-section point of head-discharge-efficiency curves of the same pump and to compare the performance of different pumps of the same size.

Application of Standards

The Bureau of Indian Standards formulated IS: 6595 and IS: 9137, which describe the specification for centrifugal pumps for agricultural purposes and acceptance tests for centrifugal pumps, respectively. These standards are intended to help the manufacturers to standardize the functional components of pumps and at the same time assist various purchasing and user agencies to select appropriate centrifugal pumps to meet their specific requirements. Thus it is only through standardization and quality control that the functional performance is achieved and energy is saved considerably.

Material and Methods

In order to check the pump performance as per referred standards and relevant clauses, three new centrifugal pumps were selected and tested with a view to assessing their quality and standardization. The observed data was analyzed (**Table 1**). The characteristic curves of these pumps are shown

Table 1 Pefformance of Sample Centrifugal Pumps (Size 100 × 75 mm)

Parameter	Condition	Centrifugal pumps (Type)		
		I	II	III
Head H (m)	Declared	23.0	12.0	9.5
	Observed	23.0	13.4	10.9
	η-H-Q curve	26.0	16.7	12.6
Discharge Q (1/s)	Declared	13.0	20.0	13.2
	Observed	13.8	19.5	17.6
	η-H-Q curve	10.2	12.1	12.4
Pump efficiency η (%)	Declared	56.0	62.0	38.0
	Observed	61.1	60.4	79.4
	η-H-Q curve	59.0	57.3	71.0
Power input (kW)	Declared	5.20	3.80	3.10
	Observed	5.22	4.23	2.47
	η-H-Q curve	4.60	3.40	2.20

N.B. a) Declared means the duty points supplied by the manufacturer. b) The values given against η-H-Q curves are from actual testing and plotting.

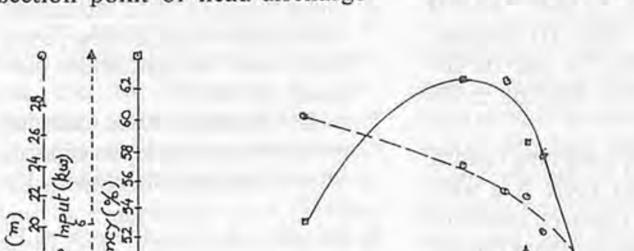

Fig. 1 Characteristic curve of Type-I C.F. pump (100 × 75mm].

Fig. 2 Characteristic curve of Type II C.F. pump (100 × 75mm).

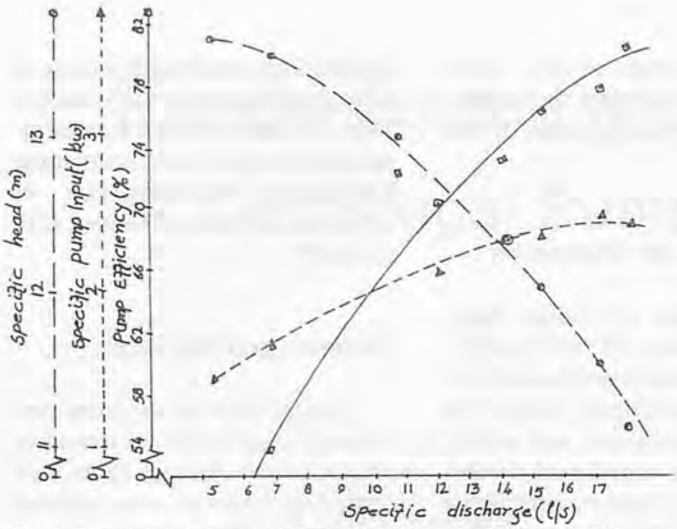

Fig. 3 Characteristic curve of Type III C.F. pump (100 × 75mm)

Table 2 Percent Variation in Observed Values from Declared Values

Parameter	Centrifugal pumps (Type)		
	I	II	III
Head	0	+11.7	+15.2
Discharge	+ 6.2	− 2.5	+33.3
Pump efficiency	− 9.1	− 2.5	+10.9
Power input	− 3.8	+11.3	−20.3

Table 3 Percent Variation in η-H-Q Curve Values from Declared Values

Parameter	Centrifugal pumps (Type)		
	I	II	III
Head	+13.0	+39.2	+32.6
Discharge	−21.5	−39.5	− 6.1
Pump efficiency	+ 5.4	− 7.6	+86.8
Power input	−11.4	−10.5	−29.0

in **Figs.** 1 and 3, respectively.

Test Instruments and Apparatus
Measurement of head:
Pressure gauge (Change in head by throttle valves)
Measurement of discharge:
Head of water flowing over a 90°V-notch and Hook gauge.
Measurement of speed:
Hand, digital tachometer
Measurement of power:
Energemeter, wattmeter
Pump input and motor efficiency:
Eddy-current dynamometer

Results and Discussion

The variation in observed valves from duty points declared by the manufacturer is presented in **Table 2**. The head varied from 0 to +15.2%, discharge from −2.5 to +33.3%, pump efficiency from −2.5 to +10.9% and power input from −20.3 to 11.3%, respectively.

The variation in η-H-Q curve valves (**Figs. 1, 2** and **3**) from duty point declared by the manufacturer are presented in **Table 3**. It is evident from the table that the head varied from +13.0 to +39.2, discharge from −39.2 to −6.1%, efficiency from −7.6 to +86.6% and power input from −29.0 to −11.4%, respectively.

Conclusions

Variations of head for the types I, II and III pump were +13.0%, +39.2% and +32.6%, respectively, which is on the high side than the limit of ±3.5% prescribed by the Bureau of Indian Standards. Discharge rate variation in Type-I, Type-II and Type-III pumps was −21.5%. −39.5% and −6.1%, respectively, which is more than the limit of ±3.5%. Pump efficiency variation in Type-II and III was −7.6% and +86.8%, which is higher than the limit of ±5%. Power input variation was −11.4%, −10.5% and −29.0% in Type-I, II and III pumps, respectively, which is also on the high side than the limit of ±5% as BIS Codes.

In view of the foregoing results, it is evident that there is a wide variation in the declared values of different parameters from the observed values and from the values which come from intersecting point of head and efficiency curves, plotted against discharge. Thus there is a need for improvement in pumps which can be attained through better design and modern manufacturing techniques. Proper testing facilities with accurate instruments of an approved type with the manufacturers should also be there in order to supply quality products which match the claimed performance and ultimately product standardization and savings in energy.

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Establishment of a Multi-crop Production System with Minimum Fluctuation in Tractor- and Man-hour Requirements

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Abstract

A technique was developed for the selection of the number and capacities of farm machines and the number of man-hours for multi-crop production such that the fluctuation in the requirements of the production resources is minimized, while ensuring timeliness of production. During the smoothing processes, the sizes of the plots for the different corps, types, capacities and number of farm implements continued to change until the fluctuation in the tractor and man-hour requirements was minimized. At the end of the smoothing processes, a short, slack period is left towards the end of the year for an elaborate maintenance of the tractor and workers' annual leave. Also, while all the available farm land is completely used for the multi-crop production, there is a reduction in the number of tractors from four to one and an overall reduction in the quantity of farm implements.

Introduction

Acknowledgement: The author is grateful to Mr.O. Ekeyi for his assistance in the collection of data and drawing of graphs.

Tractor, man and draught animal are the major power sources of farm implements and tools, and it is not possible to perform crop production processes without them. Besides the restriction on the use of draught animal to where it can be successfully reared, subsoil pan is not broken up and subsoil nutrients and moisture are not fully exploited when used (Chaudhary, 1985). Tractor and man are, therefore, the most popular farm power sources, and man is still required to operate the tractor.

The number of tractors or man-hours required at certain periods of the year is high and it is low at other periods because of the necessity to ensure the timeliness of crop production processes (Butterworth and Nix, 1983). If the required number of tractors or man hours is not available during the periods of high demand, it will not be possible to accomplish necessary production processes during the periods, resulting in too low crop production for the year. On the other hand, if tractor-hour or man-hour requirements are satisfied during the periods of high demand, many tractors or workers will be idle during the periods of low demand, resulting in too high production cost and high energy consumption (Bhatia,1985 and Ancheta and Batista, 1986). Therefore, in addition to activity scheduling (Chaudhary et al, 1987), fluctuation in tractor and man-hour requirements must be minimized in order to achieve an efficient and economic production system.

Ademosun (1986) has identified the available periods of the year and the existing farm implements for the production processes in a multi-crop farm. A smoothing technique developed to minimize the fluctuation in tractor and man-hour requirements in such a multi-crop farm is reported in this paper. The technique is applied to determine the sizes of farm plots for maize, cowpea and cassava on a 250-ha farm such that there is no appreciable change in the requirements of tractor and man-hours during the year. The determination of the duration of production operation is based on an 8-h working day and 5-day working week.

Smoothing Analysis

The result of the pre-smoothing analysis performed by Ademosun (1986) is illustrsted in **Fig. 1**. In the smoothing analysis, the possible methods of minimizing the fluctuation in tractor and man-hour requirements are as follows:

(1) Reduction in both tractor-hours and man-hours:
  (i) Increasing the capacities of the farm implements used for the operations.
  (ii) Increasing the speed of operations.
  (iii) Maximizing the effective field or material capacity of operations by minimizing time losses.
  (iv) Combining separate operations such as primary and secondary tillage.
  (v) Reduction in the scale of production of a particular crop.

(2) Redution in tractor hours while keeping the man-hours constant:
  (i) Increasing the capacities of tractor-powered stationary implements such as thresher.

(3) Reduction in man-hours while keeping the tractor-hours constant:
  (i) Replacing manual operations with manually operated implements partially or wholly.

(4) Reduction in tractor-hours, but increase in man-hours:
  (i) Changing some mechanised operations to manual.
  (ii) substitution of new crops which will involve more manual operations than mechanised operations for existing crops.

(5) Reduction in man-hours, but increase in tractor-hours:
  (i) Mechanisation of some manual operations.
  (ii) Substitution of new crops which will involve more mechanised operations than manual operations for existing crops.

(6) Increase in man-hours while keeping tractor hours constant:

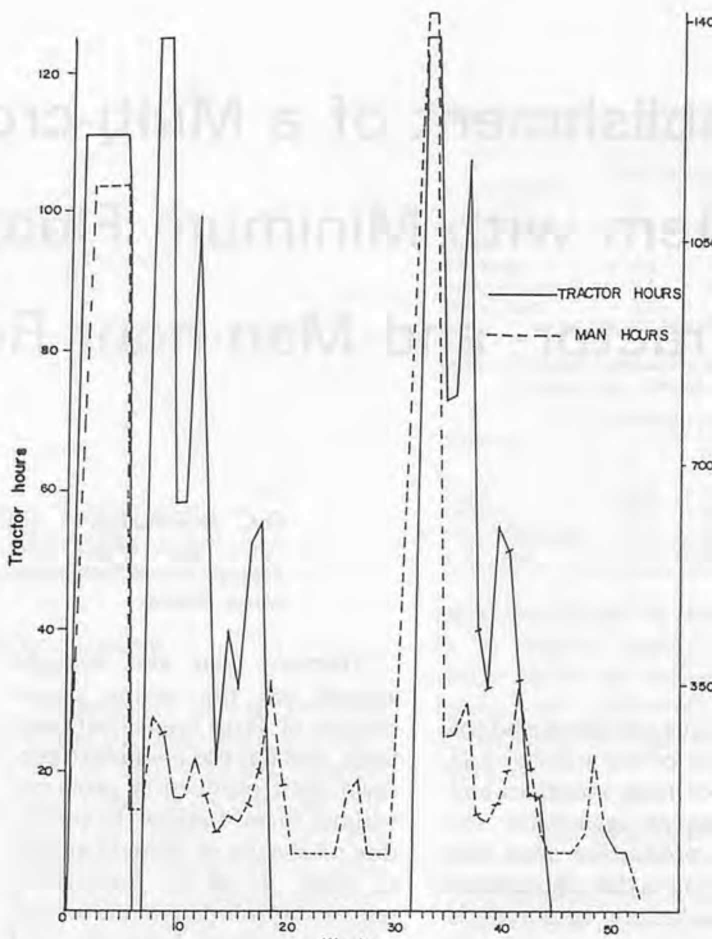

Fig. 1 Graph of tractor and man-power requirements for multi-crop production.

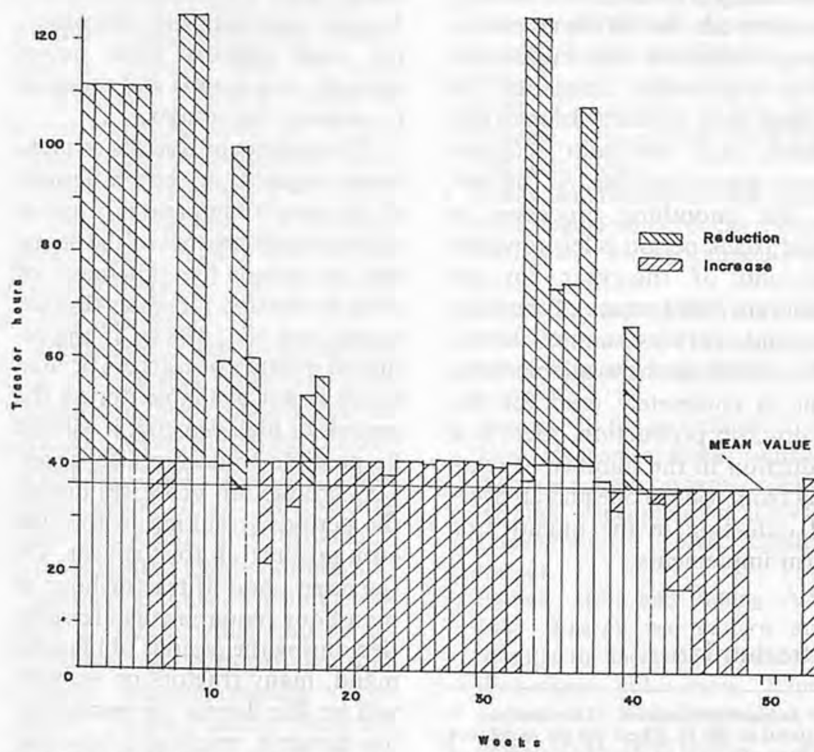

Fig. 2 Working histogram for tractor-hour requirements for multi-crop production.

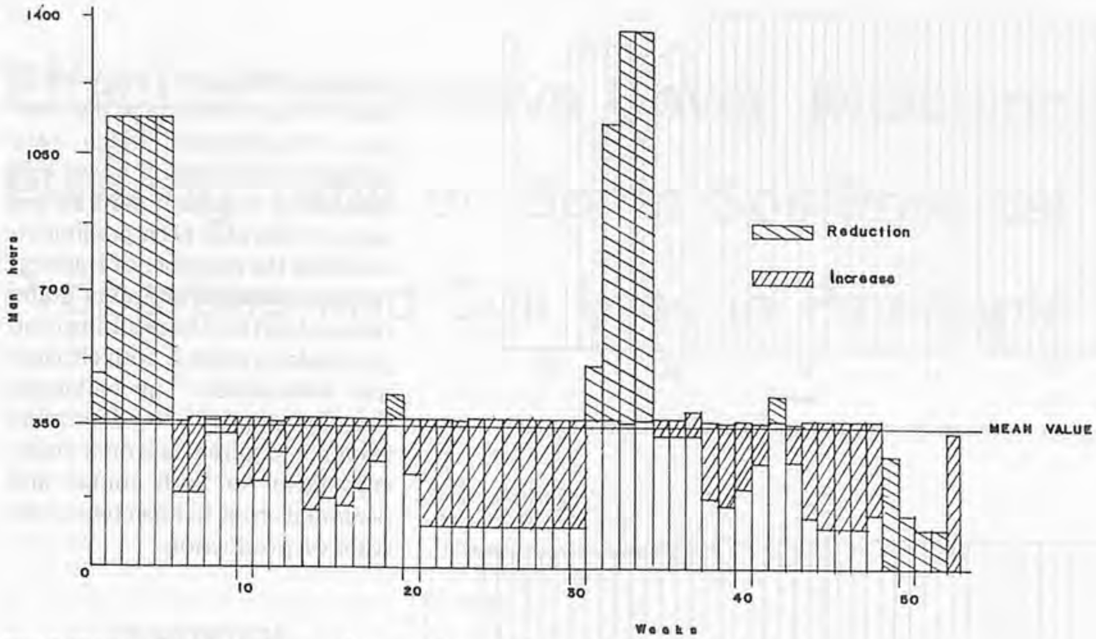

Fig. 3 Working histogram for man-hour requirements for multi-crop production.

(i) Introduction of operations not requiring tractors.

(7) Increase in tractor-hours while keeping the man-hours constant:

(i) Reduction of the capacity of tractor-powered stationary implements such as thresher.

(8) Increase in both tractor hours and man-hours:

(i) introduction of crops of which the production processes fall within the periods of low tractor and labour hours.

(ii) Reduction of the capacities of farm implements.

The total number of tractor-hours and man-hours for each week is illustrated as histograms for the purpose of performing the smoothing analysis (**Figs. 2 and 3**). The horizontal line is the mean number of tractor-hours per week for the year. The shaded portion is the number of tractor-hours or man-hours that is to be removed or added during the smoothing analysis in order to achieve minimum fluctuation of tractor-hours or man-hours.

Comparing **Fig. 2** and **Fig. 3**, it can be seen that primary tillage for maize performed in weeks 3 and 9 and primary tillage for cowpea performed in weeks 33 and 34 required the highest number of tractor -hours and man-hours. They were reduced by a reduction in the scale of production of the two crops as follows:

Time available for primary tillage
= 38.6 h per week × 16/5 weeks
= 123.5h
Width of disc plough = 1.5m
Speed of operation = 2m/sec.
Field efficiency = 0.75
The area of the farm is, therefore, reduced to:
(0.75 × 1.5 × 2 × 123.5 × 3 600)/10 000 = 100 ha.

Hence, 100 ha of maize and cowpea will be grown on the same plot at different periods of the year. From an examination of the weeks with high and low tractor-hours and man-hours (**Fig. 2** and **Fig. 3**), and the sequence of operations for various crops and the time available for the operations (Ademosun, 1986), it is found that 50 ha each of early cassava, mid-cassava and late-cassava should be grown on the remaining 150 ha of farm land. Thay cannot be grown on the same plot because of the overlap in the production cycle.

The final tractor- and man-hour requirements are illustrated in **Figs. 4 and 5**.

Discussion of Results

The high fluctuation in the tractor- and man-hour requirements has been minimized by growing 100 ha each of early maize and cowpea and 50 ha each of early-, mid-, late-cassava on a 250-ha farm instead of 200-ha each of early maize and cowpea and 50 ha each of early and late cassava. One crop has been introduced while the scale of production of two crops has been reduced. It would have been possible to introduce more crops if irrigated farming was practised.

The weekly tractor or man-hour requirment is nearly the same during the year. Only one tractor is now required throughout the year instead of requiring four tractors at some periods of the year and leaving them idle at other periods. Also, casual labourers, who demand high wages, are not re-

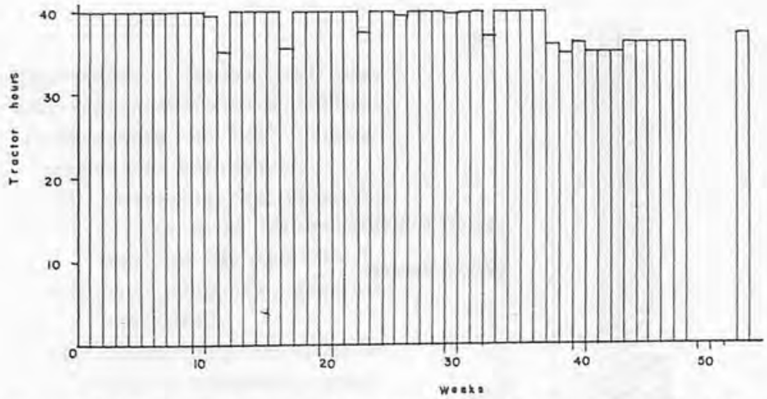

Fig. 4 Final histogram for tractor-hour requirements for multicrop production.

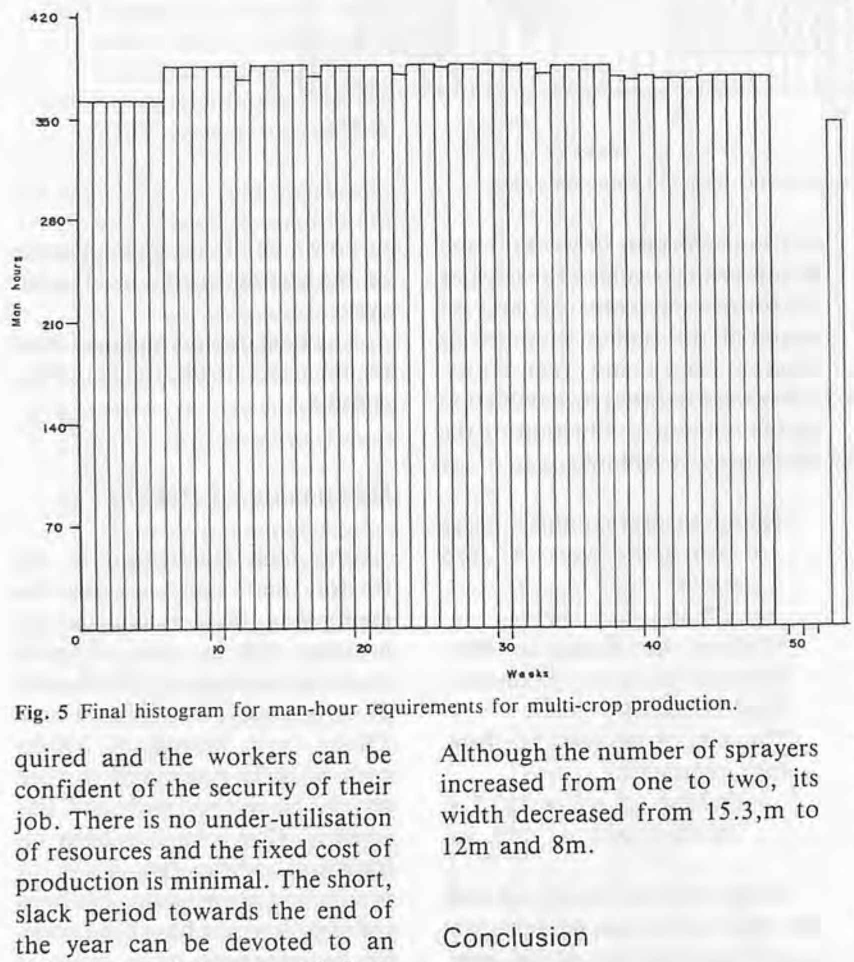

Fig. 5 Final histogram for man-hour requirements for multi-crop production.

quired and the workers can be confident of the security of their job. There is no under-utilisation of resources and the fixed cost of production is minimal. The short, slack period towards the end of the year can be devoted to an elaborate maintenance of farm machines and workers can also take their annual leave and end-of-year holiday during the period.

There is also a reduction in the number of many farm implements after the smoothing analysis: while the disc ploughs reduced from four to two, the disc harrow, disc ridger and combine planter reduced from two to one. Although the number of sprayers increased from one to two, its width decreased from 15.3,m to 12m and 8m.

Conclusion

The requirements for farm machines and labour on a multi-crop farm have been determined such that there is minimum fluctuation in the number of tractor and man-hours required for production throughout the year. With the smoothing technique, it was possible to control the tractor hour requirements which vary between 0 and 124 h per week to about 40 h per week, and the man-hour requirements which vary between 0 and 1 436.5 h was also controlled to about 400 h per week. It has also been possible to minimize the numuber of tractors, farm implements and man-hours required so that the resulting crop production system is both efficient and economical. The technique can be applied to determine resource requirements on a multi-crop farm for both annual and perennial crops irrespective of the scale of production.

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Effect of Vegetative Cover, Mulching and Planting Time on Some Soil Physical Properties and Soil Loss in Pineapple Plots

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Abstract

Studies were made on the effects of mulch materials—wood shaving (WS), rice husk (RH) and sawdust (SD) with a no-mulch control (C)—on some soil physical properties and soil loss in pineapple plots established during early rain (April), mid-rain (June) and late rain (August). Cumulative weed weight and soil loss were highest in June plantings while wood shaving controlled weeds much better and reduced soil loss than rice husk and sawdust. In April plantings, RH and SD produced significantly more leaf area than WS and C. But in June and August plantings, RH and WS had more leaf area than SD and C. Mulching reduced the percentage of sand and increased that of silt and clay at 50% flowering. It also increased the soil moisture retention, soil pH and other properties. RH, SD and C increased soil bulk density at 2 months after planting (MAP). WS consistently had lower soil bulk density than other mulch and no-mulch treatments. For the control plots, soil bulk density increased with MAP up to 6 MAP and decreased to 2 MAP values at 10 MAP.

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Introduction

Increased interest in the commercial production of pineapple in southern Nigeria has meant clearing more forest lands with the attendant rapid deterioration in soil physical properties through soil erosion, among other factors. Agronomic practices that provide ground cover quickly early in the season and maintain effective canopy throughout periods of erosive rains are known to limit erosion.

Mulches placed over the soil surface are particularly beneficial in modifying the soil physical properties, creating favourable environments for root development and reducing soil erosion. In humid and sub-humid regions where rainfall is high (1000-2000 mm per annum), rain showers heavily and concentrated between May and September, and soil highly erodable, soil erosion is a major hindrance to intensive cultivation. Hence, the most beneficial effect of mulching is the reduction of water run-off and soil erosion (Khatibu et al, 1984).

Mulches have been used profitably to increase yield in grain and root crops (Okigbo and Lal, 1980) and are known to suppress weed growth in maize plots (Agboola and Udom, 1967). Work on the effect of mulches on horticultural crops in Nigeria is very scanty. It has been reported (Asoegwu, 1987) that mulch increased plant establishment and yield in leafy amaranths. Mulched tomato plants grew taller and had greater fruit weight than staked plants (Olasantan, 1985).

Different planting dates affect periods of maturity in plantain (Obiefuna, 1986). This could be used to great advantage in making pineapple available all-the-year round in commercial quantities. This work was aimed at investigating the effects of different readily available mulch materials and different planting dates on weed growth, vegetative cover and soil loss in pineapple plots while monitoring the growth and yield of the pineapples.

Table 1 Some Climatological Data for NIHORT,, Mbato, Obtained During the Trial

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul,	Aug.	Sept.	Oct.	Nov.	Dec.
1941[1)]												
R (mm)	0.0	7.6	63.6	130.9	187.0	530.2	193.7	274.9	279.5	137.5	33.5	18.1
R.H. (%)	59	71	75	78	86	85	88	86	79	78	72	62
T (°C)	26.5	28.7	28.5	28.2	26.8	25.4	25.7	25.6	25.3	26.3	26.4	26.0
1985												
R (mm)	0.0	6.0	249.4	149.2	195.2	220.7	301.7	383.4	340.0	201.7	58.3	TR
R.H. (%)	66	54	66	73	75	78	83	81	80	73	74	51
T (°C)	26.4	27.9	28.5	27.1	26.7	26.0	24.7	25.3	25.4	26.3	27.1	25.7
1986												
R (mm)	0.0	8.7	78.1	101.0	205.2	180.1	83.4	201.7	301.8	146.7	28.1	0.0
R.H. (%)	58	61	64	68	76	80	81	81	79	75	76	55
T (°C)	26.9	28.6	27.7	26.8	26.9	27.7	24.9	24.5	25.5	25.7	25.9	24.9

1) R = Rainfall, R.H. = Relative Humidity, T = Mean Temperature, TR = Trace Rainfall.

Materials and Methods

The experiment was conducted in the years 1984/85 and 1985/86 on the fruit farm of the National Horticultural Research Institute (NIHORT), Mbato substation, Kigwe (05° 35′N and 07° 23′E, 130 m above sea level). The experimental site had been fallow for five years. The texture of the soil surface layer (0-40 cm) was sandy loam Ultisol. Soil samples were obtained at 0-15 cm depth and analysed for some physical and chemical properties at start and at 50% flowering. The 5% slope site was cleared using a cutlass before disc ploughing and harrowing once each to a depth of 20-30 cm. Thirty-five suckers at their 10 leaf stage (VIO) were soaked in 0.1% moisture of benlate and water and planted out (0.5 m × 0.5 m) in each plot measuring 3.0 m × 2.0 m across the slope. Plots have 1.0 m alleyways between them. They were planted out on the 18th day of April, June and August, 1984, representing early-, mid, and late rains. Rice husk (RH), wood shaving (WS), sawdust (SD) and no-mulch control (C) treatments were applied 2 weeks after planting. The mulch plots received 5 cm thick mulch materials. The experimental design is split plot replicated three times with planting date as the main effect and mulching as the sub-effect. Main effect blocks measured 11.0 m × 11.0 m.

Soil loss was assessed in each plot using the graduated spike (nail) technique (Schumm, 1956). Painted iron rods (8 cm long and 5 cm in diameter) were driven into and flushed with the surface of the mulch materials and the ground. Twenty spikes were placed in between rows of pineapple across the slope in each plot to enclose the 15 middle plants to be monitored for growth and yield. After each rain or group of small rains, the height of each spike above or below the surface of mulch material or soil was measured using a small ruler (to the nearest millimeter). Exposure or burial of the spikes in a plot was summed up and soil loss calculated as:

$$\text{Soil loss } (\text{kg}/6\text{m}^2) = \frac{\text{Total exposure (mm)}}{\text{No. of nails}} \times 6\text{m}^2 \times D_b \frac{\text{kg}}{\text{m}^2} \times \frac{\text{m}}{10^3\text{mm}} \quad (1)$$

where D_b = bulk density.

After each measurement the spikes were again adjusted flush with the soil or mulch material. Bulk density was measured using Black et al (1965) method at 2, 6, and 10 months after planting (MAP).

At monthly intervals, weeds were hand-uprooted and weighed fresh while the number of leaves were counted and their length (L) and width (W) measured. The leaf area was calculated using the equation by Balakrishnan et al, 1979 given as:

$$\text{leaf area } (\text{cm}^2) = 0.725 \text{ L} \times \text{W} \quad (2)$$

Fertilizers and irrigation were not applied. However, raticide and insecticide were used occasionally to control rodents and insects, respectively. The time to 50% flowering and fruit harvest as well as fruit yield were recorded and analysed for the middle 15 candidate plants plot-1. Soil loss/fruit yield ratio, fruit yield and soil loss regression equation as well as regression equations for soil loss and vegetative cover for the different mulch materials were developed.

Results and Discussion

Climatological Variables

The months of December to February were considerably dry with low relative humidity (RH) of between 51 and 71%, while May to September have the highest rainfall (180-530 mm) and the highest RH (75-88%). The mean temperature ranged between 24.9°-28.7° with the dry months having the highest mean temperatures. Rainfall was heavy and adequate at the planting times for crop establishment as the rains were concentrated between May and September **(Table 1)**. Also, different planting times had different periods of adequate rainfall immediately after planting, a factor that may have affected both soil loss, weed growth, vegetative cover and crop yield.

Soil Properties

Mulching reduced the percentage of sand but increased those of silt, clay, moisture retention and the pH. The no-mulch control (C) showed that sand and silt, bulk density and nitrogen increased with time which reduced the percentage of organic carbon and clay, available P and moisture retention (**Table 2**). Decrease in organic matter increases soil erosion by reducing soil structural stability and rendering the soil prone to crusting. It caused the decrease in the percentage of clay and increase those of sand and silt.

In **Table 3**, C increased the bulk density with MAP but at 10 MAP, the bulk density was similar to that at 2 MAP. At 2 MAP, bulk density was increased in all treatments due probably to the initial fragile nature of the mulch materials, less vegetative cover and high rainfall impact. After 6 MAP, mulching decreased bulk density for all planting dates because of significant increase in leaf area (**Table 4**), less compaction by rain drops and probably more root density. However, WS consistently produced the lowest bulk density.

Table 2 Some Soil Properties at Planting and at 50% Flowering at 0-15 cm Depth.

Parameter[1]		At planting	At 50% flowering			
			RH	SD	WS	C[2]
Sand	(%)	68.4	65.5	64.2	66.9	70.3
Silt	(%)	18.1	18.4	19.2	18.8	18.9
Clay	(%)	13.5	16.1	16.6	14.3	10.8
Bulk density	(M_g m^{-3})	1.25	1.29	1.27	1.22	1.32
Moisture retention	(%)					
Field capacity	(0.3 bar)	16.1	17.5	17.8	18.3	15.8
Wilting point	(15 bar)	6.5	8.4	8.7	8.8	6.3
PH ($CaCl_2$)		5.6	5.3	6.0	5.8	5.5
Organic carbon	(%)	1.83	1.98	1.92	1.89	1.71
NO_3-N	(mg l^{-1})	22.7	25.2	24.8	24.5	23.3
Araitable P	(mg l^{-1})	16.8	17.9	17.1	16.8	16.2
CEC	(me/100 g)	11.0	12.2	11.6	12.3	11.2

1) Data is average of three replications.
2) RH = rice husk; SD = Sawdust; WS = woodshaving; C = no-mulch control.

Table 3 Effect of Mulch Material and Planting Time on Soil Bulk Density (mg/m^3) at Different Months after Planting (MAP)[1]

Month	2MAP				6MAP				10MAP			
	RH	SD	WS	C	RH	SD	WS	C	RH	SD	WS	C
April	1.30	1.29	1.26	1.32	1.29	1.26	1.22	1.38	1.26	1.22	1.21	1.33
June	1.28	1.30	1.25	1.35	1.29	1.30	1.20	1.39	1.25	1.25	1.18	1.35
August	1.31	1.33	1.28	1.37	1.28	1.26	1.23	1.40	1.24	1.26	1.20	1.37

1) Data is average of three replications (no statistics).
2) Symbols are same as in Table 2.

Leaf Area

For 3 and 6 MAP, the leaf area was not significantly influenced by mulch material for the three planting dates. However, the leaf area increased with MAP until at 12 MAP when most plants seemed to have flowered (**Table 6**). Beyond 12 MAP the leaf area decreased in the plant crop due to increased senescence of the lower older leaves. Vegetative growth of the plant crop ceased at floral initiation and the leaf area of the first ratoon suckers did not equal those of the dead old leaves. For the June and August plantings, RH and WS mulch materials produced the highest leaf area as at 12 MAP, but in the April planting SD and WS did but not significantly differ from RH. Generally, C produced the lowest leaf area except in the June planting. The release of some nutrient from RH to the soil and seemingly good ground cover by WS and the reduction of bulk density may be responsible for their beneficial effects on leaf area.

Table 4 Effect of Mulch Material and Planting Time on Leaf Area ($\times 10^3/cm^2$) at Different MAP

MAP	April					June					August				
	RH	SD	WS	C	LSD	RH	SD	WS	C	LSD	RH	SD	WS	C	LDS
3	1.7	1.3	0.8	0.5	ns	0.6	0.4	0.8	0.6	ns	0.5	0.5	04	07	ns
6	2.3	2.8	2.2	1.5	ns	1.5	1.2	1.7	1.4	ns	2.6	2.1	1.6	1.4	ns
9	6.0	3.7	3.5	2.5	1.0	3.5	2.3	3.0	1.5	1.2	6.4	4.2	7.5	3.1	1.6
12	11.5	12.4	12.1	8.6	1.6	12.0	7.7	11.4	8.5	1.8	11.3	9.3	10.4	8.5	0.9
15	9.8	10.5	8.0	6.1	1.3	9.0	7.1	9.7	5.2	0.8	7.5	6.3	8.9	6.6	0.7

1. Symbols are same as in Table 2.

Table 5 Effect of Mulch Material and Planting Time on Cumulative Weed Weight (t/ha) at Different MAP

MAP	April				June				August			
	RH	SD	WS	C[1]	RH	SD	WS	C	RH	SD	WS	C
3	4.0	5.3	3.5	6.0	8.3	6.9	4.7	9.1	2.8	2.2	1.7	5.0
6	2.6	1.4	1.2	2.1	1.6	1.3	1.2	1.7	0.7	0.4	0.6	0.9
9	1.0	0.6	0.7	0.6	0.5	0.7	0.6	0.4	2.0	1.6	1.2	4.1
12	0.7	0.6	0.3	1.2	1.2	1.0	0.6	2.1	1.1	0.8	0.5	2.0
Total	8.3	7.9	5.7	9.9	11.6	9.9	7.1	13.3	6.6	5.0	4.0	12.0

1. Symbols are same as in Table 2

Weed Weight

Weed weight was lowest for all mulch treatments at 12 MAP for April planting, 9 MAP for June planting and 6 MAP for August planting (**Table 5**) because of the varying lengths of rainfall periods after planting. No mulch control plots produced the largest weed weights followed by RH plots. WS consistently produced the least weed weight.

Total weed weight was significantly ($P = 0.05$) highest (41.9 t/ha) in June planting and least in WS in August planting (4.0 t/ha). For all planting times the first three months were very critical for weed growth because of non-consolidation of mulch material, low vegetative cover and good rainfall. At 9 MAP, weed growth became problematic in the August planting because the onset of the rainy season renewed weed and plant growth vigour concurrently. At 12 MAP the weed weight was minimal in all plots because of maximum vegetative cover from the leaves.

Soil Loss

The higher soil loss in June planting in comparison to those of April and August **(Table 6)** was due to the protective effect of crop cover and intensity of rainfall. In June erosive rains occurred early after planting **(Table 1)** when the pineapple had not yet developed good canopy cover. Intense rains are particularly damaging when they occur in the early stages of crop establishment (Hudson, 1976). For April planting, good rainfall and rapid leaf growth rate provided fast canopy cover development to check the erosive rains which occurred later in the season. The August planting also had developed good canopy cover before erosive rains came 11-14 months later. Also the mulch materials had consolidated before the advent of the next rainy season. Soil loss was not significantly different in April and August plantings.

WS produced the lowest mean soil loss (1.09 t/ha) for all planting time which was significantly lower than the other mulch treatments with C plots having the highest soil loss (2.12 t/ha). The implications of these results are that the soil must be protected by some type of cover if soil erosion is to be minimized. And the low values of soil loss recorded in this trial even in unmulched plots compared to those obtained in other reports (Khatibu et al, 1984; Ngatunga et al, 1984; Obi, 1982) show that pineapple may be used as a good material for soil loss control while producing an important industrial raw material.

Growth and Yield

Table 6 Effect of Mulch and Planting Time on Soil Loss (t/ha), Days to and Number of Leaves at 50% Flowering; Days to 50% Harvest and Fruit Weight (t/ha), Soil Loss/Yield Ratio ($t/t \times 10^{-3}$)

	Soil loss				Time mean	Days to 50% flowering				Time mean
	RH	SD	WS	C[1]		RH	SD	WS	C	
April	1.01	1.19	0.82	1.62	1.16	309	328	320	367	331
June	2.11	1.54	1.65	2.58	1.97	338	342	325	358	341
August	1.15	1.07	0.79	2.15	1.29	329	331	345	387	348
Mulch means	1.42	1.27	1.09	2.12	9^2 = 0.32 b = 0.15	325	334	330	371	a = ns b = 30
	No. of leaves at 50% flowering					Days to 50% harvest				
April	77	68	70	61	69	406	427	417	478	432
June	69	56	60	58	61	454	486	445	477	466
August	57	58	50	54	55	452	469	489	415	481
Mulch mean	68	61	60	58	a = 4 b = ns	437	461	450	490	a = 25 b = 19
	Fruit weight					Soil loss/yield ratio				
April	95.3	82.0	82.3	63.7	80.8	10.6	14.5	10.0	25.4	15.1
June	86.3	69.7	88.3	63.3	76.9	24.4	22.1	18.7	40.8	26.5
August	102.3	75.3	84.4	62.7	81.2	11.2	14.2	9.4	34.3	17.3
Mulch mean	94.5	75.7	85.0	63.0	a = 1.8 b = 7.3	15.4	16.9	12.7	33.5	a = 5.8 b = 8.5

1) Symbols are same as in Table 2.
2) a = LSD (0.05) for planting time mean; b = LSD (0.05) for mulch material mean.

For the April, June and August plantings, the duration (7, 5, and 3 months) and amount (1733.7 mm, 1415.8 mm and 691.9 mm) of rainfall before the first dry season, affected the number of leaves produced at 50% flowering. This was due to increased vegetative growth in the early plantings and the relatively dormant 4 months dry period (November-February). On the whole, mulching did not influence the number of leaves at 50% flowering because the leaves may have acted as "mulch" as the vegetative cover increased **(Table 6)**. Mulching and not-mulch types reduced the days to 50% flowering due to its effects on soil physical properties. Planting time did not significantly affect the days to 50% flowering showing that relay cropping may be panacea for sustained all-year-round production of the crop.

Planting time and mulching had significant ($P = 0.05$) effects on days to 50% harvest with RH plots in April planting having the lowest time. C plots had increased the time to harvest for all planting times except in June when SD plots inexplicably took much longer to harvest **(Table 6)** mulching generally reduced the days to 50% harvest. The reduced time to harvest for early planting may be due to longer rainfall periods during most of its vegetative growth. The dry spell from 3 MAP for August planting must have delayed the vegetative growth phase and prolonged days to 50% flowering and harvest.

Fruit yield was significantly ($P = 0.05$) lowest in C plots. Mulching increased fruit yield by 20-50% over C plots, with RH producing the highest (94.7 t/ha). June plantings recorded lower yield except for WS while April and August yields were not significantly different from each other. These may be due to high erosive rains in June which must have caused the leaching of soil nutrient and the high soil loss. Early planting may be advocated to take advantage of early rains and longer rainfall periods before the first dry season. However, yields from late planting with reduced rainfall periods early in growth shows that the crop may be drought-resistant and may be used in relay or sequential cropping pattern for all-year-round production.

Soil Loss Fruit Yield-Vegetative Cover Relations

The soil loss/fruit yield ratio **(Table 6)** was not significantly

Table 7 Soil Loss (t/ha) for Different Vegetative Covers (%)

	0%	20%	40%	60%	80%	100%
RH[1]	2.103 (23.3)	1.336 (25.0)	0.848 (26.7)	0.539 (28.3)	0.342 (29.9)	0.217 (31.4)
SD	1.859 (20.6)	1.178 (22.1)	0.747 (23.5)	0.473 (24.9)	0.300 (26.2)	0.190 (27.5)
WS	1.828 (20.3)	0.935 (175)	0.479 (15.1)	0.245 (12.9)	0.125 (10.9)	0.064 (9.2)
C	3.266 (35.8)	1.887 (35.4)	1.104 (34.7)	0.646 (33.9)	0.378 (33.0)	0.221 (31.9)

1. Symbols are same as in Table 2.

different in the mulched plots but was least in the WS plots and highest in C plots. This shows that mulch is a very determining factor in soil loss control **(Table 7)**. Also, the April and August plantings were not significantly different from each other for this parameter but were significantly lower than for the June planting. The low value of this ratio for WS even in June planting showed that this mulch material has very good qualities for soil loss control by partially preventing rain drops from impinging on the soil surface directly and detaching the soil. Soil loss has a decreasing effect on fruit yield. A regression equation of fruit yield (y_f t/ha) and soil loss (X_s t/ha) is given by:

$$Y_f = 98.92 - 13.09 \times X_s, \quad r = -0.57^{**} \qquad (3)$$

The decline in fruit yield in highly eroded plots is associated with deterioration of both soil physical and nutritional characteristics (Lal, 1981).

The regression equation of soil loss (Y t/ha) and vegetative cover (X_v %) are given for the different mulch materials as follows:

$$Y_{RH} = 2.103\ e^{-0.0227X_v}, \quad r = -0.91^{***} \qquad (4)$$

$$Y_{SD} = 1.859\ e^{-0.0228X_v}, \quad r = -0.85^{***} \qquad (5)$$

$$Y_{WS} = 1.828\ e^{-0.0335X_v}, \quad r = -0.86^{***} \qquad (6)$$

$$Y_C = 3.226\ e^{-0.0268X_v}, \quad r = -0.87^{***} \qquad (7)$$

For all mulch treatments, soil loss decreased exponentially with increase in vegetative cover as seen from equations (4) to (7). The value of soil loss for different percent vegetative cover is given in **Table 7**. WS was consistent in producing the lowest soil loss for all the vegetative covers because of its effect on soil physical properties.

Conclusions

1. Mulching increased soil physical properties of bulk density, organic matter content and moisture retention capacity.
2. Wood shaving suppressed weed growth, reduced soil loss/fruit yield ratio.
3. Mulching did not significantly affect the number of leaves at 50% flowering while planting time did not significantly affect the days to 50% flowering. Relay cropping with mulching is suggested for all-year-round production of pineapple.
4. Soil loss has a decreasing linear relationship with fruit yield of pineapple.
5. Soil loss decreased exponentially with vegetative cover, it is over 2 times higher in bare soil than in woodshaving mulched soil.

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Tractor Power Utilization on Mechanized Farms

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Abstract

The utilization percentage of 7 models of tractors in the power range of 30 to 90 bhp was studied on a mechanized farm having an area of 4000 ha. In each model 6 tractors were selected and categorised into various groups of 30 to 50 bhp, 50 to 90 bhp, indigenous and foreign makes. The most effective utilization was found up to 10 000 working hours. However, for higher horsepower tractors (50-90 bhp) the effective utilization was up to 15 000 h of use. Foreign-made tractors had higher utilization (68%) as compared to indigenous models (55%) for 10 000 h of use. Mathematical models have been developed to predict utilization percentage of tractors at their different period of use.

Introduction

Agricultural tractors and equipment play an important role in increasing production through timeliness of agricultural operations and increased cropping intensity. The wheel tractors were introduced in Indian agriculture in the 1950s with imports from foreign countries but indigenous manufacture of tracotrs started in 1961. At present there are 14 manufacturers of 4-wheel tractors in India which manufacture 34 models in the power range of 15 to 75 bhp (Metha, 1985). It is estimated that there were a total of about 0.65 million tractors in use on Indian farms in 1986.

With increasing number of tractors being used on Indian farms, several problems are being faced regarding their systematic use as well as repair and maintenance. There is a lack of data on these aspects which is essential for determining the downtime and actual utilization of tractors in a particular year. One of the important factors affecting the hourly cost of operation of a tractors is the cumulative time of utilization. Obviously, a large use factor is desirable but extended use may lead to increase in breakdown frequencies and repair costs. With these points in view, the present study was undertaken which will help in planning the field work effectively with different tractors such that the operations can be completed in time. This would also give an overall view of the utilization of a tractor in a particular set of working conditions.

Literature Review

In India, limited published work is available on effective available time for tractor utilization and its reliability. Most of the works on these aspects have been reported on foreign tractors. Fenton and Barger (1940) conducted a survey covering 1325 tractors on American farms and estimated their average service life to about 11.20 years. Later on, Parson et al (1960) estimated the mean life of the tractors as 16.5 years with assumed yearly use of only about 605 h. The increase in life of tractors in their study was claimed to be due to the use of better metal and technology for the fabrication of various components.

The cost of operating an equipment is dependent upon its cumulative use as well as on current utilization rates as described by Terbergth (1949) in his work on dynamic equipment policy. The condiition of the engine of a tractor plays an important role in the utilization of power of the tractor and a better repaired tractor will be available for longer periods of time in a year (Oubrecht, 1975). The studies carried out on the economy of Russian tractors by Popov and Komrov (1976) indicated that the tractors were used for longer period than their economically profitable life period because of shortages of machine. Use of tractors for more than their economical life increased the cost of repair by 23.60% of their new value. Prolonged use of machine also reduced the level of utilization.

The level of utilization of tractor power on an Indian mechanized farm was evaluated by Singh and Singh (1975). In their study, the tractors of two power groups of 35 and 75 bhp were selected. The maximum use of tractors took place during November whereas it was minimum during August and September. The range of power utilization varied from 24% to 46% and 30% to 59% for 35 and 75 bhp tracotrs, respectively, on operations like ploughing, harrowing, threshing and transportation. Mittal et al (1984) worked on the service life of commonly used farm machineries and suggested the useful life of power tiller, tractors, self-propelled combine and pull type combine as 8000, 1000, 3000 and 2000 h, respectively. In a similar study, Panesar and Singh (1985) collected data from 185 farms situated in Punjab state of India and reported the average annual use of tractors, diesel engines and electric motors as 656, 1211, and 1849 h, respectively. The level of use of tractors for transportaion and soil manipulation was 48.17% and 39.54%. In a recent work, Singh (1986) reported the most effective utilization of tractors up to 10 000 h, however, for good make and higher horse power (50-90 bhp) tractors, utilization was up to 15 000 h.

Materials and Methods

The basic data on different models of tractors were collected from the fleet of tractors working at the University farm, Pantnagar. This farm has about 4000 ha of cultivated land and owns about 80 wheeled tractors in the power range of 30 to 90 bhp. Based upon the horsepower, make and models, tractors were categorized in broad groups of 30 to 50 bhp and 50 to 90 bhp as well as indigenous and foreign makes. Various tractor models selected for the study were designated as T_1(90 bhp), T_2(75 bhp), T_3(72 bhp), T_4(70 bhp), T_5(58 bhp), T_6(47 bhp), and T_7(30 bhp). In each model six tractors were selected for study purposes.

The Pantnagar University farm is divided in three zones which maintain its own fleet of tractors and machineries at well-equipped service stations. Two to three tractors from each service station were selected to overcome the effect of management factor. The data ranging from 5 to 13 years of useful service life of tractors which depended upon the year of purchase were collected. The total operation time of a tractor was recorded from the log book of the tractor or balance sheet statement maintained by each station.

In general, tractors operate at the University farm in two shifts of 8 h each every day during the peak season which amounts to almost 6 months in a year. However, during the lean season of the year, they operate in one shift of 8 h. Hence, the average hours of operation per day was assumed to be 12 h for each tractor for calculating the total actual available working hours in a year. Holidays or rest days were not considered in the calculation. The utilization of a tractor was determined by dividing the actual working hours in a year with the total available working hours in that year and was presented on percentage basis. The time utilization percentage has been calculated by considering only the down times due to major repairs.

Results and Discussion

The relationship of percentage utilization of tractors models with their period of use in years and cumulative hours of operation was established and mathematical models were developed which are discussed below.

Yearly Utilization of Different Tractor Models

The relationship between period of use (years) and utilization percentage for various individual tractor models is shown in **Fig. 1.** It is evident from the figure that in general, the utilization percentage is higher in the second year than the first year of operation for models T_2, T_3, T_4, T_5 and T_6 and thereafter, it started decreasing over the entire period of use. However, for models T_1 and T_7 the utilization shows an increasing trend up to 60th year and 3rd year, respectively, but decreased over the remaining period. For Model T_1, utilization was more that 100% during the 6th and 7th years of use but decreased to about 40% and 15% in its 9th and 10th years of use.

The utilization of different tractor models in their third year of operation varied between 60% to

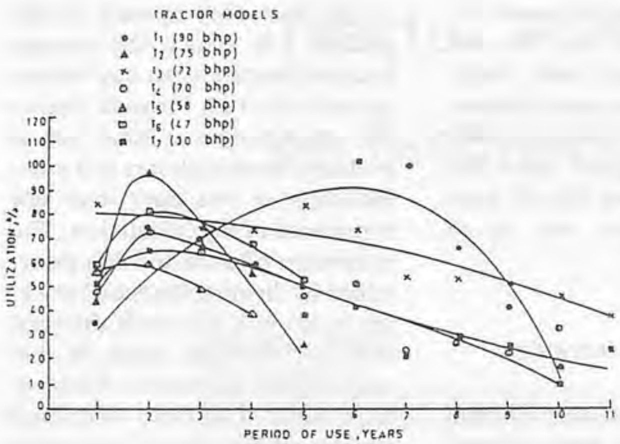

Fig. 1 Period of use and utilization percentage for individual tractor models.

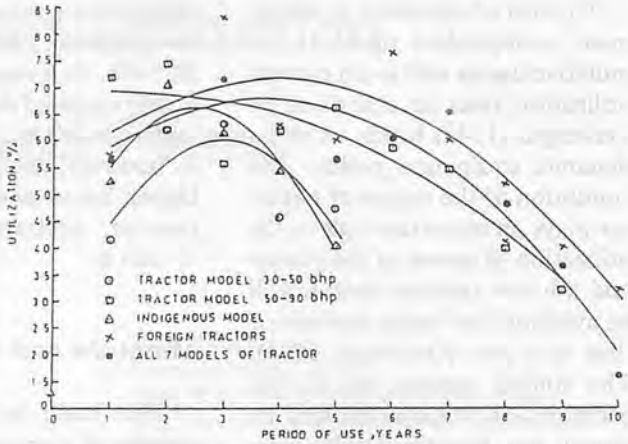

Fig. 2 Period of use and utilization percentage for different categories of tractor models.

75% and the rank in the order of their importance with respect to their utilization is T_3, T_6, T_2, T_4, T_7, T_1 and T_5.

At the 5th year of use, the utilization was between 25% to 75%. The utilization for models T_6, T_4 and T_7 was about 50%. However, for models T_1 and T_3, it is higher to about 70% which may be due to their heavy use in primary tillage operations during seedbed preparations under dry land condition. The down time days for model T_4 was found more due to their use in wet land condition. The utilization has reduced substantially to about 45%, 30%, 12% and 10% at 10th year of the use of tractor models T_3, T_7, T_1 and T_4, respectively. This indicates that these models have outlived their useful life at this stage and if at all the tractors are used beyond this period then it is at the cost of very low utilization percentage and a low level of operating economy.

The utilization percentage for two broad categories of tractor models in the power range of 30 to 50 bhp and 50 to 90 bhp has also been calculated and its relationship with years of use is shown in **Fig. 2.** It is observed from the figure that the tractors in 50 to 90 bhp range have lower utilization than the 30-50 bhp range during their 1st year of operation. However, after the first year the trend of utilization has completely reversed. The reason for higher utilization of 50-90 bhp tractors may be attributed to their heavy use on tillage operations for seedbed preparation whereas the lower hp tractors in the range of 30-50 bhp are mostly used for light cultivations, puddling and transport. It may also be seen that beyond the 7th year of use, there is a sharp fall in utilization of the 50-90 bhp range tractor which is only about 20% at the 9th year of use. This may be due to these tractors having passed their economical life and in view the old age minor defects have increased manifold.

Fig. 2 also illustrates the utilization percentage of indigenous and foreign make tractors. It is observed that the latter tractors have more utilization percentage than the indigenous models throughout their entire period of use. However, both models have the same utilization percentage of about 70% during their second year of use. At their 5th year of use, the utilization of indigenous and foreign make models were 40% and 75%, respectively. The data beyond 5th year was available only for foreign make tractors whose utilization was about 40% and 32% after 7th and 10th year of use, respectively. The average utilization of all seven models shows maximum utilization during th 2nd year of use to about 80% which decreased to 65%, 35% and 25% during their 5th, 9th and 10th year of use, respectively.

Mathematical models have been developed to predict the percentage utilization of tractors at different years of their use and are presented in the following form:

Table 1 Values of Constants a, b and c of Eqn.1 for Determination of Percentage Utilization of Tractors at Different Years of Use.

Tractor models	Constants			R^2	Standard error	
	a	b	c		SE_1	SE_2
Y_{T30-50}	24.83	23.67	−4.01	0.5748	14.00	2.40
Y_{T50-90}	68.95	1.24	0.57	0.8350	3.80	0.37
Y_{Ti}	36.35	23.07	−4.52	0.8857	8.80	1.40
Y_{Tf}	53.00	9.00	−1.13	0.7681	4.10	0.36
Y_{T30-90}	51.29	8.72	−1.18	0.8365	3.8	0.34

Suffixes to Y: T_{30-50}, tractors models in 30-50 bhp group; T_{50-90}, tractors models in the 50-90 bhp group; Y_{Ti}, indigenous tractors; Y_{Tf}, foreign tractors; Y_{T30-90}, all the tractor models in the 30-90 bhp range.

$$Y_T = a + bx + cx^2 \quad (1)$$

where,

Yt = utilization of tractors, %

x = period of use, years

a,b,c = Empirical constants **(Table 1)**

Cumulative Hours of Utilization

The relationship between cumulative average time utilization percentage and cumulative hours of use for different tractors is shown in **Fig. 3.** It is evident from the figure that up to 5000 h of use, most of the tractors have increasing trend of cumulative utilization percentage except tractor model T_3. The average utilization percentage were 75, 75, 70, 50, 57, 56 and 53 for models T_3, T_4, T_2, T_6, T_7, T_5 and T_1 respectively, at 5 000 h of work. Beyond 5 000 h of use a gradual decrease in average utilization percentage could be seen for most of the tractors except tractor model T_1 which shows an increasing trend up to 17 700 h of operation. Higher utilization percentage of models T_1 and T_3 during their later periods indicate minor repairs of these models. Tractor T_4 has comparatively higher utilization percentage upto 7000 h of use of because of its extensive use in puddling operation during the initial life period in addition to its use in dry land cultivation. Thereafter, the average utilization percentage declines at a higher rate due to major breakdown.

Tractor model T_5 has given a very poor average utilization percentage beyond 4500 h and upto 7300 h of use which was due unavailable or late procurement of spare parts. Tractor model T_2 has given a good overall utilization of about 67% at the end of 7300 h but dropped to only 55% at about 8000 h of use due to major repairs. Tractor model T_6 also has given a good utilization of about 62% upto 11 400 h of use which indiates less repairs. Heavy electrical repairs during initial period of work may be one of the reasons for the poor utilization of tractor model T_7 as compared to T_3, T_4, T_2 and T_6 models . A comparison among different models at 10 000 cumulative hours of use reveals about 76%, 61%, 60%, 60% and 55% utilization for models T_3, T_4, T_6, T_1, and T_7, respectively. The models T_2 and T_5 have not been used up to 10 000 h.

Fig. 4 shows the cumulative average time utilization of the 30-50 bhp and 50-90 bhp tractor models. Data for the 30-50 bhp tractor models were available only up to about 10 777 h whereas for the 50-90 bhp range models, it was up to 17 000 h of operation. The relationship shows that the 50-90 bhp range tractors have more overall utilization than the 30-50 bhp range throughout their entire period of use. The cumulative average time utilization for indigenous and foreign make tractors were as 60% and 64% at 5 000 h, and 55-68% at 10 000 h of use, respectively. For foreign tractors, utilization has remained constant at 68% up to about 12 500 h of use but slightly decreased to about 64% at 17 000 h of use. The cumulative average time utilization of all the seven models of tractors in the power range of 30 to 90 bhp shows an increasing trend up to about 8500 h of use after which it decreased at a slow rate which was about 65%, 64%, 60% and 53% at 10 000, 12 000, 15 000 and 17 000 h of use, respectively.

Mathematical models were developed for computing the cumulative utilization percentage of various tractors at different cumulative hours of utilization and have the following form:

$$Y_{TC} = a_1 + b_{1x1} + c_1 x_1^2 \quad (2)$$

where,

Y_{TC} = average cumulative utili-

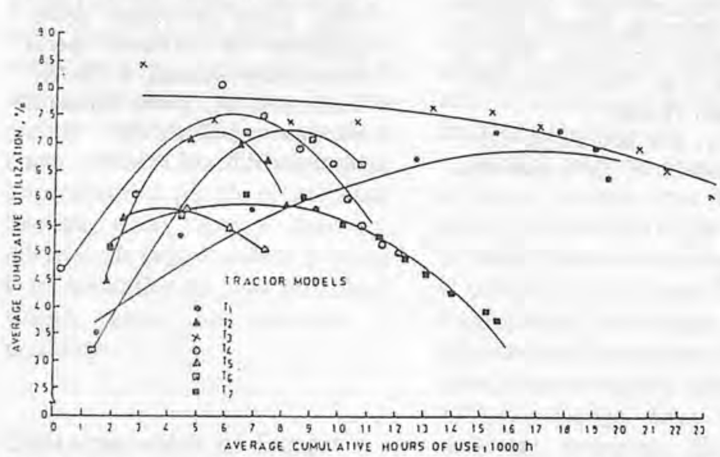

Fig. 3 Average cumulative hours of use and average cumulative utilization percentage of individual tractor models.

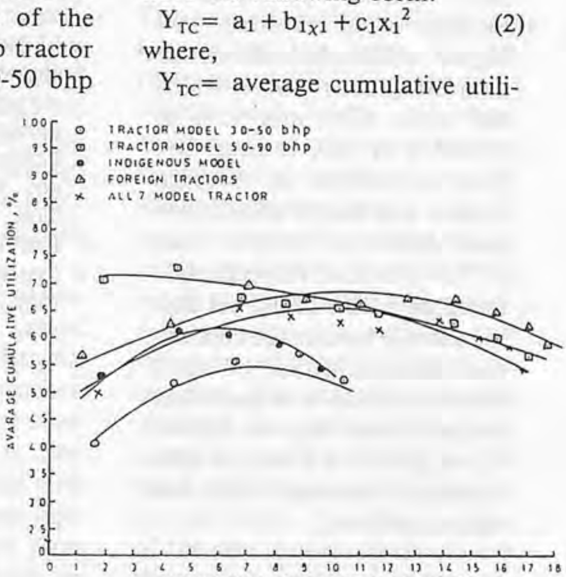

Fig. 4 Average cumulative hours of use and average cumulative utilization percentage for different categories of tractor models.

zation, %

X_1 = average cumulative hours of use, 1000h

a_1, b_1, c_1 = empirical constants **(Table 2)**

The R^2 values of different equations were, in general, greater than 0.90 which were significant at 5% level of confidence, hence showing a good fit of data.

Table 2 Values of Constants Used in Eqn.2 for Determination of Average Cumulative Utilization Percentage at Different Average Cumulative Hours of Use.

Tractor model	Constants			R^2	Standard error	
	a_1	b_1	c_1		SE_1	SE_2
Y_{TC1}	31.47	4.29×10^{-3}	-1.2×10^{-7}	0.8677	0.11×10^{-2}	0.48×10^{-7}
Y_{TC2}	10.67	2.24×10^{-2}	-2.03×10^{-6}	0.9950	0.12×10^{-2}	0.12×10^{-6}
Y_{TC3}	69.03	1.09×10^{-4}	-3.22×10^{-8}	0.7810	0.71×10^{-3}	0.25×10^{-7}
Y_{TC4}	43.18	1.02×10^{-2}	-8.12×10^{-7}	0.9109	0.12×10^{-2}	0.96×10^{-7}
Y_{TC5}	45.27	6.23×10^{-3}	-7.65×10^{-7}	0.9999	0.97×10^{-4}	0.10×10^{-7}
Y_{TC6}	13.93	1.40×10^{-2}	-8.42×10^{-7}	0.9844	0.17×10^{-2}	0.14×10^{-6}
Y_{TC7}	44.82	4.24×10^{-3}	-3.08×10^{-7}	0.9807	0.41×10^{-3}	0.22×10^{-7}
$Y_{30\text{-}50}$	32.95	5.97×10^{-3}	-4.04×10^{-7}	0.9799	0.72×10^{-3}	0.59×10^{-7}
$Y_{50\text{-}90}$	73.43	5.17×10^{-4}	-1.82×10^{-8}	0.9179	0.50×10^{-3}	0.25×10^{-7}
Y_{TCi}	42.67	-6.33×10^{-3}	-5.16×10^{-7}	0.9877	0.50×10^{-3}	0.42×10^{-7}
Y_{TCf}	52.55	3.18×10^{-3}	-1.54×10^{-7}	0.8920	0.42×10^{-3}	0.20×10^{-7}
$Y_{TC30\text{-}90}$	46.52	3.95×10^{-3}	-2.05×10^{-7}	0.7871	0.80×10^{-3}	0.40×10^{-7}

Suffixes: TC1to TC7 individual tractor model; TC30-50, models in 30 to 50 bhp group; TC50-90, models in 50 to 90 bhp group: TCi, indigenous; TCf, foreign; TC30-90, all tractors in 30 to 90 bhp range.

Conclusions

1 The most effective utilization of tractors was 10 000 working hours. The average percentage utilization at this stage were 76, 61, 60, 60 and 55 for tractor models T_3(72 bhp), T_4(70 bhp), T_6(47 bhp), T_1(90 bhp) and T_7(30 bhp), respectively. However, for good make and higher horse power (50-90 bhp) tractors, good effective utilization was up to 15 000 h of use.

2 The tractors in the power range of 30-50 bhp have higher utilization percentage than the 50-90 bhp tractors during their first year of use. However, beyond this period the 50-90 bhp tractos have comparatively more utilizaiton percentage.

3 Foreign make tractors had higher utilization percentage than indigenous models which was about 68% and 55% at 10 000 h of use, respectively. The utilization of foreign models was less at about 68% and 64% at 12 500 and 17 700 h of use, respectively.

4 Based upon 12 h of use per day, the average percentage cumulative time utilization of all 7 models of tractors in the power range of 30-90 bhp was 62, 65, 64, 60 and 53 at 5 000; 10 000; 12 000; 15 000 and 17 000 h of use, respectively.

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Computer Expert System for Breakdown Diagnostic of Agricultural Tractors

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Introduction

An expert system is a computer software system that is able to provide advice on a particular subject area equal in quality to that which could be provided by an acknowleged human expert. Expert systems do not generate new knoledge. What they do is provide access to existing expert knowledge. However, that knowledge. What they do is provide access to existing expert system, and herein lies its benefit.

Expert systems, unlike most existing computerized aids to decision making, involve the use of reasoning, that is logical relationships, to draw conclusions, rather than numerical relationships. Expert systems draw their conclusions based on the logical relationships between statements which are asserted as correct by the expert, without all the numerical calculations. It is the logical approach that people actually use to make many types of decision. All that the expert system is doing is to formalize the way an expert would assess the situation in practice.

Characteristics of Expert Systems

Expert systems study is considered to be a component of the so-called 'artificial intelligence' domain. Artificial intellingence (AI) as defined by Barr and Fegenbaum (1981) is "the part of computer science concerned with designing intelligent computer systems, that is, systems that exhibit the characteristics we associate with intelligence in human behavior — understanding language, learning, reasoning, solving problems, and so on." In other words, AI is concerned with programming computers to perform tasks that are presentlly done better by humans, because they involve such higher mental processes as perceptual learning, memory organization and judgemental reasoning. The process of constructing an expert system is often called 'knowledge engineering,' and is considered to be applied artificial intelligence.

Insight into the special nature of expert systems can be gained from a comparison of the elements of expert systems and conventional computer programs. The most fundamental difference is that conventional programs deal with data, whereas expert systems deal with knowledge. Data are facts that are observed directly or derived by experimentation and calculation. Computer data bases store the facts and numerical data retrieved later by the user for interpretation. Knowledge implies an awareness or understanding gained through experience or study. A knowledge base goes beyond the mere storage of facts to the point of interpreting the data and relating stored information to new facts in order to provide advice.

Knowledge Base

One of the main components of an expert system is the knowledge base. It contains of all the domain-specific facts and knowledge. There are serveral formal methods for knowledge representation (Waterman, 1985), but the most widely used is the rule-based method. In a rule-based system, knowledge is represented as 'if-then' statements (rules). The 'if' portion of a rule contains one or more conditional clauses consisting of parameters and their values. A parameter is a variable that helps describe the nature of the problem. For example, a system designed for service and maintenance of tractor will include the hours of operation of the tractor as a parameter. The 'then' portion of the rule consists of conclusion that is drawn after all of the conditional statements are satisfied. This method of representation is most appropriate when knowledge results from compiled experience in solving certain types of problems. The system operates by checking the rules against information about the current situation. The current information may be obtained by direct observation or by consultation with a client. When the 'if' portion of a rule is true in the current situation, the action specified by the 'then' portion is performed, that is the rule is executed.

The Inference Mechanism

The other major component of an expert system, the inference mechanism (or inference engine), is the part containing general problem-solving logic. The concept of the inference mechanism often causes confusion because there is no simple, general way to characterize the mechanism and because many possible methodologies can be followed in constructing it. Fundamental to the power and structure of expert systems is the separation of knowledge (expertise) from the general problem-solving logic. Separate maintenance of these components is somewhat analogous to the separation of a computer program from its data. A program designed to calculate the mean of a column of numbers can be used as an example. By maintaining the data separate from the program, more data can be added, data can be changed, and different data sets can be substituted for the original without affecting the operation of the program. Likewise, in an expert system, rules can be edited, removed, and added without interrupting the logic that enables the knowledge base to be thoroughly searched for the solutions to the problem.

The essence of the inference mechanism is in its capacity to search and execute the rules. Because it is maintained separately from the knowledge base, new rules can be added without interfering with the operation of the system.

Ability to Explain

Another characteristic inherent to expert system software is the ability to explain its actions. After all, who will trust the diagnosis and recommended therapy of an expert who cannot explain the basis on which they were made. In the rule-based system, each time a rule is used the system records which rule it was and what was being proved or deduced by it. A special command menu that appears on the screen of the computer monitor offers a 'how' selection that can be used to ask the system how it arrived at a certain conclusion. Such explanations can be made available because the knowledge base is separate from the inference mechanism. A conventional program normally cannot explain what rules it used, and the programming tasks to make it do so would be overwhelming.

A final distinguishing feature of expert systems that underscores their utility and special nature is that they can operate with unknown or incomplete data. In response to a prompt for new information, a user can answer "don't know" and still be able to produce a conclusion. The conclusion is likely to be uncertain, but certainty values based on the best estimate of the human expert can be programmed into the system. Incomplete data usually are not acceptable on conventional computer systems.

Creating An Expert System

Whilst it is quite possible to create an expert system using a computer language such as BASIC or FORTRAN, the dependence of the mechanism of inference upon logical relationships means that such systems are best designed using a "declarative" computer language, such as PROLOG (PROgramming in LOGic) and LISP (LISt Processing). Because these languages allow the evaluation of rules by matching the results and antecedents directly, they are more efficient in both creation and execution.

It has been apparent, in the development of the ideas behind expert systems, that many of the operations needed were common to a number of applications. Such operations would include the forward or backward chaining mechanism, the facilities for explanation, the common requirement for rule design and the need for quesitoning the user. This led to the distinction between the expert system "shell," which contains these facilities but no actual rules and so on, and the "knowledge base," which consists of the rules and certainty factors which apply to a particular application. An expert systems shell can, therefore, be regarded as an empty system since it has no knowledge base. There are quite a number of 'shells' on the market at the present time. Features for potential system builders to look for include the type of inference mechanism used, the capacity for handling large numbers of rules, the ease with which the knowledge base may be constructed and the ease with which acceptable screen presentations may be designed. An example of such shells is EMYCIN. This shell was developed based on the expert system called "MYCIN (Shortliffe, 1976). It is one of the first and most widely used expert system. The purpose of MYCIN is to assist a physician who is not an expert in the field of antibiotics with the diagnosis and treatment of blood infections. Currently, there are quite a number of 'shells' on the market, such as LEVEL5, VP-EXPERT, EXSYS and GURU.

These shells are skeletal systems with the inference mechanism already in place. Only the domain-specific knowledge (rules and parameters and their values) is encoded by the knowledge engineers. Skeletal systems greatly facilitate the development of an expert system but lack the flexibility to tailor the system to specific problems. It seems likely that most systems will be built using shells rather than by other means.

Knowledge Engineers and Domain Experts

Expert systems are built by skilled individuals with experience in computer programming, known as knowledge engineers, and other individuals proficient at solving problems within a narrow domain, known as the domain experts. Building an expert system requires frequent and extensive interviews between the domain expert and the knowledge engineer to structure and articulate the domain knowledge into rules. The process includes continual testing of the program and expansion of the knowledge base to include new rules for previously overlooked cases. Completion of the project is likely to take months, perhaps years, because the emphasis is on knowledge that has not been formally documented in a public forum and validation is very involved. The focus is on knowledge acquired through experience — rules of thumb (heuristics) that enable a human expert to extrapolate and make educated guesses when necessary and to recognize promising approaches to a problem and deal effectively with incomplete data. This type of knowledge makes an expert system a unique and powerful tool to help solve problems conventional programs are unable to address.

System for Breakdown Diagnostic of Agricultural Tractors

All problems appropriate for expert system solution share two features, namely; they normally are thought to require a human expert for their solution, and that they occur repeatedly. The problem of breakdown diagnostic of agricultural tractors fits these requirements, since usually a qualified mechanic is required (the expert), and the problem occurs repeatedly on the farm. An expert system to be used for the problem was developed at the Faculty of Engineering, Universiti Pertanian Malaysia.

The expert system is given the code-made 'TRAPERT'. The system is able to diagnose most of the major failures in agricultural tractor and provide suggested remedy to the user.

Structure of the System

The system is written on PROLOG (TurboProlog version 1.1). **Figure 1** shows the opening display of the system. The main menu of the system is shown in **Fig. 2**. The major option of the main menu is consultation. The consultation item consists of knowledge base and inference engine and able to diagnose most of the major failure for engine, hydraulic system and power transmission of agricultural tractor. All the major failure and their significant symptom will be displayed in a pull-down menu form which was created with the help of Turbo-Prolog Toolbox, named 'pull-down pro'. The advantage of using this tool is that the choice or option chosen by the user will enable the system to eliminate a number of quesitons to get the basis of the rules in the knowledge base, and reduce the scope of the rules under consideration. This facility makes the system act more like a human expert, who tends to ask a series of related questions rather than jump back and forth from questions of one category to another.

After an option has been chosen from the pull-down menu, a series of quesitons related to the failure under consideration would

Fig. 1 Opening display of the expert system.

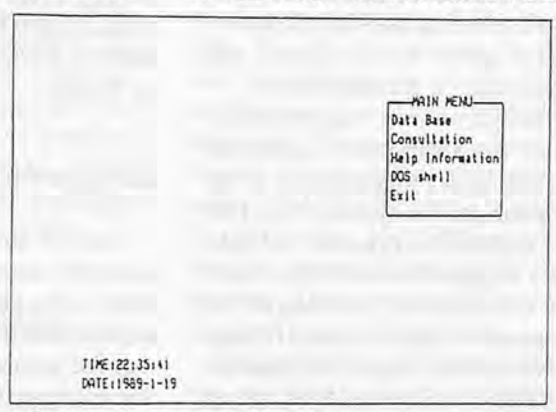

Fig. 2 Main menu of the system.

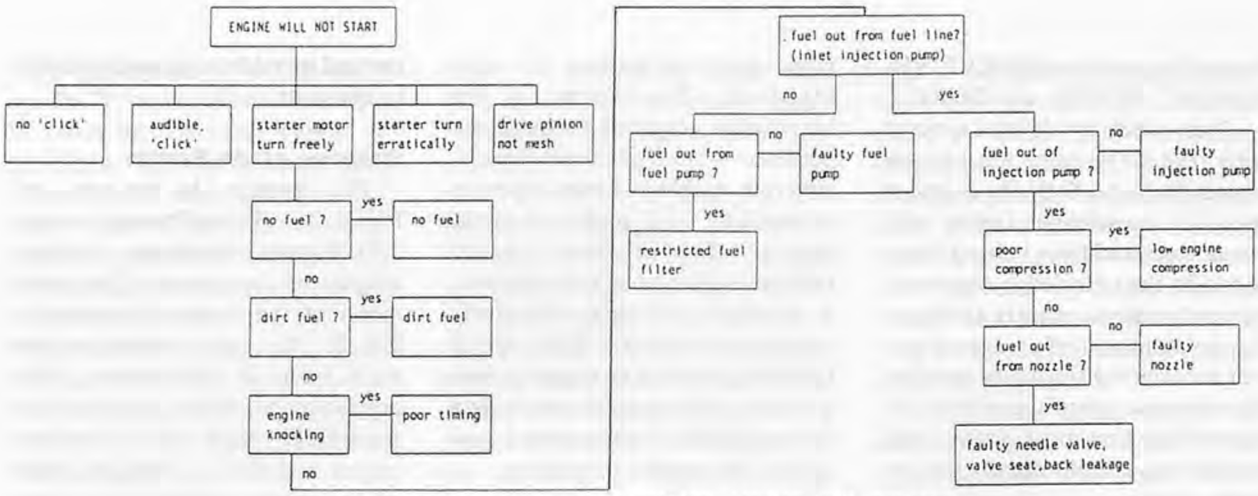

Fig. 3 Flow chart for an example problem (engine will not start).

be prompted to the user accompanied with procedure of testing/observation for particular component. The process ends when a diagnosis is determined. Explanation will then be given for possible cause of particular failure, and the recommended repair for that failure. **Figure 3** shows the flow chart for an example problem (engine will not start).

The 'database' option allows the user to update and recheck the database, the 'procedure of testing or checking,' and the 'possible cause and suggested remedy' which were used during the consultation. From the 'recheck database' option, the user can get the full information on how far the system has covered a particular failure. Another important option is 'update database' which allows the user to update the database on finding out that the information given by the system was incomplete or unsatisfactory.

'Backtracking mechanism' which is an important feature of TurboProlog, was adhered in the program for the system. This feature enebled the program to backtrack toprevious condition, when any condition in the chain of the program execution fails. It then tries to prove it again with another variable binding and then moves forward again to see if the failed condition will succeed with the new buld-up. With this technique, solution can be genereated with the non-procedural way.

Stand-alone Program

The program has been converted into a 'stand-alone' format. A 'stand-alone' program is one which will execute externally without TurboProlog running on the computer. This is for the convenience of the user whereby he will only need DOS facility to execute the program.

Using the System

The system is easily operated and is also versatile because the end user just have to supply simple replies during the interaction with the system. The hardware required for running the system is an IBM or IBM-compatible PC with at least a RAM of 640K. The operating system required for the program is a DOS of the version 3.1 or higher.

Conclusion

One of the most exciting features of expert system development is the availability of this very sophisticated compupter technology for immediate practical use by the entire agricultural community. There is a great need for reliable decision support systems for many phases of crop management, including disease diagnosis and control. Commercial agriculture will benefit from expert systems substituted for the travel-limited specialist. Immediate attention to their problems by expert systems will avoid costly delays as well as frustrations associated with multiple phone calls to elusive specialists. Agricultural extension specialists will be able to reclaim time once spent travelling to pursue other extension activities and conduct developmental research in areas important to production agriculture. Because the knowledge base can easily be amended to include new information generated by the research, the system can be kept as current as the human expert.

Other areas in agriculture where expert systems developments are in progress include monitoring of greenhouse (Jones et al, 1986), grain marketing (Peart et al, 1986), irrigation scheduling (Thomson and Peart, 1986), and technology transfer decisions (Lal et al, 1987). Development of expert systems for providing financial advice on the basis of accounts are also underway (Webster and Amos, 1987).

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Energy Needs and Production of Rural Areas in Punjab, Pakistan

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Abstract

An irrigated village in Punjab, Pakistan was studied in order to assess the energy needs and available resources. More than one-half of the energy consumed in the village was utilized by the domestic sector. Traditional sources of energy provided 90% of domestic energy requirements. Energy needs for farming were mostly met from diesel and electricity. Only 12% of the farmers used draught animals for cultivation.

Introduction

About 72% of the population in Pakistan resides in the rural areas. The rural energy scenario is different from that of the urban area to mixed use of commercial as well as non-commercial fuels. It was estimated that 90% of the rural households met their energy needs by use of bio-mass (1). The use of bio-mass for cooking and for space and water heating was to the extent of 99% (2).

In order to assess the needs and utilization of commercial and non-commercial fuels and potential of available energy resources a village ''Ghunaoor'' was studied. The village is situated at a distance of 7 km from Lahore-Gujranwala road at Sadhuke. The village is representative of the tubewell-irrigated areas of Punjab. The structured questionnaire/informal interview system was adopted for data collection.

The village consisted of 339 households with a human population of 3 500 persons. More than 50% of the population had farming as their major occupation. The area of the village was 1 634 ha. Rice-wheat cropping pattern was practiced normally. The livestock population consisted of 4 700 head (including 2 000 buffaloes and 2 374 sheep and goats).

Results and Discussion

Energy Requirements

For the purpose of this study and energy consumption point of view, the village activities were divided into two sectors; domestic and productive. The productive sector consisted of farming, livestock management and support services. The consumption of various sectors in the village are noted in **Table 1** while **Fig. 1** shows the demand for various fuels.

Table 1 indicates that more than 50% of the energy consumed in the village was utilized by the domestic sector. Almost 90% of domestic energy was provided by agriculture based fuels like cattle dung, crop residues and firewood **(Fig. 2)**. Electricity was mostly used for lighting only. Nearly 14% of the houses were not served by electricity. Those without electricity and others during shut down hours of electricity used kerosene oil for lighting. Very little quantity of kerosene oil was burnt for cooking. The other use of electricity was for operating fans.

In agriculture the farm power was provided by diesel, electricity, humans and animals. Only 12% of the farmers used bullocks for

Table 1 Energy Utilization

Sector	Source of energy	Total units	Consump'n per unit/year (GJ)	Total annual consump'n (GJ)
Domestic				
Cooking & heating	D.Cakes + R. Straw + K.Oil + Charcoal	3 500 persons	4 935	17 272
Lighting + electric appliance	Electricity + K.Oil	3 500 persons	254	889
Farming				
Rice	Man + animal + diesel	1 377 hectares	5 774	7 951
Wheat	Man + animal + diesel	1 033 hectares	4 912	5 074
Bersam*	Man + diesel	574 hectares	4 778	1 742*
Sorghum*	Man + diesel	239 hectares	3 209	767*
Livestock mgt				
Fodder Production	Man + diesel	2 000 buffaloes	1.43	2 921
Feed Preparation	Man	2 000 buffaloes	0.37	797
Support services				
Shellers/ Grinders	Diesel & elect.	4 Nos.	130	520
Iron smith/ Carpenters	D.Cakes + f.wood	4 Nos.	5	20
Total				35 444

*Not included in total.

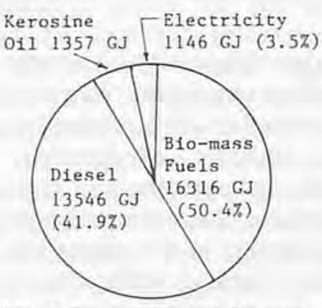

Fig. 1 Present demand for various fuels.

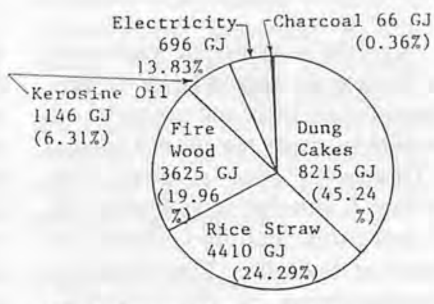

Fig. 2 Sources of domestic fuel.

cultivation. However, the use of draught animals for transportation was still common. Land preparation was mostly done with tractors and sowing (100%) with manual labour. About 80% of the area was irrigated with diesel engine tubewells and the rest with electric tubewells. Threshing of rice was done manually while wheat was mechanically threshed. Only about 20% of the products was transported with the help of tractors from field to village (average 2 km).

On the average, medium-sized tractors have been reported to consume 4 litres diesel per hour (3). In the study area diesel-operated tubewell in one hour consumed 1.5 litre diesel and an electric motor 8 kW. Average per hectare production of rice and wheat in the study area was 1.85 and 1.76 tons, respectively. Rice crop needed comparatively more energy than wheat **(Table 1)**.

One animal (buffalo) in the study area needed 5 MJ per day both for fodder production and feed preparation. A buffalo consumed 40 kg green fodder per day.

Table 1 shows that fodder production needed three times more energy than feed preparation. Harvesting of fodder, it's transporation, size reduction, mixing and distribution were mostly done manually and included in feed preparation.

The support services in the village included shelling of rice, grinding of grains and other service activities. With average work load one sheller/grinder in the study area in one day (8 h) consumed 584 MJ when operated with diesel engine and 158 MJ with electric motor. One iron smith/carpenter needed 14.5 MJ per day.

Fuel Resources

The locally available fuel resources consisted of cattle dung, agricultural wastes and firewood. Nearly 100% energy for cooking and heating is provided by these resources **(Table 2)**.

In the study area, from dung production point of view, only buffaloes and cattles were important. The daily dung production by a buffalo and cattle is reported as 15 and 10 kg, respectively, (4) and the dung collectibility rate as 50% (5). It was found that one ton of fresh dung gave 250 kg of dry dung cakes (6).

Straws of rice and wheat and paddy husk were produced as agricultural wastes. Wheat straw was mostly used as fodder and not available for energy production. About 41% of rice straw was consumed as fodder while the rest could be used as fuel. During

Table 2 Fuel Sources.

Source	Total units	Residue/unit (tons)	Total residue (tons)	Energy contents (GJ/ton)	Total energy (GJ)
Farm by-products					
Rice straw	1 377 ha	1.755	1 426	16.15	31 492
Rice husk	1 377 ha	0.6	826	15.92	13 150
Dung cakes	2 043 animal	—	1 388	8.7	12 076
Fire wood (Tree prunes)	1 634 trees	0.2	327	14.53	4 751
Total					61 469

shelling of rice, husk was produced as waste. It was mostly used for brick burning. One kg of rice grain after shelling gave 0.32 kg of husk.

Very few scattered trees of "Kikar" (*Acacia nilotica*) and "Ber" (*Zizyphus mauritiana*) could be found on the farmland in the study area. The shruby vegetation was almost absent. On the average, only one tree was found per hectare. Only small branches of the trees were pruned for use as firewood. The main stem and large branches were used for construction of buildings, furniture and agricultural implements.

Conclusion

The energy production potential of the study area was greater than the energy needs. More than 95% of energy requirements for cooking and heating were met by agriculture based fuels. Energy needs of farm sector and support services were mostly met by diesel and electricity. Agricultural wastes exhibited greater potential as energy resource.

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Computer Expert System for Breakdown Diagnostic of Agricultural Tractors

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Influence of Timing and Date of Harvest on Wheat Grain Losses


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Abstract

Grain losses affected by timing and delayed harvesting in different varieties of wheat were studied at the Latif Experimental Farm, Sind Agriculture University, Tandojam in 1987. The agronomical parameters of the various wheat varieties like plant height, number of tillers and number of earheads per plant did not differ much from each other.

Grain losses among the wheat varieties were significantly influenced by various timing and date of harvest. Minimum grain losses were recorded when wheat was harvested from 8.00 AM to 12.00 noon. Minimum grain losses were observed up to 10 days of late harvesting after the normal date. It was concluded that grain losses increased with the delayed harvesting after ripening of the crop. Grain losses increased with both late timing and date of late harvest. Further, grain moisture content was significantly influenced by the date of harvest and linearly decreased with delay in harvesting. It was also observed that grain loss increased with a decrease in grain moisture. The grain moisture for normal harvesting and minimum grain loss was 14 to 15%.

Introduction

Wheat is the major cereal crop of Pakistan and is grown in all provinces of the country. However, commercial production is largely carried out in provinces of Sind and Panjab. Late harvesting of wheat crop results in considerable grain loss and damage.

Grain losses take place during pre-harvest, harvest and post-harvest operations. Major grain losses are influenced by the date and timing of harvest. Delayed harvesting and harvest at various timings lead to lower yields because of shattering of the grains. Iqbal et al (1980) observed that losses with manual harvesting of wheat in 1979 varied from 3 to 7% after ripening of the crop. Further, it was concluded that harvesting loss in wheat increased as the harvesting was delayed after the ripening of the crop and increased linearly with time after ripening of the grain (3% in first week and 7% in the third week). Arnold et al (1958) found that the least damage occurred to grain harvested at grain moisture content between 19 and 22%. Hunt (1977) reported that the moisture content of the crop is very important in deciding when to harvest. The optimum range of moisture for wheat is 13 to 15% on wet basis. The time of crop harvest is a major decision for a farmer in reduceing harvest losses. Further, Hunt (1997) quoted the work of Johnson that in combining soft red winter wheat, the grain loss amounted to 13.5 kg/ha for each day of delay in harvesting. Bela et al (1980) found that moisture content at the time of the harvest has the significant effect on wheat grain losses. The traditional method of harvesting and threshing at 15.47% moisture gave the lowest grain loss of 4.09%.

The object of the present

research was to determine the grain losses of prominent varieties of wheat as influenced by various dates and timings of harvest under Tandojam conditons.

Materials and Methods

An experiment was carried out to determine grain losses of various wheat varieties on clay loam soils at the Latif Experimental Farm, Sind Agriculture University, Tandojam on 15.11.87. Three wheat varieties (Pavon, Sarsabz and ZA-77) were drilled by single colter wheat drill. The row-to-row spacing of 12cm was maintained and each wheat variety was planted on an area of 1/2 hectare. Full doze of DAP fertilizer was applied at the time of drilling The urea (fertilizer) was applied in two split doses: one dose at the time of first irrigation and the second does at third irrigation. The observations for each variety recorded were: number of plants, number of tillers per plant, number of earheads per plant, and grain yield per square meter and per hectare. The number of tillers and number of earheads were studied on plant basis. The plant population and grain yield were calculated on per square meter and hectare basis. The shattering loss influenced by various dates was studied at normal date of harvesting with five days interval up to 30 days late after normal date of harvesting. For this study, an area of 10m × 6m from plot for each variety was selected randomly and harvested manually on 25-3, 30-3, 4-4, 9-4, 14-4, 11-4 and 24-4-88. The shattered earheads and grains were collected by using square meter frame at different locations randomly selected from an area of each variety and were threshed and weighed.

The evaluation of grain losses as affected by various timings of harvest was made on the same dates at six timings of the day, i.e. 8-10, 10-12, 12-14, 14, 16, 16-18, and 18-20 hours from experimental plots of each variety.

Table 1 Meteorological Data of Wheat Harvest Dates

Date	Temperature Max. (°C)	Temperature Min. (°C)	Relative humidity % per day mean	Rain evap'n/h (mean of 24 h)	wind velocity h	Rain-fall m	Sunshine h/day h-min.	Interval
25-3-87	33.5	13.2	34	0.34	4.3	—	10-25	Normal day
30-3-87	32.5	11.5	24	0.28	3.1	—	10-25	5 days late
04-4-87	36.0	19.0	40	0.31	2.9	—	10-00	10 days late
09-4-87	37.2	22.5	51	0.42	6.4	—	9.5-00	15 days late
14-4-87	36.0	20.0	39	0.39	3.5	—	9.0-00	20 days late
19-4-87	37.5	22.0	44	0.47	6.4	—	10-40	25 days late
24-4-87	38.1	33.6	27	0.59	11.1	—	9-52	30 days late

Results and Discussion

The data on meteorological observations are given in **Table 1** which indicate that the maximum temperature ranged between 33.5 and 38.1°C, relative humidity ranged from 24 to 51%, and sunshine ranged from 9.86 to 10.41 h/day during experiment.

Date regarding various agronomical characteristics of the wheat varieties are presented in **Table 2.** The data indicate that the number of plants per square meter, number of tillers per plant, number of earheads per plant and plant height were more or less similar.

Table 2 Characteristics of Wheat Varieties Studied

Parameters	Sarsabz	Pavon	ZA-77
No. of plants per m^2	621.00	624.05	620.00
Plant height, cm	86.42	85.35	84.75
No. of tillers per plant	7.80	8.11	7.66
No. of earheads per plant	7.50	7.99	7.50
No. of earheads per m^2	638.50	596.50	573.52
Grain yeild kg/ha	3540	3450	2946
Straw yield kg/ha	3670	3650	3560

Data regarding the grain losses

Table 3 Wheat Grain Losses as Influenced by Date and Timing of Harvest

Date and varieties	6-8	8-10	10-12	12-14	14-16	16-18	18-20
Normal Day							
Sarsabz	25.0	23.5	23.5	26.0	30.0	32.0	23.0
Pavon	24.7	22.5	23.0	24.5	28.0	30.0	33.0
ZA-77	26.7	24.0	25.6	28.0	32.9	33.8	38.0
5-days late							
Sarsabz	28.0	26.5	28.0	31.5	36.5	41.0	45.0
Pavon	27.0	25.5	27.6	31.0	33.5	37.2	41.3
ZA-77	29.8	28.0	33.0	38.5	42.7	47.8	50.8
10 days late							
Sarsabz	29.0	27.0	29.5	33.0	30.5	45.0	53.0
Pavon	28.5	25.9	28.0	32.0	37.6	41.7	45.0
ZA-77	30.5	28.9	33.9	39.6	43.9	49.5	55.9
15 days late							
Sarsabz	35.0	34.0	34.5	40.0	46.9	56.8	64.0
Pavon	34.0	32.5	35.2	37.4	49.7	44.5	48.0
ZA-77	37.0	36.5	40.0	46.9	51.5	58.2	66.3
20 days late							
Sarsabz	55.0	51.5	54.0	60.5	64.8	71.3	78.0
Pavon	52.0	50.0	53.4	57.3	62.5	67.9	73.5
ZA-77	60.0	56.0	60.3	65.0	67.3	69.9	73.3
25 days late							
Sarsabz	64.0	63.0	66.4	70.2	74.9	80.2	87.5
Pavon	62.5	51.5	55.0	63.7	71.0	76.3	83.5
ZA-77	68.0	65.0	76.6	72.0	78.1	81.3	90.2
30 days late							
Sarsabz	70.0	69.0	78.0	83.7	88.9	93.2	99.5
Pavon	68.0	66.5	74.0	76.0	79.6	81.5	85.0
ZA-77	77.0	77.7	80.0	87.1	94.7	103.3	107.9

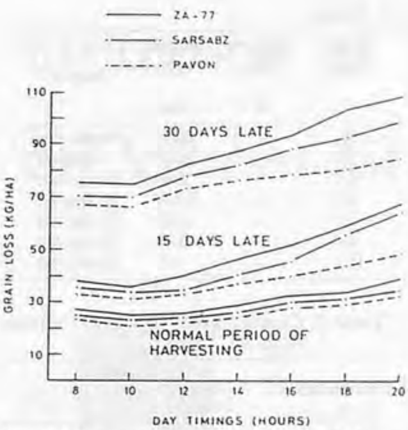

Fig. 1 Wheat grain losses as influenced by timing of harvest.

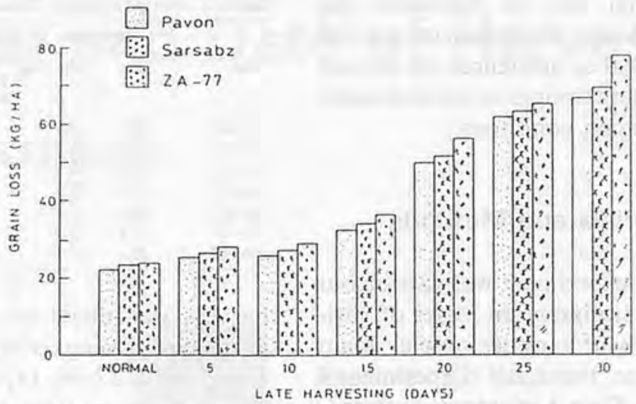

Fig. 2 Wheat grain losses as influenced by different harvest intervals.

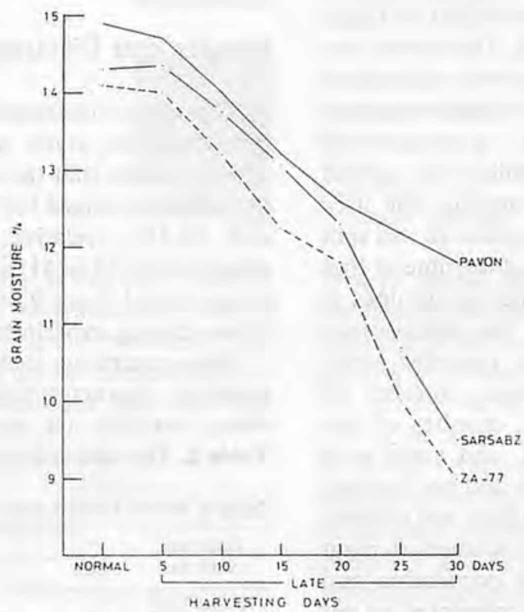

Fig. 3 Wheat grain moisture as affected by late harvesting.

in various wheat varieties influenced by various timings of harvesting is given in **Table 3** and **Fig. 1**. The highest grain losses were observed when the wheat harvesting operation was performed between 1600 and 2000 (thin) and lowest between 0800 and 1200 for all the varieties at various intervals. Grain losses increased by harvesting the crop in late hours because the wheat stalk and grains dried due to the heat of the sun.

Table 3 and **Fig. 2** also indicate that highest grain losses were observed with the delay in harvesting for all three wheat varieties and grain losses increased linearly with timing and interval of harvesting. Grain losses were observed highest for ZA-77 variety followed by Sarsabz sand Pavon.

The data further reveals that 10 days after the due date for harvest grain losses increased significantly. **Fig. 3** indicates that the maximum moisture content of grains was observed on normal day of harvest which ranged from 14 to 15%. The moisture content of grains decreased with delays in harvesting. The moisture content of grains linearly decreased in relation to increase in harvesting intervals. Further, **Figs. 1-3** show that with decrease in moisture content of grains, grain loss increased. The lowest grain loss was observed at 14-15% grain moisture content. The findings of this research study are in close agreement with the findings of Iqbal et al (1980), Bela et al (1980), Hunt (1977), Arnold et al (1958) and Bukhari et al (1988).

It is concluded that grain losses under Tandojam conditions increased with delays in harvesting and at different timings of harvest. Grain loss also increased as the crop is dried due to late harvesting and harvesting time.

Suggestions

1) Wheat harvesting should be carried out at proper times to minimize grain losses.
2) Wheat combines and reapers should be used to complete the wheat harvesting in scheduled harvesting dates so that grain loss due to late harvesting is minimized and land is freed for the next crop.

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Mechanized vs Traditional Cultivation of Sugarcane Crop in Pakistan

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Abstract

Three mechanized tillage treatments were compared with conventional tillage treatment for sugarcane production. The cane sets, fertilizer, pesticide, irrigation, soil type and method of cultivation were constant for all treatments. Time and cost of production of each treatment were recorded.

The analysis reveals that the cane growers preparing land by using moldboard plow, tandem disk harrow, cultivator and tractor blade (first set of machines) earned net profit of Rs. 1.59 per rupee expense being 42% more than traditional trial. It is also observed that the first set of machines gave better results than the other three combinations due to proper depth of plowing and levelling operations.

Introduction

Sugarcane is a major crop of Pakistan. It is the main source of sugar production and plays an important role in the economy of the country. The sugarcane yield per acre is still low as compared to developed countries. Though there is an introduction of power machines on farms, yet bullock power is not uncommon even on progressive farms. The cultivation practices of sugarcane crop require to be planned on modern lines to select suitable machines and to fetch increased yields and returns. The farmers can only accept new methods when they derive demonstrated benefits out of modern farm technology replacing less productive traditional methods of cultivation.

Considering the importance of farm machinery use, experiments were conducted at different locations to determine the best combination of tillage implements and to demonstrate the comparative advantages in terms of both mechanical as well as economic efficiency. These trials will hopefully result in appropriate set of implements.

Methodology

The study was carried out in order to compare various mechanized and traditional systems of sugarcane cultivation on selected farms in Sindhi Province in Pakistan. Tractor implements were used to carry out different tillage operations on mechanized farms and the tillage treatment with local implements (bullock-drawn) was also performed by bullock power.

On the study area, four treatments of tractor and bullock-drawn implements were used. The plot size for treatments I, II, and III was 25 ha for each treatment and for treatment IV the plot size was one hectare. The treatments used were as follows:

Treatment I:
Moldboard plow + tandem disk harrow + cultivator + blade

Treatment II:
Disk plow + tandem disk harrow + cultivator + blade

Treatment III:

Tandem disk harrow + cultivator + blade

Treatment IV:

Sindhi plow + Meston plow + plank + leveller

The use of machines for the cultivation of sugarcane on the selected farms was limited to operations leading to seedbed preparation only. The output of the tractor and various machines used in carrying out different operations were determined. The cultivation standard of each treatment was recorded. Moldboard plow, tandem disk harrow, cultivator and tractor blade were used for plowing, clod breaking and levelling. Bundmaker, ditcher and ridger were also used for dyke and channel making and furrow preparation. The sowing and post-sowing operations were performed by man and bullock-power.

Sugarcane sets, fertilizer, pesticide, intercultivation, type of soil (clay soil) and number of irrigations were similar for all four treatments. The total number of operations and time taken for each operation in all the treatments were recorded. All the expenses incurred on each treatment were calculated and the cost of cultivaiton per hectare was determined. The land, labour and capital, including machinery costs were aggregated and related to the revenue productivity. The economic efficiency for different levels of mechanization was worked out for the combination of tillage implements to estimate the relationship of input to output.

Results and Discussion

In these experiments, three treatments of power machines and one treatment of conventional implements were studied in order to compare the effect of plowing, levelling and land-preparation for sugarcane produciton. The study was based on the comparison of machine use within different sets of machines and as a whole to the use of bullock-drawn implements. To test the significance and adaptability of different machine treatments, a study was conducted and the data was analysed. The tillage implement treatments were conducted for testing the effect of tillage implement combination with the traditional one. The time consumed by different treatments was measured for individual treatment for computing the economic effects of each machine combination and the traditional cultivation.

Machine Hours

The time taken per hectare by different machine treatments is given in **Table 1**. In the first machine trial the seedbed was prepared by tractor moldboard plow, tandem disk harrow and cultivator at an average depth of 25cm and the time taken per hectare were 7 h, 3.5 h and 3.72 h, respectively. Treatment I required for levelling operation, channel making, furrow preparation, set covering, and transport of sugarcane sets and fertilizer application were 6 h, 2.25 h, 0.76 h, 1/25 h and 5 h, respectively. In Treatment II, the seedbed was prepared by disk plow, tandem disk harrow and cultivator at an average depth of 20 cm. The time required per hectare for tilling by individual machine were 5 h, 3.50 h and 3.76 h, respectively. The levelling operation, bund/channel preparation, furrow preparation, set covering and transport of sets and fertilizer consumed 6 h, 2.25 h, 0.76 h, 1.25 h and 5 h, respectively.

On the third machine trial, the seedbed preparation was done by tandem disk harrow and cultivator at a depth of 15cm. The time consumed for disking, cultivating, levelling operations, bund/channel preparation, furrow preparation, set covering, transport of sets and fertilizer were 7 h, 3.8 h, 5 h, 2.2 h, 0.72 h, 1.2 h and 5 h, respectively. The average time and fuel consumed by Treatments I, II and III are also shown in **Table 1**.

Man-Animal Work Hours

Sugarcane is a labour intensive

Table 1 Time and Fuel Consumption/hectare of Mechanized Operation

Operation/ Implement	Treatment I			Treatment II			Treatment III		
	Machine passes	Tilling time (h)	Fuel consumption (l)	Machine passes	Tilling time (h)	Fuel consumption (l)	Machine passes	Tilling time (h)	Fuel consumption (l)
Plowing									
Moldboard plow	1	7.00	51.0	—	—	—	—	—	—
Disk plow	—	—	—	1	5.00	30.0	—	—	—
Tandem disk harrow	2	3.50	18.0	2	3.50	19.0	4	7.00	39.00
Cultivator	2	3.72	23.0	2	3.76	26.00	2	3.80	23.00
Leveling									
Tractor blade	1	6.00	24.0	1	6.00	24.0	1	5.00	20.00
Bund making									
Border disk	2	1.25	7.0	2	1.25	7.00	2	1.20	7.00
Channel making									
Ditcher	1	1.00	7.0	1	1.00	7.00	1	1.00	7.00
Furrow preparation									
Ridger	1	0.76	5.00	1	0.76	5.00	1	0.72	4.00
Set-covering									
Cultivator with patio	1	1.25	8.00	1	1.25	9.00	1	1.20	8.00
Trailer	—	5.00	38.00	—	5.00	30.00	—	5.00	30.00
Total		48.00	173.00	—	27.52	157.00	—	24.72	138.00

crop which involves considerable labour inputs for its cultivation throughout its cropping season. It was observed that the extent of machine use was only limited to land preparation. The tractor power as well as manual labour and bullock power were also used for one or other operations. The detailed man-animal work hours observed for different jobs for different machine treatments were 1295, 1195 and 1160 working hours in Treatments I, II and III, respectively. The bullock power was used for interculture operations and recorded 30 h in Treatments I and II and 35 h for Treatment III. The manual hours for Treatment I recorded in bund making/dressing, channel making/dressing, planting, set covering, irrigation application, fertilizer application, pesticide application, interculture, harvesting, loading and transport of sets/fertilizer for different machine treatments were 8-16-250-72-6-15-30-800- and 60- h, respectively. In treatment II 8-16-250-60-6-15-30-750- and 60- working hours, respectively. Whereas Treatment III consumed 8-18-250-50-6-15-35-720- and 60 h, respectively.

Table 2 shows the time taken by man-animal operation. In Treatment IV (control) all the operations were performed with man and animal power. The man and animal power required was 1 324- and 196.5 work hours, respectively.

Table 2 Time Required for Various Man-animal Operation/Hectare

Operations	Implements	Treatment I		Treatment II		Treatment III		Treatment IV	
		Man-hours	Bullock-hours	Man-hours	Bullock-hours	Man-hours	Bullock-hours	Man-hours	Bullock-hours
Plowing	Sind plow and Meston plow	—	—	—	—	—	—	110	110
Clod crushing	Roller	—	—	—	—	—	—	4	4
Levellling	Wooden leveller	—	—	—	—	—	—	20	20
Bund making/dressing	Spade & dandar	8	—	8	—	8	—	15.5	—
Channel making/dressing	Spade	16	—	16	—	18	—	31	—
Furrow preparation	Meston plow	—	—	—	—	—	—	—	—
Planting & set covering	Axe, sickle, Meston plow and patio	250	—	250	—	250	—	250	22.5
Irrigation application	Spade	72	—	60	—	50	—	50	—
Fertilizer application	—	6	—	6	—	6	—	6	—
Pesticide application	Hand spade	15	—	15	—	15	—	15	—
Inter-culturing	Meston plow; spade	30	30	30	30	35	35	40	40
Harvesting	Axe and sickle	800	—	750	—	720	—	700	—
Transport	Tractor and trailor	60	—	60	—	60	—	60	—
Total		1 257	30	1 195	30	1 160	35	1 324	196.5

Table 3 Cost of Cultivation per Hectare

Items	Treatment I		Treatment II		Treatment III		Treatment IV	
	Amount Rs.	Percent	Amount Rs.	Percent	Amount Rs.	Percent	Amount Rs.	Percent
Capital inputs								
Fixed (land)	1 235	9.26	1 235	9.56	1 235	9.80	1 235	9.76
Physical inputs	4 070	30.53	4 070	31.49	4 070	32.29	4 070	32.15
Labour inputs								
Machine	2 301	17.26	2 145	16.60	1 928	15.29	—	—
Man	5 481	41.12	5 230	40.47	5 089	40.37	5 858	45.48
Animal	244	1.83	244	1.89	284	2.25	1 596	12.61
Total	13 331	100	12 924	100	12 606	100	12 659	100

Economic Analysis

The production cost of sugarcane crop was analysed in terms of land input and labour input, including machine costs and management and capital inputs. The land input was calculated by estimating the rent of land per hectare on the basis of contract rate for farm locality and land tax, "usher" and water charges fixed by the government were also added. The labour costs were calculated on actual bullock work hours, man work hours and machine work hours for the production of sugarcane crop. The capital costs comprised of the economic inputs for the purchase of sugarcane sets, fertilizer and pesticides. The data regarding the costs of different items is shown in **Table 3**. The data reveals that the average costs of cultivaiton recorded were Rs. 13 331, Rs. 1 294 and Rs. 2 606 per ha for the mechanized Treatments I, II and III whereas Treatment IV (control) covering all non-mechanized operations was Rs. 12 659 per ha for various inputs. Cost benefit relationship for different treatments is shown in **Table 4**. The data reveals that the combination of tractor-drawn implements gave better revenue as compared to the combination of bullock drawn implements. However, among the combinations of tractor-drawn implements Treatment I resulted in better revenue. The input-output ratio for Treatment III was 1:2.29; and for Treatment IV, 1:2.06. The analysis further reveals the on an average the cane growers using power machines earned 21.53% higher revenue than tradional ones and input-

Table 4 Cost Benefit Relationship for Different Treatments

Treatments	Physical productivity		Revenue productivity				Cost benefit ratio
	Main product (tons)	By-product (tons)	Main product (Rs)	By-product (Rs)	Total (Rs)	Cost of production (Rs)	
Treatment I Moldboard plow + tandem disk harrow + cultivator + tractor blade.	111.7	22.4	31 136	3 360	34 496	13 331.00	1:2.59
Treatment II Disk plow + tandem + disk harrow + cultivator + tractor blade.	102.5	20.5	28 700	3 075	31 775	12 924	1:2.46
Treatment III Tandem disk harrow + cultivator + tractor blade.	93.3	18.6	26 124	2 790	28 914	12 606	1:2.29
Treatment IV Meston plow + sindhi local plow + double pair wooden leveller	84.0	16.8	23 520	2 520	26 040	12 659	1:2.06

output ratio on machine trials was calculated at 1:2.45 against 1:2.06 on traditional trial.

Conclusions and Suggestions

The research results indicate that an average depth for Treatment I was about 25 cm which gave the highest yield and net profit of Rs. 1.59 per rupee expense being 42% more than traditional trial. For of Treatment II, the depth of tilling was 20 cm and earned net profit of Rs. 1.46 being 30% more than control treatment whereas for Treatment III, the depth of tilling was 15 cm as compared to Rs. 1.06 per rupee expense on control treatment.

Treatment I (moldboard plow + tandem disk harrow + cultivator + tractor blade) gave better response than other three treatments due to the proper depth of tilling and levelling operations.

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(*Continued from page 58*)

Influence of Timing and Date of Harvest on Wheat Grain Losses

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Single-row Model II Cassava Harvester

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Abstract

The evolution of the Model II cassava harvester from a semi-mounted Model I developed in 1979 is presented. The single-row Model II cassava harvester prototype, developed in 1986, is a fully mounted compact machine. Its novel design involves two gangs of reciprocating p.t.o.-driven diggers which dig two opposite sides of the ridge from the furrow bottom, in order to uproot the bunch of cassava tubers. The design of the gang of digger ensures a clean harvesting operation, minimizes damage to the harvested tubers and leaves a well pulverized harvested row with good soil tilth. The harvester operates well at 2.5 to 4 km/h forward speed which is equivalent to a theoretical harvesting rate of 0.25 to 0.4 ha/h.

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This work featured as a poster presentation No.AE88/405 at the AG E 88 International Conference held in Paris, March 2-5, 1988.

Introduction

Engineering research effort aimed at the mechanization of cassava harvesting has been undertaken in many parts of the world, but it has in effect, been insufficient to put an acceptable commercial cassava harvester on the market (Odigboh, 1983). Consequently, cassava harvesting, like all the other cultural field operations for cassava production, is done manually by the producers who are predominantly peasant farmers in the tropics. But harvesting cassava by hand is slow, laborious and expensive; Echeverria (19710) reported a manual cassava harvesting rate of 215 man-h/ha, the author recorded a rate of about 0.01 ha/h in Nigeria (Odigboh, 1976) and Philips (1970) credited over 40% of total cost of cassava production to harvesting costs. Consequently, manual harvesting is definitely no longer adequate for, or compatible with, the commercial-scale processing and utilization of cassava which is progressively taking place nowadays in many of the cassava producing countries where cassava is fast becoming a plantation crop. Therefore, mechanized harvesting of cassava, which had engaged the attention of earlier researchers such as Essais (1954), Bates (1963), Krochmal (1966), Echeverria (1971), Makanjuola et al (1973), Kemp (1978) and others, has recently become an urgent necessity. Johnson et al (1981) reported more recent work related to the development of an API cassava harvester Mark III (API, 1981), which indicates current active interest in the problem.

Evolution of the Model II Cassava Harvester

As discussed by Odigboh (1976), the problems involved in the mechanization of cassava harvesting are very many and arise principally from the random growth patterns of the tubers and the equally random branching of the cassava stems, as well as from the fact that cassava has no specific harvesting season. So, an effective harvester must be able to work in the parched hard soils of the tropical dry season and the drenched muddy soils of the rainy season, as well as in soils of conditions varying between these extremes. The harvester must also be capable of digging to depths of 250 - 300 mm below the surface and of handling about 0.25mm3 or about 500 kg of soil to harvest one cassava plant, assuming the usual planting density of 10000 plants/ha (Odigboh and Ahmed, 1982).

The Semi-mounted Model I Cassava Harvester

The semi-mounted cassava harvester illustrated in **Fig.1** was developed in 1979 and was described in detail by Odigboh and Ahmed (1982). It has an independently powered rotary cutter mounted in front of the tractor to cut the above ground cassava stems, with an arrangement to collect and windrow the cut stems off the path of the tractor. Behind the tractor, the cassava root lifter is semi-mounted with a special hitch attachment. The root lifter consists of the reciprocating hoe shown in **Fig. 1B**, driven from the tractor p.t.o. and designed to move under the cassava roots to dig and lift up the tubers. The reciprocation action of the hoe at about 540 rpm of the tractor p.t.o. is designed to reduce draught and facilitate the harvesting of cassava under different soil types and conditions.

The Single-row Model II Cassava Harvester

The overall form and the semi-mounting or trailing of the Model I cassava harvester make it difficult to manoeuvre in the field or to turn at corners on the road. The hoe of the Model I harvester penetrates via the crown of the ridge to below the cassava roots; this requires that the hoe and the soil-engaging part of it be of considerable length, with inherent technical disadvantages. The hoe has a blade cutting edge which is easily impeded in stumpy field conditions; the suspension of the hoe from swinging links **(Fig. 1A)** also causes difficulties in trashy fields.

In the single-row Model II Cassava harvester, which is the subject of this paper, all the above shortcoming of the Model I harvester have been removed. The Model II harvester prototype, developed in 1986, is fully mounted so that manoeuverability is not a problem at all. As shown in **Fig. 2**, the Model II harvester prototype is a compact machine, with a novel design which involves two gangs of p.t.o.-driven reciprocating hoes, designed to penetrate to below the cassava root zone by digging two opposite sides of the ridge from the furrow bottom. As illustrated in **Fig. 3**, this arrangement makes it possible to utilize the minimum soil engaging length of the hoe while ensuring the minimum possible damage to the harvested cassava tubers. As visible in the photograph of **Fig. 2**, the hoe design has done away with the blade cutting edge of Model I harvester and replaced it with single and independently mounted chisel-tipped diggers, fashioned from high-strength steel rods and ganged as shown. Also, the reciprocation of the two gangs of diggers is designed as a slider-crank arrangement which is more robust than the swinging link mechanism of the Model I prototype. The Model II harvester prototype has provisions for mounting it in line with, or off-set from the centre line of the tractor, to facilitate harvesting of cassava planted on the flat or on the ridge, at the agronomically recommended row spacing of one metre. In line or off-set, the gangs of reciprocating diggers are driven from two shafts from a 120 bevel gearbox. The shafts are in turn driven from the tractor pto shaft by a vee-belt drive designed to make the diggers reciprocate at 270 rpm corresponding to the tractor pto speed of 540 rpm. The bevel gear box and drive shaft arrangement illustrated in **Fig. 4**, show how the connecting rods designed as (5) from eccentric wheels (3)keyed to the shafts of the bevel gears (2), transmit power to and cause the oscillation of the slider-crank mounts (6) which carry with them the ganged diggers.

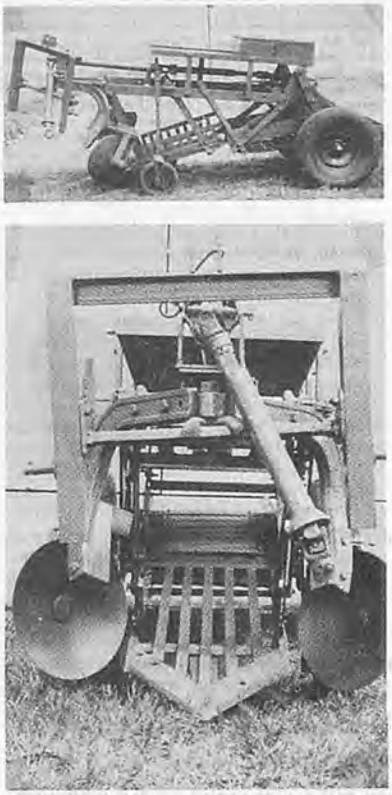

Fig. 1 Semi-mounted model I cassava harvester prototype. A — side view:; B — close-up view of the hoe.

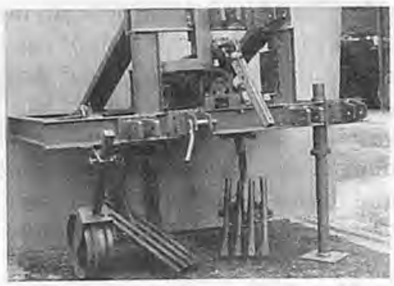

Fig. 2 Single-row model II cassava harvester prototype.

Discussion

It has been pointed out that mechandized harvesting is needed to economically supply cassava tubers to the emerging large-scale cassava processing enterprises because harvesting by hand is too slow and too expensive. The situation is even further complicated

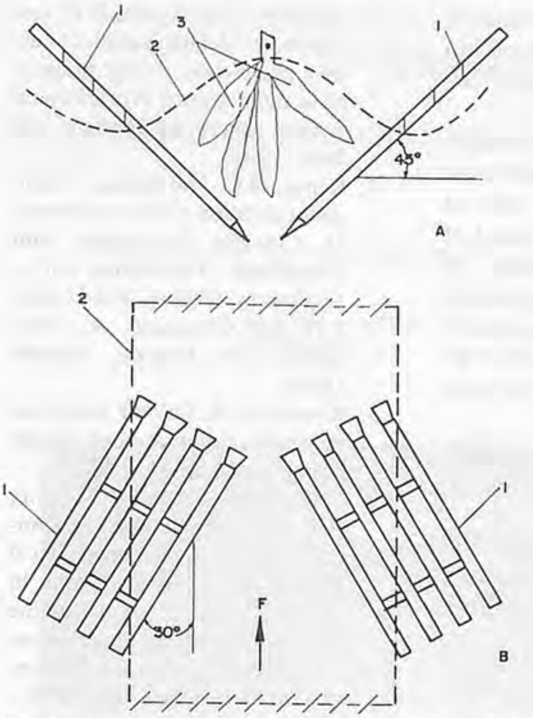

Fig. 3 Illustration of orientation of diggers: A — front view; B — top view; F — direction of forward travel; 1 — gang of diggers; 2 — outline of ridge; 3 — outline of bunch of cassava tuber.

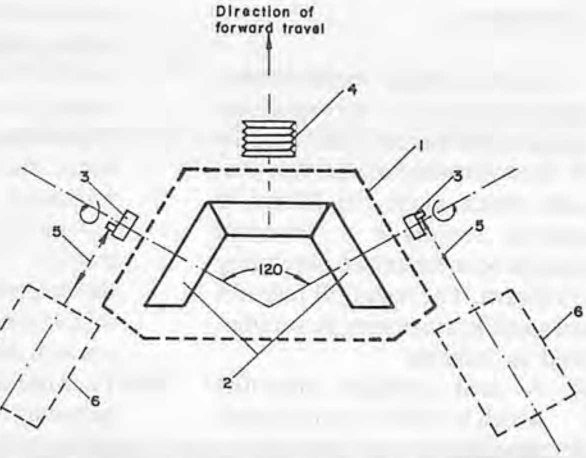

Fig. 4 Sketch showing top view of the bevel gear drive for the reciprocation of the diggers. 1 — gear box; 2 — bevel gears; 3 — eccentric wheels on shafts of 2; 4 — multiple vee-belt drive from pto; 5 — line of action of connecting rod; 6 — slider mount of reciprocating diggers.

because the processing plants cannot resort to long-term or even short-term storage since cassava tubers do not store well at all and begin to deteriorate 2 to 4 days after harvest. However, experiments and tests in Colombia have consistently shown that pruning the cassava plants by cutting the stem just above the ground, about 3 weeks before harvest, permits successful storage, without any further treatment, for above 5 days (Odigboh, 1983). This means that it is not necessary to cut and move the above ground vegetation simultaneously with the harvesting operation. Therefore, provision for the removal of the cassava stems and branches was not considered as an integral function of the harvester.

The single-row Model II cassava harvester prototype operates well at forward speeds of 2.5 to 4 km/h, depending on soil type and the field conditions and requires a medium size tractor of 45 to 70 kW. The harvester prototype thus can achieve harvesting rates of 0.25 to 0.4 ha/h. The quality of the harvesting job done, in terms of the effectiveness of lifting the cassava root cluster and shaking it free of soil and with very little damage, is considered very good indeed. This proves the efficacy of the novel idea of digging two opposite sides of the cassava stand from the furrow bottom. The use of ganged-up diggers gives a well pulverized strip of the ridge or row, with the cassava root bunches left cleanly on top for subsequent collection, manually or mechanically.

It is evident that the harvester can be employed effectively in cassava plantations with straight rows or ridges. Also, when harvesting cassava planted on ridges, it becomes necessary to use off-set mounting of the harvester; the tractor then works with the unharvested field on its right hand side. to avoid the tractor wheels running over the uprooted cassava tubers, it is necessary to collect the uprooted tubers before the next pass of the tractor. Even where the tubers have to be collected manually, this can be done by one operator.

Lifting the cassava roots in clusters does leave some amount of work to separate the tubers for subsequent processing. But, this is work that can be done in the factory with relative ease. It must be recognized that the site of most severe mechanical damage, which pre-disposes cassava tubers to deterioration, is usually the neck of the tuber where it is attached to the plant stem. There is evidence that, if the individual cassava tubers are left attached to the plant stem during storage, then deterioration is reduced. In this regard, harvesting the cassava tubers in bunches is advantageous in industrial-scale applications, although that would involve reduction in bulk density of the tubers in transit to and storage at the factory (Odigboh, 1983).

Conclusion

The low draught requirements, the good tilth of the harvested row and the cleanliness of the uprooted cassava root bunches are features which make the Model II cassava prototype a practical solution to mechanized harvesting of cassava. The technical features and specifications may be summarized as follows:

(i) A neat compact machine which is fully 3-point linkage mounted to facilitate manoueverability.

(ii) Has provisions for in-line as well as off-set mounting to permit harvesting of cassava planted on the flat or on the ridge at between-row spacings of 1 m.

(iii) A novel design involving two gangs of reciprocating diggers,p.t.o.-driven at 270 rpm through a bevel gear drive arrangement illustrated in **Fig. 4**; the diggers work from two opposite sides of the ridge, digging from the furrow bottom to below the root zone, to uproot the cassava tubers in intact bunches, **(Fig. 3)**, thus ensuring mini mum possible damage to the tubers.

(iv) The diggers consist of single and independently mounted chisel-tipped rods, fashioned from high carbon steel and ganged together as shown.

(v) The reciprocation of the diggers is through a robust slider-crank arrangement, instead of the swinging link mechanism of the model I prototype.

(vi) The novel arrangement and design of the diggers ensure an effective and clean harvesting operation which leaves uprooted bunches of cassava tubers, shaken free of soil, on a strip of well pulverized harvested row.

(vii) Depending on field conditions, the Model II harvester prototype operates well at 2.5-4 km/h forward speed of tractor, corresponding to theoretical harvesting rates of 0.25-0.4 ha/h, using a medium size tractor of 45-70 kW.

(viii) Technical specifications summary:

- Basic dimensions — width 1.70 m, depth 0.95 m, height 1.25 m
- Frame unit — 1 section and sheet steel welded structure
- Min. tractor size — 45 kW
- Working depth — up to 0.30 m from furrow bottom
- Field capacity — 0.25-0.4 ha/h (Theoretical)

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Reducing Grain Post-harvest Losses

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Abstract

This paper discusses the importance of food grain losses with emphasis on maize which contributes about 50-60% of total cereals produced in Ghana. It is not a report of any original research but puts together information on grain post-harvest technology relevant to the reduction of losses.

Estimates of losses in Ghana have been given at one time or the other as 12% (1951), 25% (1968), 10-30% (1976), and 25.3% (1985). Most of these losses have been attributed to damage caused by rodents, insects, rainwater, birds, fire, moulds and ground water. Inadequate and improper grain handling, drying and storage methods have also contributed to these losses.

Improvements in the storage mentods and structures on farms could help reduce some of these losses. In doing so, however, the socio-economic factors under which the farmer operates should be taken into consideration.

Introduction

In spite of continuous effort at increasing food production, Ghana has not met her rapid increasing demand, resulting in an imbalance between supply and demand. To make up for the shortfall the country spends a lot of foreign exchange in order to import grains over the years. The improvement of the nation's food self-sufficiency is the most important problem in the national economic policy (Agricultural Policy Document 1984-86).

The Government has spent considerable effort and resources to increase food production, but the full benefits of high production are not being realised due to inadequate harvest and post-harvest management practices. Thus, a considerable amount of food produced is lost. The immediate solutions to the problem of food deficit include: 1) to put more land under cultivation; 2) plant high yielding varieties; and 3) improve husbandry practices. Although accurate figures are not easy to obtain, it is generally conceded that considerably less resources are required to conserve food than to produce on equal quantity of food.

Bottrel (1979) stated clearly that the vital and neglected step towards producing more grains for the society is to reduce the losses that occur between harvest and consumption.

The crops sector contributes about 80% of the agricultural gross domestic product in Ghana with maize as the major staple accounting for 50-60% of the production of cereals, (Danida, 1986). Maize which is mainly a small-holder crop is produced in all the regions of Ghana. It is, therefore, important that all the maize produced is saved for consumption. Unfortunately, the handling of the maize crop from the time of harvest until it reaches the consumer is fraught with high levels of losses both in quantity and quality.

Losses Defined

Parkin (1956) cited by Adams et al (1977) divides losses into 'general estimate' or informed guess-work of the expert, and the 'experimental estimate' based on some actual measurements. The term 'post-harvest losses' is not clearly defined, particularly in field estimates and hence comparisons become difficult even when data are obtained from the same locality (Adams, 1977).

Post-harvest losses could have different meanings when viewed from the point of the individual farmer or society. For example, pilferage of grain from a truck or store is a loss to an individual, but not to society since it is ultimately consumed.

Bourne (1976) gave a working definition of loss as follows: "Post-harvest loss is the weight of the wholesome edible product (exclusive of moisture content) that is normally consumed by humans and that which has been separated from the medium and site of its immediate growth or production by deliberate human action with the intention of using it for human feeding but which for any reason fails to be consumed by humans. Post-harvest losses can also be defined as losses which occur between the period of harvest of the crop and the time of consumption."

Estimates of grain loss due to inadequate post-harvest management vary but are known to be high. Tyler et al (1984) state that the early comprehensive review of literature on post-harvest losses clearly showed that much of the data on the extent and types of losses was not particularly meaningful up to 1965 when Howe reviewed the literature and in 1977 when Adams did the review and did vary in the identification of focal points for loss reduction programmes. Estimates of losses have been given in Ghana as far back as 1951. These estimates include 12% by the Department of Agriculture (Halm, 1978) and 25% for maize during a period of 5-6 months (Reusse, 1968). Adams (1976) observed that for a storage period between 4-5 months, a loss of 6.7% was attributed to weight loss and 43.5% to damage. Nyanteng (1972) estimated grain losses to be between 10% and 30%. The Crop Research Institute and the Food Research Institute Storage team estimated losses at between 0.05% and 38.6% in 1982. Ofosu (1983) comparing the effectiveness of the Ashanti Crib and Ewe Crib obtained loss figures ranging between 1.5% and 25.3% for the farmer and 0.6% to 17.7% for the latter.

Loss figures are likely to differ depending on the location, the method of assessment and storage method used. In addition to the loss of grain, there is a considerable grain quality loss and this is of great significance to subsistence level families who obtain the greater part of their daily requirements from the grains. There is also a loss in terms of the inputs and efforts that have gone into land preparation, planting, weed and pest control and harvesting.

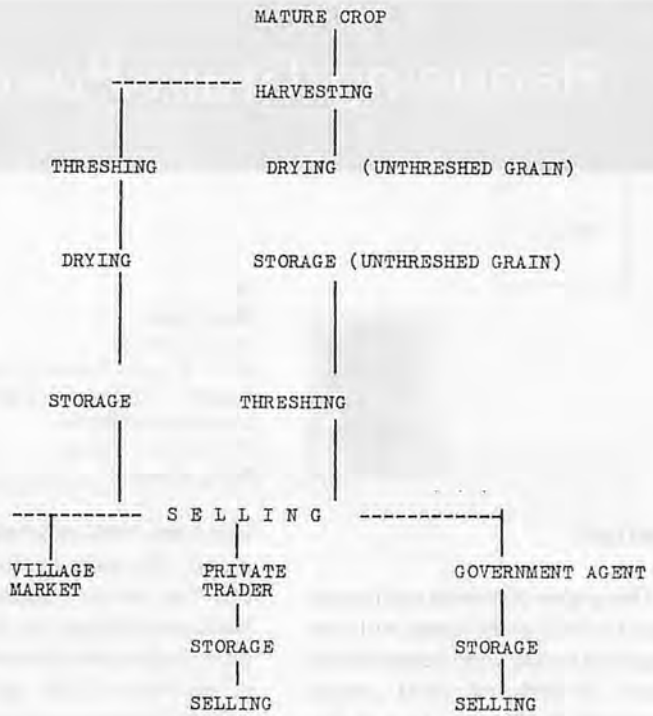

Fig. 1 Grain post-harvest system.

A typical post-harvest system for maize operating in most tropics and subtropical areas is shown in **Fig. 1.** Losses occur at each stage in the system and it is important that this fact is recognized when introducing any post-harvest reduction programmes. General reports about food loss levels are without meaning but commonly poor conditions of housing, drainage and sanitation combined with low access to knowledge and material resource, create a situation where food loss levels can be very high. Nyanteng (1972) reported that insects are the most important causal agents of storage losses and damage in granaries in Ghana, and listed other causal agents as rodents, rainwater, birds, fire, mouldiness, lizards and groundwater. The main causes of grain damage and losses are improper and inadequate grain handling and storage methods used.

Storage Methods and Structures

Methods of grain storage can be classified on the basis of the methods used in controlling the environment to suppress or eliminate destructive agents. Included under this classification are the followings:

1. Refrigerated storage in which low temperatures are employed to control enzymatic action and growth of insects and micro-organisms.
2. Modified atmosphere storage

Fig. 2 Some traditional storage structures in Ghana.

in air-tight containers or storage in an artifical atmosphere low in oxygen and high in carbon dioxide.
3. Storage in which removal of moisture to control microbial growth is achieved by natural ventilation.
4. Mechanical ventilation and artificial drying.

Storage methods can also be classified according to the form in which the produce is to be stored. This classification recognizes two methods, namely; in bag storage and bulk storage.

Many different structures have been designed and built according to these classifications. The functions of these structures in storage are, however, similar in the sense that they are structures designed to hold grain, keep out moisture, dry grain, control enzymatic activity and microbial growth, keep out rodents and insects and, to some extent, prevent unauthorized distribution.

The important structural requirements common to grain storage structures are as follows:
1) The foundations, floors, walls and bracings should have adequate strength to support the lateral and vertical pressure developed by the grain.
2) Roofs and floors should be constructed to exclude moisture and rain water.

Grain storage on the farm is done in barns, granaries, baskets, claypots, cribs, sacks and above fireplaces. These structures often leave the grains vulnerable to insects, rodents and birds. Golob (1984) mentions three main ways in which improvements could be made to the small holder storage system. These are:
1) Improve the storage qualities of the varieties of grain grown.
2) Improve the structure of the food store; and
3) Use protectants to control insect pest damage.

The development of grain varieties resistant to both field and storage pests wil help in the fight against insect infestation in store. Simple modifications to the traditional crib like reducing the width, raising the height above ground level to a height of about 1 m and the incorporation of rodent guards could improve grain drying and rodent control, respectively. Shelling of maize and treating with appropriate insecticide will reduce the incidence of insect attack and damage. However, the use of chemicals in the control of storage pests is sometimes unacceptable. The main reasons being:
1) Unskilled operators will be at risk if they use hazardous chemicals;
2) Some storage insects have become resistant to some of the chemicals; and
3) Chemicals require foreign exchange to purchase, a limiting factor in most developing countries.


Fig. 3 An experimental metal crib.

In the introduction of improved storage methods, materials of construction and construction procedures must be kept as appropriate as possible. Availability and cost of materials and ease of replacing damaged components quickly are important factors that should be considered. Reusse (1976) observed that in storing grain at the farm level, farmers have certain advantages over commercial storage. These include the skillful use of abundant locally available materials for storage and pest control and many generations of experience.

Modern grain storage structures have been introduced into many developing countries, including Ghana where 17 000 t storage facility have been provided (GFDC, 1984). Its usage, however, is restricted to Government, semi-Government and private commercial farms. A high degree of technical ability is required for construction and the initial capital cost, maintenance and replacement parts involve a high element of foreign exchange. Governments have entered into grain storge with primary objectives of making effective use of what is produced, obtaining a more even distribution through time and reducing price fluctuations. Attaining these objectives, however, have been met with many difficulties among which are the following:

1. The moisture content of the marketable produce is normally around 20% but Government agents restrict the moisture up to 18% in order to reduce the cost of drying. Growers are not normally prepared to dry the grains to lower moisture contents than the one at which it was harvested. To encourage farmers to dry their grains to acceptable moisture contents it will be necessary to pay a premium for grain that is brought in at the acceptable moisture content.
2. Government agent's buying prices are fixed and cannot be raised without affecting the consuming public.
3. Farmers normally find it difficult to sell to the Government's agent because of difficulties associated with the purchasing system. Often the farmers obtain loans from grain merchants and are therefore obliged to sell their produce to them. More often than not these middlemen have little or no knowledge about post-harvest technology. Availability of credit facilities to farmers is likely to improve the situation.

Conclusion

In conclusion, it is important that structures, institutions and policies are put in place which would promote the development and extension of post-harvest technology. By so doing we would be taking the first steps towards increased production and availability of food.

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Development of Brush-type Ginger Peeling Machine

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Abstract

This paper presents the final prototype development of an abrasive brush-type ginger peeling machine. The machine essentially consists of two continuous vertical abrasive belts with a brush of 32 guage steel wires, 2.00 cm long and spacing of 1.90 cm as recommended by Ali et al. The peeling zone has a length of 135 cm and width of 30 cm. The performance of the machine was evaluated and was found to operate satisfactorily with a peeling efficiency of about 85% and material loss of the machine was 200 kg/h.

Introduction

Giner (*Zingiber officinal* Rose) belongs to the family of Zingiberaceae, the same familly to which turmeric, plantain and canna belong. It is an underground modified stem commonly grown as a garden crop in tropical countries.

India is the largest producer and exporter of ginger. The total area under production of ginger was 60 680 ha with the total annual production of 90 000 t in 1983-83 (4).

Peeling of ginger is one of the most important unit operations in processing which hastens the process of drying and maintaining the quality of dried ginger. The process of peeling, if carried out properly, is a very delicate one as the objective is to remove the skin under which lies the cells containing much of the oil, upon which the aroma of ginger depends. Excessive or careless removal of peel will result in damaging of these cells leading to the loss of essential oil and its economical value since this oil is a prime factor in fixing the price of dried ginger (5).

An abrasive brush-type, ginger-peeling machine was designed and developed by Agarwal et al (1).

It was concluded that the design principles involved in the development of this machine were possible for application to ginger peeling.

Ali et al (2) modified the peeling unit of this machine with three sets of brush wire height and three sets of spacing. They recommended the optimum operating parameters and capacity of machine.

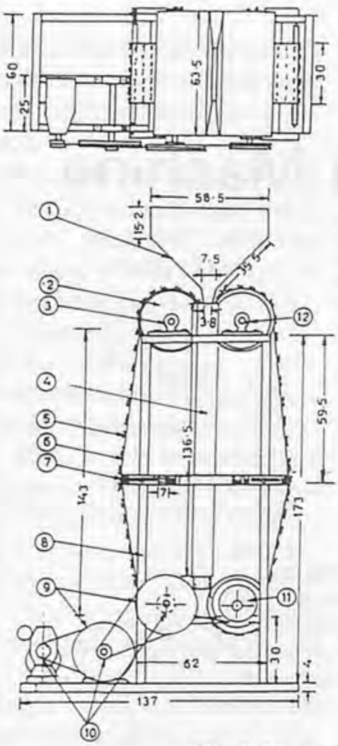
Materials and Methods

The functional requirements of ginger peeling machine are that it should remove as much skin from ginger as possible and cause as little material loss as possible from underneath the skin.

Therefore, the machine should have high peeling efficiency but at the same time the loss of material from underneath the skin should be minimum. Heavy material loss will result in loss of essential oil and the value of ginger may go down considerably. In general, high peeling efficiency is associated with high material loss. Therefore, peeling efficiency should be optimized against the material loss.

Description of Machine

The machine consists of the fol-



S.N	PARTS	MATERIAL
1	HOPPER	M.S.
2	PULLEY	C.I., 25-ϕ
3	PLUMMER BLOCK	C.I.
4	SIDE FLAP	M.S. SHEET
5	BELT	CANVAS 30 WIDE
6	BRUSHES	STEEL 32 GAUGE
7	IDLER	G.I. PIPE 3-ϕ
8	FRAME	M.S. ANGLE 4x4
9	V-BELT PULLEY	C.I. 30-ϕ
10	V-BELT PULLEY	C.I. 7.5-ϕ
11	V-BELT PULLEY	C.I. 20.3-ϕ
12	SHAFT	M.S. 2.54-ϕ

DIMENSIONS IN CM.
SCALE:- 1:9

Fig. 1 Ginger peeling machine.

Fig. 2 Ginger peeling machine.

lowing components: abrasion unit; transmission system; belt tensioner; hopper and side cover; and frame.

Abrasion Unit—The abrasion unit consisted of two endless canvas belts 370 cm long, 30 cm wide and 1 cm thick giving an effective abrasive surface area of 135 × 30 cm each, when mounted on a 25 cm diameter and 35 cm wide cast iron flat pulleys. The brushes were made by threading 20 steel wires of 32 guage at a spacing of 1.9 × 1.9 cm, and 2 cm length as suggested by Ali et al (2).

Power Transmission System—The power was provided by a 1.0 hp, 1440 rev/min single phase motor through a V-drive. The rev/min of the motor was reduced from 1440 to 87 for the pulley moving the belt in downward direction and 65 for the other pulley moving the belt in upward direction. The power from the motor, having a 7.5 cm diameter B-groove pulley was transmitted to a jack pulley with a diameter of 30 cm. The power from another jack pulley with a diameter of 7.5 cm was transferred to the main shaft with a pulley of 30 cm diameter as shown in **Fig. 1.** Another pulley of 7.5 cm diameter was mounted on this shaft to transfer the power to the other shaft, moving the brush belt in upward direction through a 20.3 cm dia, pulley using a V-belt and idler pulley. Thus, the linear velocities of both belts moving downward and upward direction were 114 and 85 cm/s, respectively.

Belt Tensioner—A belt tensioner was provided at both sides of vertical frame to maintain a proper tension in the moving belt at minimum friction. These were made up of galvanized iron pipe of 2.5 cm dia, amd 60 cm long each. The tensioning devices were provided with the mechanism of moving in and out with the help of a bolt.

Hopper and Side Cover—A 50-kg capacity hopper made of 20 guage mild steel sheet was provided at the top to feed unpeeled ginger between the two belts. To restrict the throw of ginger from sides of the brush belt, side covers were provided.

Frame—The whole unit was fixed and supported on M.S. angle of 38 × 38 × 6.35 mm. The total dimension of the machine was 137 cm long, 60 cm wide and 248.5 cm high.

Performance Evaluation

The initial theoretical skin weight of ginger was determined by hand trimming after soaking it in fresh water overnight. It was assumed that the skin weight so determined represented the skin weight of whole lot.

For evaluating the performance of the machine, it was set at the recommended operating parameters. A sample of 3000 g soaked fresh ginger was peeled with the machine, after removing the excess water. After one pass the weight of the same was determined and approximately one third of the peeled sample was removed and kept in polyethylene bag to avoid moisture loss. The remaining two-thirds sample was again fed to the machine for the second pass after which the ginger was once again weighed and half of the sample was removed and kept in polyethylene. The remaining sample was once more passed through the machine for the third time and the weight was recorded after peeling.

Hand trimming of the ginger peeled in the machine with different passes was done and peeling efficiency and material loss was determined by using the following formulae:

Peeling efficiency, %

$$= \frac{(Y-X)}{Y} \times 100$$

where,

Y = theoretical weight of skin on ginger, g

X = weight of skin removed by hand trimming after mechanical peeling, g

Material loss, %

$$= \frac{(W_1 - Y) - (W_2 - X)}{W_1} \times 100$$

where

W_1 = total weight of ginger before peeling, g

W_2 = total weight of ginger after mechanical peeling, g

Each experiment was replicated five times and the average peeling efficiency and material loss were determined for each pass. The capacity of the machine for ginger peeling was also determined.

Results and Discussions

The average theoretical skin weight of ginger was 13.3% (3). It was assumed that the average theoretical skin weight so determined was representing the skin weight of individual pawn in the whole lot.

Performance of Machine

The weight of the ginger sample before and after mechanical peeling and after hand trimming for evaluating the performance of ginger peeling machine at different number of passes are presented in **Table 1** along with peeling efficiency and material loss.

Table 1 Performance of Ginger Peeling Machine*

Rep.	No of passes	Weight of ginger, g: Before peeling	After mechanical peeling	After hand trimming	Peeling efficiency (%)	Material loss (%)
I.	1.	1000.00	905.66	865.60	69.60	0.176
	2.	1000.00	877.67	846.21	76.34	2.070
	3.	1000.00	858.60	839.15	85.37	2.785
II.	1.	1000.00	895.66	840.41	58.45	2.650
	2.	1000.00	858.16	818.04	69.83	4.896
	3.	1000.00	832.16	805.96	80.30	6.100
III.	1.	999.96	903.30	861.15	68.30	0.585
	2.	1000.00	873.35	841.17	75.81	2.278
	3.	1000.64	853.35	834.22	85.56	3.277
IV.	1.	1000.00	898.33	851.33	64.66	1.560
	2.	1000.00	863.30	827.03	72.72	3.990
	3.	1000.00	839.20	816.13	82.65	5.080
V.	1.	1000.00	900.00	858.00	66.16	1.200
	2.	1000.00	867.00	833.00	74.93	3.400
	3.	1000.00	835.00	823.00	83.45	4.400

Average: 1 - 65.43, 1.23. 2 - 73.82, 3.38 3 - 83.46, 4.33.

* (Brush wire height 2 cm, Brush wire density 2864 sets per sqm, with 1.9 × 1.9 cm spacing).

It will be shown in the table that the average peeling efficiency and material loss increased with an increasing number of passes. The peeling efficiency after the first pass was 65.43% and after second and third passes were 73.82% and 83.46%, respectively. Similarly, the material loss after first, second and third passes were 1.23, 3.38 and 4.33%, respectively. The material was not passed for the fourth time as there was no substantial increase in peeling efficiency but the material loss increased significantly as reported by Ali et al (2).

The capacity of the machine at the recommended parameters was 200 kg/h as compared to 30 kg/h reported by Agarwal et al (1).

Conclusions

1. The peeling zone of the ginger peeling machine was increased from 15 × 90 cm to 30 × 135 cm. Thus, the number of passes were reduced from five to three.
2. The gear reduction device was replaced by the jack pulley for power transmission.
3. The peeling efficiency and material loss were 83.46 and 4.33%, respectively.
4. The capacity of the machine was 200 kg/h.

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Potentials of and Constraints to the Adoption of Agricultural Mechanization Technology in the Middle East Region

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Abstract

Several conditions converge in the Middle East region in a manner that retards the effective application of agricultural mechanization technology and the consequent development in agricultural practices. This paper presents some of those conditions, and reviews the recent issues pertaining to both the obstacles and potentials of the adoption of this technology in the region. Constraints have been divided into primary: land, capital and technology adoption, and secondary: lack of a supporting production system, product price structure, servicing and spare parts, research and testing, training and extension, import system and assembly, and adequate infrastructure. A backview on the region's current food status and that of its potentials are presetned. Those potentials stem from the region need to increase production and stabilize labor mobility.

Introduction

The Middle East region is a strip of countries that extends from Morroco to Iran and from Sudan to Turkey. Nearly 80% of the total territory of the region falls in an area receiving less than 600 mm of annual rainfall and of the total 88 million ha of available arable land, only one-third is irrigated (FAO,1987a).

The Middle East region remained outside the food security umbrella during the last decade despite the numerous investments in agriculture by several of the regions' countries. Regional and international food production forecasts have not been encouraging and predicted a continued extensive dependence of the region on food imports. In the year 1987 alone, the countries of the Middle East region imported 50 million tons of food estimated at US$45 billion (IFAD,1988). Accordingly, individuals in the region are importing almost 40% of their needed food raising the average food demand by 6% since 1977. The more alerting figure, however, is that of the drop in the average rate of agricultural development which declined from 30% in 1977 to less than 2.5% in 1987 (FAO,1988). Those figures did not fall short from the known Indicative World Plan (IWP), produced by FAO in 1969 (FAO,1970), and in which it was suggested then that the increase in the demand for food in the developing countries was likely to be over 140% greater in 1985 than in 1962. Of this increase, 74% was expected in the Middle East to result directly from population growth and 26% from higher income per capita.

Two conclusions follow:
(a) the human effort and the investments required to keep pace with projected demand for food will serve mainly to feed more people; and (b) changes in the composition and quality of the diet will be relatively slow as long as part of the additional income has to be spread over a rapidly increasing population.

Effective implementation and adaptation of technology to increase output has often been the impetus to the more complex process of rural, economic, and social development (Pretty, 1980). In addition, political considerations and realities frequently intervene in projects and delay them while acceptable ways of circumventing public stances are worked out.

Development strategies have often followed a horizontal stratum with more emphasis on expanding quantity production at the expense of quality products of distinguished attributes. Higher production, increceased efficiency, and intensified output is the general concern yielding the application of very basic agricultural mechanization technology only. This technology has been unfortunately very commonly limited to tractorization and field operations rather than the application of its much broader concept pertaining to the use of mechanical systems in the process of food, feed and fiber production, protection and handling. We consider that both local and regional constraints and potentials to the adoption of mechanization technology has constantly been overlooked. Those concerns are as such presented in this paper as a prelude to this consideration.

Table 1 Total Number of Tractors in Several Countries of the Region and the Average per 1000 ha of their Distribution, 1973-86.

Country[a]	Tractor population (*1000)			Percent increase in tractor population[b]		Tractors per 1000 ha (1986)
	1973	1980	1986	1973-80	1981-86	
Algeria	41	44	62	7	41	8.2
Egypt	20	25	44	25	76	18.1
Iran	43	77	112	79	46	8.4
Iraq	18	22.2	37	23	66	6.8
Jordan	3.3	4.5	4.8	36	6	11.4
Kuwait	0.02	0.03	0.04	50	33	10
Libya	13	23.5	29.5	81	25	13.8
Morocco	16	24.5	32	53	31	4
S. Arabia	0.73	1.2	1.75	47	55	23
Sudan	8	11	19	38	72	1.5
Syria	11.6	27	47.5	132	76	8.4
Tunisia	27	34	26	26	−23	1.67
Turkey	241	431	611	79	42	22.2
Yemen Ar	6.5	2	2.2	−69	10	0.78
Yemen PDYR	1.2	1.3	1.1	8	−15	0.81

a) Countries listed are those with available data only as reported (FAO, 1987b, 1980 Production Yearbook); b) Negative values refer to a lower number of tractors in a specific period compared to the one before it.

Table 2 Total Number of Combine Harvester-thresher in Service in Several Countries of the Region and the Average Number/1000 ha of Cereal Land, 1973-86.

Country[a]	Harvester population (1000)			Percent increase[b] in harvester population		Total[c] cultivated cereal land (1000) ha	No. of harvesters/ 100 ha of ceral land
	1973	1980	1986	73-80	80-86	1986	1986
Algeria	3.8	6.4	6.2	11	48	2754	2.25
Egypt	1.8	2.4	2.3	33	− 4	1906(−)	1.21
Iran	2.4	2.9	2.9	21	0	9183	0.32
Iraq	4.6	5.4	6.7	17	24	2433	2.76
Jordan	0.18	0.24	0.32	25	33	95(−)	3.4
Morocco	2.5	3.2	3.2	7	0	5220	0.61
S. Arabia	0.23	0.4	0.55	74	38	614	0.9
Sudan	0.75	1.1	1.2	46	9	6612	0.18
Syria	1.7	2.4	2.9	42	21	2178	1.33
Tunisia	2.7	3.4	3.4	26	0	1059(−)	3.2
Turkey	11.2	13.1	11.45	17	−12.6	14747	0.78
Yemen PDR	0.011	0.014	0.015	27	7	69(−)	0.22

a) Countries listed are those with available data only as reported (FAO, 1987b, 1980 Production Yearbook); b) Negative values refer to a lower number of harvesters in a reported period compared to the one before it; c) Negative values refer to a decline in the total area cultivated with cereals in that year compared to the period before it.

Regional Status of Agricultural Mechanization

Almost all nations in the region conceive agricultural mechanization as a major component of any agricultural development strategy and production expansion process. The region, however, continues to present a model of agricultural practices in transition and while there exist a variety of machinery in all the countries, their use is neither widespread nor intensive. Farming remains lightly mechanized and large areas still rely on simple tools and implements that have been used for decades. The obstacles of the achievement of a sustained and rapid adoption of technology are great and seems to be lodged deeply in an extremely dynamic socio-economic and political fabric. The adoption of agricultural mechanization technology has consequently resulted in an active differential of quantity and quality which varies as a function of both the development period and the country **(Tables 1, 2)**.

Countries such as Syria, Sudan, Iran, Turkey, Egypt, and Iraq increased their tractor populations over the last decade tremendously, yet their respective per hectare distribution remains low, especially in Sudan (1.5 tractors per 1 000 ha). Local manufacture of tractors has been the main reason for this population increase. Syria currently produces two lines of tractors (60 and 80 hp) at a rate of 4 000 per year. The country assembles the tractor — called FORAT — and produces 67% of its components along with all the needed spare parts. Iraq has been producing "ANTAR" (60, 70, AND 80 hp) since 1972 and as of the year 1985, more than 65% of the Iraqi tractors were locally manufactured (Hussain and Khafaf, 1988). Egypt is likewise producing "NASR" tractors (65 hp) at an annual rate of 3200 units. Iran and Turkey have established full production lines of all size tractors and whose respective annual capacities are 45 000 and 28 000 units for both agricultural and industrial uses (UN, 1987). Algeria also produces a similar line of tractors at a 4 500-unit annual rate. In additon, both Turkey and Algeria produce medium-sized diesel engines at an annual rate of 17 000 and 11 000 units, respectively.

Table 3 List of the Total Machinery (1000) Produced by :Turkey and Algeria during 1986 (UN, 1987)

Country	Water pump	Plow	Harrow	Cultivator	Planter	Thresher
Turkey	95	14.5	36.7	4.4	2.4	2.6
Algeria	4	4.2	—	1.4	—	—

Although comprehensive data on the size, type, condition, and use of tractors in the Middle East region is lacking, a number of reports have episodically mentioned their manner of use and the problems associated with them (Danok et al.,1978, Henderson and Fanash,1981). Most tractors and several implements are used for off-farm jobs, especially transportation and domestic services. A number of countries had only a meager increase in tractor population and some, like Tunisia and Yemen, had even a decrease in the number over previous years. A more realistic view of the situation is reflected by the total number of harvesters and threshers. While Jordan, for example, had a relatively higher rate of harvester population growth (33%) over the last decade, its total land cultivated with cereals dropped during that same period. This has been a consequent result of the decline in the other needed machinery as reflected by the parallel drop in their respective tractor population.

The average total units of power input per hectare of arable land (including those with permanent crops) has been estimated at 0.2 hp/ha in the Middle East region (AOAD, 1987). This number remains low when compared to the 0.5 hp/ha needed for effective agricultural development and several of the basic agricultural operations are acceptably mechanized. This included tillage and seedbed preparation, planting and fertilizer application, spraying and crop protection, and irrigation. The size of operations, however, ranges from low power input per hectare in the terraced agricultural production sytems in Syria, Lebanon, Turkey, Yemen and Algeria, and greenhouse cultures in Lebanon, Jordan, Turkey, Kuwait and United Arab Emirates, to a more intensive and higher power input in the wheat fields of Syria, Iraq, Iran, Saudi Arabia, Turkey, Egypt and Sudan and the cotton fields of Syria, Egypt and Sudan. Both Turkey and Algeria have developed elaborate machinery manufacturing facilities that cover their domestic requirements in addition to export (**Table 3**). Iran is currently producing 600 harvesters annually. Several specific operations are highly deficient in mechanization in the region. Examples of those operations comprise fruit and vegerable mechanization, livestock production and its harvest and post-harvest handling, forestry and timber production, and fisheries and aquatic production.

Constraints to Effective Mechanization

The lethargy of the world economy and its pervasive negative effects on global demand and policies toward trade and international cooperation continues to play an extremely important role in the adoption of technology. In addition, local and regional conditions provide specific grounds for the development of a set of constraints particular to the region. The arrangement of those constraints in terms of their relative weight in the inhibition of technology adoption process, however, varies from one country to the other, as can be expected from the region's wide disparity in resources, production systems and public stances. Those constraints have as such been classified as primary and secondary. Primary constraints include: i) land, ii) capital and iii) adaptive technology. Secondary constraints include: i) field and/or production system suitable for mechanization, ii) product price structure and production incentive; iii) servicing, spare parts supply, operators and mechanics; iv) research, testing and data; v) training and extension; vi) import system, assembly and manufacture; and vii) adequate societal facilities and public infrastructure.

Primary Constraints

Land — When arable land is available, several problems are usually associated with it that tend to limit the application of machinery systems, and present one of the most important barriers to efficient and economical operations. Some of those problems include land fragmentation due to physical causes such as terraces and tenure. The latter is a direct result of the lack of an effective land consolidation policy as well as other factors such as laws of inheritance. Non-contiguous farm holdings have reduced the capability of each individual farmer to financially sustain a feasible machinery system, increased the off-farm travelling time and distance between the small scattered plots and decreased farm machinery efficiency and capacity. This is particularly true to Jordan and Tunisia, and extremely serious in Lebanon, Afghanistan, Sudan and Egypt, where in the latter, for example, 7% of the cultivated land is between 20 and 40 hectares while 15% is between 0.2 and 2 ha only (Henderson,1978). Other land problems are: land topography mainly from a grading point of view, and shape, especially in terms of lack of defined bounderies, and general squareness for easier machine maneuverability. Small farming units are as much of a reality as the desire and need for development and improvement of mechanization. Although ultimately consolidation may contribute to the solution in some countries, in many instances it is necessary to deal with the existing situations (Downing,1975).

Capital — The economic nature of the region presents very diverse situations ranging from the super-rich to the super-poor. Overall, the safest assumption is that each country's total economic activity and thrust is under the firm direction of the government and the methods used to accomplish this vary significantly from country to country. Economic developments are extremely dynamic and the most recent striking one occured in oil exporting countries, which faced a precipitous fall in export earnings from oil caused by a collapse in international fuel prices. Nearly all oil-exporting countries experienced a marked fall in GDP during the last decade. With export earnings falling 19% annually, oil exporters resorted to stringent trade adjustment measure. After a buoyant growth during the 1970s, merchandise imports declined nearly 2% annually in value terms during 1980-85. In non-oil exporting countries, the economic situation was also largely linked to developments in the oil market. While lower fuel bills provided financial relief and economic stimulus, an important source of gain for labor-surplus countries (remittances from expatriates) was drastically cut. Furthermore, financial flows from abroad, in particular new loans from regional bilateral/multilateral financing agencies, became rarer, and several countries raced increasing problems of liquidity and indebtedness. Unfavorable price relationships have been the basis of an erosion in the import capacity of a majority of agricultural machinery exporters and users. The decline of several local currencies against foreign ones has not only inhibited the purchase of new equipment but has even has restrained the buying of spare parts essential for maintaining the equipment on hand. In Lebanese local currency, for example, the amount paid for a 45-kW tractor in 1984 would only buy its 12-volt battery in 1989.

Adaptive technology — Most of the countries of the middle East region are faced with a challenge comprised of the compelling need to accelerate economic growth by overcoming the greatly inhibiting cultural,institutional and political barriers. To translate that challenge into a series of concrete steps, however, is the task of administrators and planners who should be intimately aquainted with the specific conditions that govern the production system and are capable of professionally recommending the appropriate adaptive technologies that perfectly answer to those conditions.

Most of the countries of the region launched pilot production projects to illustrate sophisticated models of high technology operations to the farmers in their neighbourhoods. Almost all of those projects failed unfortunately and were either terminated or maintained as ideal islands because of their non-adaptive nature. Primary reasons for this failure are embedded in the fact that technology are copied exactly from their source without any awareness of the new setting in which the technology has to be applied. In addition, many of those projects depend on the consultancy and advice of experts foreign to the local conditions and lack both the incentive and the competence to identify the possibilities of upgrading the technology in certain sectors of the country and who have a short term commitment to the project. While in the country, those experts spend most of their time ordering machinery without establishing a trained local follow-up system. It is a very commom consequence to see in most countries that have those projects with new machines that remain boxed in their original packages until obsolescence or assembled and left for the dust because no one knows how to use them(Clawson et al., 1971).

It is worth while mentioning here that several of those projects are also the victims of the complex socio-political process which makes of them an essential attribute to the process propaganda and an inherent credit of its self-pride. The projects are effectively initiated with luxuriously inflated budgets and exuberant hardware, especially machinery that are neither adaptive nor absolutely necessary for the project operation but that serves its political demonstrative objective. Minimal hardware maintenance resulting from the usual drop in the project drive over time have frequently led to the discard of the hardware. Unluckily the failure of the project is usually correlated to that of the hardware instead of the other reasons and which, consequently, minimizes the chances of local technology adoption. Examples of this include the potato harvesting project in PDYR (Haffar, 1985) and the Niaamah-Kenaf Project in Sudan(Ahmed, 1989).

Several of the machines now available on the markets of the Middle East nations show inadaptability to the operational circumstances and incompetency in the field. The selection and recommendation of agricultural machinery should as such be made based on the local demand rather than the imported technology even if this technology has been proved successful in other regions of the world.

Secondary Constraints

Lack of integrated production system — A number of machines are inefficiently and unfeasibly operated in several countries because the production system of a specific enterprise is not totally fit for mechanization in an integrated form. Typical examples are the date-palm farms in Iraq and the United Arab Emirates (Brown et al, 1983) and the citrus farms in Turkey, Iraq and Lebanon. Orchard mechanization in those areas fails because neither are those orchard established in a manner that allows their mechanization, nor are the post-harvest handling and marketing operations complementary to the remaining operations. A competent mechanized production system is that where all of its competents are integrated and preset for mechanical operations. Those should encompass the socio-economic in addition to the operational components.

Product price structure — Increased production specialization resulting from mechanization and the consequent undue economic risk dictates that farmers have a predictable and stabilized product price structure that assists them in operational forecasting and planning.

Most of the agricultural products in many nations of the region are usually subject to both inter-and intra-competition from similar imported goods, and to a lack of price forecasting at both local and regional levels. This has generally led to the loss of production incentive or to trends in the farming practices that tend to maintain traditional cultivation methods by diversifying the numbers and crops planted on a farm. Those trends serve as a financial cushion for the farms in case a market was not secured for a special crop. However, they eliminate the opportunity for a farmer to establish a specialized crop mechanization system. That results in either the inadequacy in the application of mechanization technology or the encumbrance of a very high overhead cost of the mechanical system by the farmers. Shortcomings in the attempts to mechanize olive harvesting in Syria and Tunisia, for example, focus mainly on the issue of a stabilized price structure.

Servicing, spare-parts, operators and mechanics — There is a general inadequacy in the available spare parts in the region and a concurrent difficulty in attaining them from the their source. The reliability index of tractors is less than 50% in many countries. This has been a direct consequence of the unprofessional operational and maintenance practices. Lack of knowledgeable and skilled mechanics have often magnified the problem. Several countries have effectively established centers for training operators and mechanics (AOAD, 1986).

Research, testing and data — Statistical records pertaining to gereral machinery operational and management data are deficient in most of the countries of the region. Information belonging to numbers, types, uses and applications of machinery is very rare and depends on either non-professional estimates by commercial dealers or subjective evaluation by goverment institutions. This has usually led to hindering the capacity to plan and forecast future needs and strategies, leading to a chaotic application of the technology. Research into the adaptability of machine systems to local conditions and its evaluation and feasibility assessment is very rare. As a result, little is on system durability, performance and possible applicability under local conditions (Datt and Ojha, 1988).

Training and extension — Transfer of information and technology communication to the different involved sectors in agriculture is almost null and the obstacles to an effective extension are enormous. Most of the extension services have inadequate training and financing, weak communication skills, poor motivation, and defective administrative structures and support services (Chaudry and Ryan, 1984).

Import system, assembly and manufacture — Weak international communication, improper specification matching and recommendation, slow reply and forwarding, and complicated customs procedures have all made the process of acquiring machinery systems (especially spare parts) a very intricate one. In addition, expensive spare parts costs resulting primarily from high labor wages in the manufacturing countries have greatly prohibited the adoption of sophisticated systems. Several countries in the region have now plans for local manufacturing and assembly of machine components in an effort to solve those problems.

Adequate infrastructure — Among the prohibitive cotributors to the adoption of mechanization technology is the lack of infrastructure. Its deficiency leads to slower and inefficient utilization of service facilities, delays the prompt handling of farm products, reduces technology transfer, and increases the prospects that drive rural away from their farms.

Potentials to Technology Adoption

While mechanization would accomplish relatively little unless accompanied by better practices and other components of a technologically advanced agriculture, conversely, most if not all of these components call for mechanization to be effective (Clawson et al., 1971). Consequently, there exist great potentials for enhancing the application of agricultural mechanization technology in the Middle East region and almost all countries are convinced by its general framework. Those potentials emerge from the advantages embedded in the application of appropriate mechanization technology and of which two are of specific regional relevance: i) intensified utilization of available agricultural resources; and ii) proper manipulation of excessive labor mobility.

Intensified utilization of agricultural resources is achieved by: i) larger utilized lands because of the availability of more output power thus expanding the production area and carrying out all those operations demanding excessive energy inputs far beyond those limited to either man or animal power (deep tillage, for example); ii) higher yields due to uniformity and precision of operations, multiple cropping, handling optimization and losses minimization, and larger utilized resources, especially irrigation water; and iii) higher production efficiency due to timely operations that minimize the cost of timeliness.

Agricultural mechanization in the Middle East has given the opportunity to eliminate the stoop labor-labor intensive type of farm work generally executed under very difficult and severe geoclimatic conditions. Yet the major interest arises from the proper manipulation of labor mobility which is far more complex since it is both a local and regional issue. At the local level, agricultural mechanization provides the promising and ultimate alternative for the rural farm labor shortage resulting from urban migration and leading to unaffordable and infeasible labor wages. This migration has long depleted the rural areas from its human resources and created a man-power overflow toward the urban ones. This has generally been complemented by a number of potential problems, including social disorder, unemployment, improper human resource balance, and other typical migration consequences.

International labor migration, a common and long standing problem in the region, increased significantly in the early 1970s. Migration, largely from non-oil to oil-exporting countries, intensified by the end of that decade. With the end of the oil boom, however, it reversed abruptly and large scale repatriations have taken place (FAO, 1987c). During the first phase, the economic boom enjoyed by oil-exporting countries brought about a massive increase in their investment programs and associated labor requirements. For neighbouring low-income countries such demand for additional manpower was both a source of badly needed foreign exchange, in the form of remittances and an opportunity for their surplus labor to be absorbed.

In the early 1980s, it was estimated that the expatriate workforce was over 4.5 million in oil-exporting countries of the region, of which 70% were temporary labor(AOAD, 1987). Twenty-three percent of this workforce belonged to either Pakistani or Indian nationalities. Such a growing flow of expatriates ended up assuming major proportions of the local labor force, and in some countries such as United Arab Emirates, Qatar, and Kuwait the proportions were 91%, 70%, and 70%, respectively. Countries like Saudi Arabia and Oman had smaller proportions but that still accounted for more than half the labor force (FAO, 1987c). The phenomenon of labor migrations, and the remittances it created yielded unquestionable economic and social benefits for labor-surplus countries. It improved current account balances, boosted savings and investment in domestic construction, and improved access to foreign technology. However, it had a negative impact on agriculture in some respect as a substantial part of the agricultural labor force of these countries was involved. For instance, it is estimated that farmer migrants from the Yemen Arab Republic totalled 14% of the total agricultural labor force while those from Jordan comprised one-third of the total. Migration caused severe labor shortages in agriculture and in some cases transformed the patterns of production. In addition, labor market distortion was observed since most of the departing laborers are the skilled ones (FAO, 1981).

Almost all farmers secure additional seasonal income using their machines off the farm in both agricultural and other jobs such as water transportation. This increase in income leads to a better community's purchasing power as a whole and provides a catalyst for changing the attitudes and raising the social status and dignity for those who work in this career.

Conclusions and Recommendations

It is recognized that agricultural production — which commands top priority in the Middle East region — is the proper management of the application of inputs. The efficiency of inputs, in turn, is a combination of the availability of power and techniques, and agricultural machines are the most important media for enhancing production through the economic and efficient utilization of resources. Until recently, development strategies in the region have given only a subordinate role to the agricultural sector, and attention is still focused on industrialization. However, owing to the uncertain prospects regarding long-term food supplies, and to the increasing import bill and labor flow, there is now greater official interest in and concern for food problems.

In the absence of an appropriate regional development framework, objectives for agricultural development have been almost entirely focused on the individual interests of these countries. Conflicts in agricultural production and trade policies among Middle Eastern countries have eventually arisen. However, it should be difficult to establish clear and consistent objectives for regional development which take into account the priorities and interest of the individual nations.

The impact of agricultural mechanization on development have positively been ascertained. Efforts are currently being exhausted to steadily and progressively gear up its role to achieve the potential levels of production and their feasible and profitable exploitation. The application of mechanization technology can be enhanced by :

1. Goverment support to farmers, especially in terms of financial and technical assistance;

2. Establishment of service, training, testing, research and extension centers;

3. Establishment of spare parts depot and adaptive small-scale machinery manufacturing facilities. This is a three-fold asset: i) it reduces farm labor displacement by producing machines that tend to maintain the same number of manpower (usually unskilled) while increasing their production efficiency; ii) it develops local industries that help preserve the national currency, increase job opportunity and reduces unemployment; and increases efficiency of machines by making readily available the repairs and spare parts needed, and stabilized the prices at affordable costs; iii) it provides a custom-made technology that perfectly fits the local requirements;

4. Forecasting and analysis of market demand and product price structure; and

5. Establishment of rental stations, cooperatives and adequate societal facilities and infrastructures.

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Estimation of Higher Heating Value of Biomass in Tropical Regions

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Abstract

The objective of this study was to develop correlation models relating to anhydrous high heating value to some proximate compositions (ash and volatile matter) of biomass and densified bio-fuel. Biomass is categorized into 3 groups: 1) agricultural residue, 2) weeds, and 3) wood. The value of tropical biomass presented in the study shows its energy potential to be used as substitution of fossil fuel. The regression models developed for the biomass and densified bio-fuel are fairly adequate for estimating their heating values and can be used for the preliminary study of the heat production system.

Introduction

In tropical developing countries, bio-energy consumption residues in rural areas are in the form of heat for domestic purposes, cottage industry, and some agro-industry such as rice mills, tobacco ageing plants, rubber ageing plants and so on. Biomass, which is in attention for the purposes, is easily found from agricultural waste, weeds, forest residue, and fast grown wood. It is normally used as solid fuel for heat energy, especially by combustion and other thermochemical conversion, both in original form and in densified form. This biomass can be raw material for thermochemical conversion because species, size, and their nature and not major importance in this process (Hillis, 1985). However, the heating production systems are still developed for higher efficient use of biomass and for more practical and economical systems.

Properties of biomass entering the systems are important factor in determining the system design. Among the properties heating value is an outstanding one. The purpose of this work is to develop correlation models relating high heating value to some proximate composition (ash and volatile matter) of biomass and densified bio-fuel. The use of the correlation models should be restricted to primary design calculations and should not be substituted for detailed analysis of potential fuels (Jenkins and Ebeling, 1985).

Methodology

The higher heating value, and proximate composition of 39 kinds of biomass and 27 kinds of densified bio-fuel were measured in research and development laboratory of the National Energy Agency, Thailand, using the ASTM standard methods for coal and coke since there is still no standard method for biomass. These measured values are listed in **Table 1** where 39 kinds of biomass were classified into three groups: 1) agricultural residue 2) weed and, 3) wood and one group of densified bio-fuel. The correlation models related higher heating value to ash content and volatile matter were developed from the proximate analysis.

Proximate Analysis

The ASTM standard method for proximate analysis of coal and coke, D 3172-73 (ASTM, 1977) was used to measure moisture, fixed carbon (by difference) in the biomass samples. The relative amounts of ash, volatile matter and fixed carbon in biomass fuel samples are presented as percentage on wet basis (wb). These

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Table 1 Proximate Composition, and Higher Heating Value of Biomass and Densified Bio-fuel

Agricultural residue	%MC (wb)	%ash cont.	%vol mat.	%fix. C	HHV, db MJ/kg
Sorghum stover	4.31	8.63	68.84	18.22	17.71
Corn stover	4.35	8.35	68.35	18.95	17.31
Rice straw	2.68	11.24	65.64	20.44	15.06
Corn cob	7.28	2.48	70.31	19.93	18.67
Coconut fiber	7.05	3.49	58.64	30.82	17.49
Sugarcane bagasse	13.83	2.61	64.73	18.83	19.29
Oil palm husk (Elacis quineensis)	28.78	2.52	53.79	14.91	26.8
Leucaena leucocephala (Lamk.) De Wit	3.36	7.64	71.31	17.69	19.14
Lontar palm, Whole three (*Borassus flabelifer* Linn.)	12.44	2.45	65.25	19.86	20.51
Physic nut husk (*Jatropha curcas*)	.89	16.99	63.74	18.38	13.93
Rice husk	5.34	16.42	59.23	19.01	14.91
Coconut shell	11.5	3.67	64.34	20.49	19.07
Lontar palm cotalydon	14.33	16.2	62.1	7.37	20.33
Weed	**%MC (wb)**	**%ash cont.**	**%vol mat.**	**%fix. C**	**HHV db MJ/kg**
Eichornia crassipes Solms.	6.47	10.08	67.75	15.7	15.62
Gossypium herbaceum Linn.	9.33	4.77	67.95	17.95	18.66
Pennisetum polystachyuo Schult.	5.91	8.04	66.97	19.08	17.52
Euphorbia heterophylla Linn.	2.63	16.89	65.25	15.23	14.32
Biophytum sensitivum DC.	8.03	6.3	66.02	19.65	18.53
Artoearpus altissimus J.J. Smith	7.93	5.33	67.74	19.0	18.86
Psilotrichum ferrugineum	8.57	9.88	65.23	16.32	19.86
Imperata cylindrica Beauv.	5.75	6.53	65.3	22.42	16.75
Euphorbia tirucalli Linn.	7.47	14.96	63.94	13.63	12.41
Thevetia peruviana Schum.	7.62	8.11	67.68	16.59	16.71
Plumeria alba Linn.	7.4	8.63	68.17	15.8	17.27
Wood	**%MC (wb)**	**%ash cont.**	**%vol. mat.**	**%fix. C**	**HHV, db MJ/kg**
Hevea brasiliensis Muell.-Arg.	3.94	4.54	18.46	73.06	30.2
Deciduous forest woods	4.65	10.7	19.09	65.56	28.75
Avicenia	3.72	2.33	34.13	59.82	27.22
Chankraboon (Thai name)	3.32	3.81	23.81	69.06	29.81
Rhizophora	2.4	4.44	20.29	72.87	30.96
Hopea (Iron wood)	3.24	2.17	25.06	69.53	29.53
Afzelia xylocarpa (Kurz) Brib	8.66	4.77	6.16	80.41	30.02
Xylia xylocarpa (Roxb.) Taub. var. kerrii (Craib & Hutch.)	3.21	3.64	27.03	66.12	28.33
Eucaliptus globulus Labill.	7.13	4.41	67.44	21.02	20.56
Peltophorum pterocarpum (DC.) Back. ex Heyne	7.92	2.46	69.95	19.67	18.48
Pithecellobium dulce	7.29	2.42	63.86	26.43	21.31
Luecaena leucocephala (Lamk.) De Wit	18.31	3.15	61.63	16.91	21.31
Acacia curiculaeformis Cunn.	10.85	1.11	69.06	18.98	16.77
Casurina junghuhniana Miq.	4.6	6.55	69.55	19.3	20.01
Acacia catechu (Linn.f.) Willd	4.37	2.12	25.64	67.87	29.43
Artemisia vulgaris Linn. + horse manure	17.96	13.14	50.14	18.76	19.08
Eupatorium adenophorum Spreng. + horse manure	9.67	17.06	64.65	8.62	19.52
Horse manure + saw dust	6.7	38.28	47.89	7.13	12.87
Casuarina junghuhniana Miq. (leaf) + horse manure	9.11	15.41	53.54	21.94	16.62
Pennisetum polysanchyon Schult. + *Leucaena leucocephala* (Lamk.) De Wit	4.34	6.35	69.48	19.83	18.99
Typha angustifolia Linn. + *Leucaena leucocephala* (lamk.) De Wit	5.13	3.87	69.47	21.53	18.86
Scirpus grossus Linn. f. + *Leucaena leucocephala* (Lamk.) De Wit	5.04	5.98	68.84	20.14	19.23
Azima sarmentosa Benth. & Hook. f. + *Leucaena leucocephala* (Lamk.) De Wit	4.78	9.09	68.06	18.07	17.69
Eichornia craassipes Solm. + *Leucaena leucocephala* (Lamk.) De Wit	5.02	12.09	62.24	20.65	18.56
Eupatorium stoechadosmus Hance + *Leucaena leucocephala* (Lamk.) De Wit	5.34	6.05	68.4	20.21	18.7
Jatrapha gossypifolia Linn. + *Leucaena leucocephala* (Lamk.) De Wit	4.87	7.79	69.38	17.96	17.78
Rice husk briquette	6.17	17.95	57.36	18.52	16.62
Saw dust (compressed lump)	6.12	4.64	66.7	22.54	17.71
Sugarcane bagasse + mollase	8.42	9.34	62.17	20.07	16.11
Sugarcane bagasse + solid waste from alcoholic production	3.55	6.0	66.82	23.63	20.86
Rice husk + mollase	6.65	19.51	59.78	14.06	14.29
Rice husk + solid waste from alcoholic production	2.88	28.31	52.68	16.13	14.57
Corn cob + mollase	5.61	9.15	66.89	18.35	16.85
Corn cob + solid waste from alcoholic production	4.81	8.71	67.23	19.25	19.2
Dry sugarcane bagasse briquette	6.18	19.4	35.17	39.25	22.27
Wet sugarcane bagasse briquette	56.95	16.94	20.68	5.43	30.08
Charcoal dust + sugarcane bagasse	5.82	6.42	39.17	48.59	25.79
Fermented sugarcane bagasse 100%	6.89	7.38	62.93	22.8	18.54
Sugarcane bagasse + lignite (4:1)	7.41	33.18	40.18	19.23	16.74
Rice husk + lignite (4:1)	12.15	39.78	30.46	17.61	16.2
Rice husk + lignite (6:5)	.48	43.43	35.82	20.27	13.62
Sugarcane bag. + charcoal dust (1:2)	4.45	7.29	27.99	60.27	27.36

values indicate the percentage of fuel burnt in gas and solid state. Assuming that volatile constituents are burnt in the flame, fixed carbon is burnt on the furnace grate and ash is left back. The moisture content of samples measured is presented also in wet basis. In heat production systems, moisture of fuel reduces the heat available from conversion process in two ways (Lyons et al, 1985). Firstly, the initial higher heating value is lowered by the presence of water, which does not contribute to heating value. Secondly, the conversion efficiency is reduced due to heat required for evaporation of this water in the first state of conversion process and flame temperature is lowered.

Higher Heating Value

The higher heating value measured is heat produced by combustion of a biomass sample, at constant volume, in an oxygen bomb calorimeter using ASTM standard method for gross calorific value of solid fuel by the adiabatic bomb calorimeter, D 2015-66 (ASTM, 1977). The higher heating value measured (HHVm, MJ/kg) is the total energy in a unit weight of biomass which included heat of condensation released from water vapour of the combustion products. The values were converted into anhydrous higher heating value (HHV, MJ/kg), total energy of dry matter content of biomass, when dry matter content is (100-mc)/100 where mc is the decimal moisture content (wb) of biomass. The anhydrous higher heating value of dry biomass is

$$HHV = HHVm/(1\text{-}mc)$$

It is very seldom that the energy released by condensation is recovered in practical biomass combustion system (Ebeling and Jenkins, 1985). Therefore, the lower heating value (LHV, MJ/kg) can be calculated by subtracting the latent energy of vaporization of water from anhydrous higher heating value.

LHV = (1-mc) − (λ) (mc) − (1-mc) (λ) (18H/200)

where H is hydrogen concentration in biomass (%db), λ is the latent heat of water evaporization (MJ/kg water), λ (mc) is the latent heat of moist biomass, and (1-mc) λ (18h/200) is the energy loss due to the formation of water from biomass hydrogen.

Regression Model

To get the best-fitting straight line which relates the behaviour of dependent variable, anhydrous higher heating value (HHV), to a linear function of one or set of independent variables, ash content (Ash, %wb) and/or volatile matter (Vol, %wb), the regression equations are formed:

1) HHV = K1 + K2 (Ash)
2) HHV = K1 + K2 (Vol)
3) HHV = K1 + K2 (Ash) + K3 (Vol)

where K1 is a constant or interception of the straight line equation, and K2 and K3 are coefficient(s) of independent variables.

The PROC GLM command of the SAS programme which performs an analysis of general linear model, estimates a constant term and a coefficient term for each independent variable and also tests the hypothesis whether the dependent variable (HHV) depends on two or more independent variables (Ash and Vol). The best regression equation giving the smallest sum of squares of error and highest correlation value (R-square) is consequently selected.

Results

Ranges of proximate composition and anhydrous heating value of 4 catagories of biomass and densified bio-fuels are shown in **Table 2**.

Moisture content in biomass and densified bio-fuel are not intrinsic characteristic. It is changed by environmental conditions and handling methods. Biomass ash content is low (6.69% as average), especially wood and some kind of agricultural waste, while volatile matter and fixed carbon content are high (55.63%, and 30.33% as average, respectively).

Anhydrous higher heating value is noticeably high for > 50% fixed carbon content wood, 27-30 MJkg, and the average value for others (< 50% fixed carbon content) is 19.7 MJ/kg, while the average anhydrous higher heating values of diesel oil and general purpose coals are 46 MJ/kg at 15°C and 32.8-34.4 MJ/kg, respectively (Rose and Cooper, 1977). This supports the potential of biomass to be a renewable energy resource substituting fossil fuel. The densified bio-fuel has high ash content when rice busk and/or lignite are constituents, consequently low in heating value. Sugarcane bagasse densified bio-fuel gave a promising high heating value, and the weeds gave fairly good values.

Table 3 lists the regression models developed for biomass and densified bio-fuel. although, the models for agricultural waste and weeds inadequately predict their

Table 2 Ranges of Proximate Composition and Anhydrous Heating Value of Biomass Fuel

Biomass	Low value	High value
Agricultural waste		
% MC (wb)	.89	28.78
% Ash cont. (wb)	2.45	16.99
% Vol. cont. (wb)	53.79	71.31
% Fixed C (wb)	7.37	30.82
HHV (MJ/kg)	13.93	26.8
Weed		
% MC (wb)	2.63	9.33
% Ash cont. (wb)	4.77	16.89
% Vol. cont. (wb)	63.94	68.17
% Fixed C (wb)	13.63	22.42
HHV (MJ/kg)	12.41	19.86
Wood		
% MC (wb)	2.4	18.31
% Ash cont. (wb)	1.11	10.7
% Vol. cont. (wb)	6.16	69.95
% Fixed C (wb)	16.91	80.41
HHV (MJ/kg)	16.77	30.96
Densified bio-fuel		
% MC (wb)	.48	56.95
% Ash cont. (wb)	3.87	43.43
% Vol. cont. (wb)	.48	56.95
% Fixed C (wb)	5.43	60.27
HHV (MJ/kg)	1287	30.08

Table 3 Correlation Model Developed for Biomass and Densified Bio-fuel

(a) Models Based on Ash Content

Categories	HHV = K1 + K2 (Ash)			Number of observations
	K1	K2	r**2	
Agricultural waste	21.082	−.329	.33	13
Weed	20.985	−.445	.61	11
Wood	23.416	.537	.06	15
All biomass	24.78	−.601	.26	39
Densified bio-fuel	21.026	−.153	.2	27

(b) Models Based on Volatile Matter Content

Categories	HHV = K1 + K2 (Vol)			Number of observations
	K1	K2	r**2	
Agricultural waste	33.566	−.235	.13	13
Weed	−28.708	.686	.21	11
Wood	33.884	−.209	.94	15
All biomass	34.663	− .25	.8	39
Densified bio-fuel	24.53	−.106	.16	27

(C) Models Based on Ash and Volatile Matter Content

Categories	HHV = K1 + K2 + K3 (Vol)				Number of observations
	K1	K2	K3	r**2	
Agricultural waste	37.542	−.341	−.254	.49	13
Weed	23.57	−.454	−.038	.61	11
Wood	34.152	−.054	−.21	.94	15
All biomass	36.009	−.373	−.229	.89	39
Densified bio-fuel	38.163	−.345	−.258	.85	27

heating values, the model developed for all biomass, which has only volatile matter as independent variable, can be used for estimating their heating value.

HHV = 34.663 – 0.250 (Vol)
r**2 = 0.80 (all biomass)

The model of predicting wood heating value has also high accuracy using only volatile matter as independent parameter.

HHV = 33.884 – 0.209 (Vol)
r**2 = 0.94 (Wood)

The model developed for densified bio-fuel inadequately predict high heating value if only ash content or volatile matter is used as independent parameter, but the accuracy is pretty accepted when both parameters are used.

HHV = 38.163 – 0.345 (Ash) – 0.258 (Vol)
r**2 = 0.85 (Densified bio-fuel)

The comparison of estimated and experimental heating values of all biomass, wood, and densified biofuel are shown in **Figs. 1, 2** and 3, respectively.

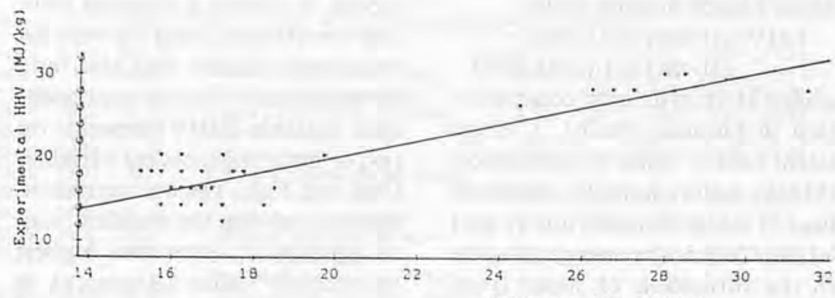

Fig. 1 Comparison of estimated and experimental heating values of biomass.

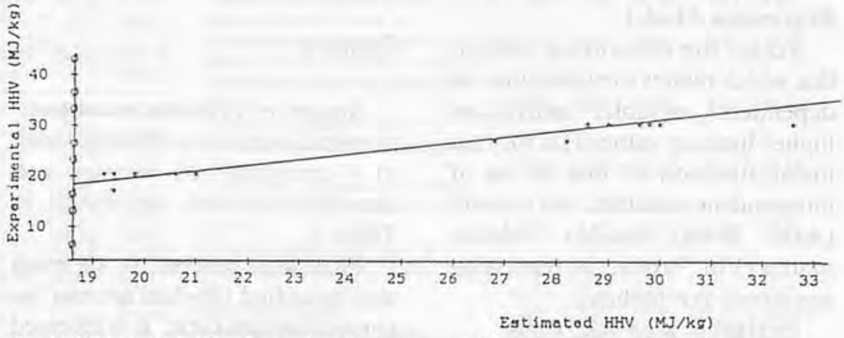

Fig. 2 Comparison of estimated and experimental heating values of wood.

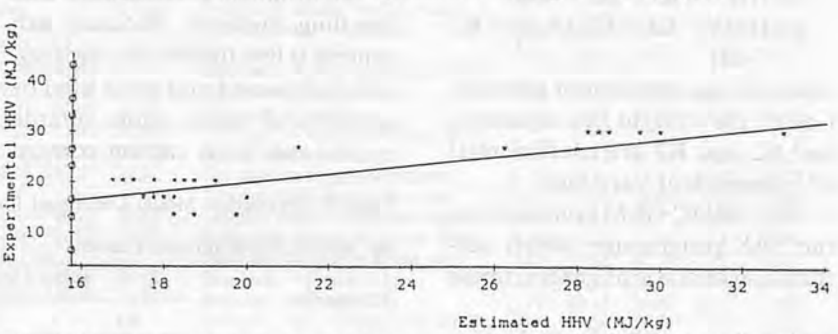

Fig. 3 Comparison of estimated and experimental heating values of densified bio-fuel.

Conclusion

Energy potential of biomass fuel in tropical developing countries is a promising renewable energy resource for substituting fossil fuel. The higher heating value of the fuel can be approximated by ash and volatile matter content from proximate analysis which is not complicated to perform. Predicated value should be used for preliminary thermal-conversion system design but not for the detailed one.

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11th India International Trade Fair

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All aspects of industry, trade, science and technology will be on display at this Fair. In addition, there will be special display on following sectors of industry.

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AGENG 92 International Conference on Agricultural Engineering

June 1-4, 1992
Uppsala, Sweden

It is the fifth AGENG Conference after Cambridge (UK), Noordwijkerhout (NL), Paris (F) and Berlin (D). The Conference is intended to present the latest developments and future directions in agricultural, horticultural and forestry engineering research.

The Conference is organized by the Swedish Institute of Agricultural Engineering and will be held at the Swedish University of Agricultural Sciences in Uppsala during the period of June 1-4, 1992. Uppsala is located close to Stockholm's international airport Arlanda and it is easy to get there by air, train or car.

Call for Papers will be sent at the beginning of 1991 to all national societies and participants of the AG ENG Conference 1990.

The scientific programme will be divided into four parts.

1 Plenary sessions with key note addresses by invited speakers.
2 Parallel lecture sessions
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For information contact:
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International Symposium on Stored Grain Ecosystems

June 7-10, 1992
Winnipeg, Canada

The International Symposium on Stored Grain Ecosystems will be held in Winnipeg, Manitoba, Canada, on June 7-10, 1992. The Department of Agricultural Engineering at the University of Manitoba is organizing the Symposium.

The objective of the Symposium is to assemble internationally recognized experts in all fields of grain storage research to share current knowledge and to explore future needs, from both a research and an application perspective. This objective will be met through a program of invited speakers, who will focus on identified topics in grain storage, and an extensive poster session which will provide a breadth of current topics.

The speakers will discuss topics which will include, but are not limited to, expert systems-based management; biological interactions of grain and insects; computer modelling of heat, moisture, intergranular gas and pest populations; structural loads on storage bins; tansportation of grain; physical and chemical control of insects and mites; health hazards; economics of storage; and sampling techniques. Industrial displays will showcase the latest in equipment for applications ranging from the research laboratory to the field.

For further information contact D.S. Jayas, Associate Professor, Agricultural Engineering, University of Manitoba, Winnipeg, Manitoba, R3T 2N2 [Ph. 204-474-6292, Fax: 204-275-3773].

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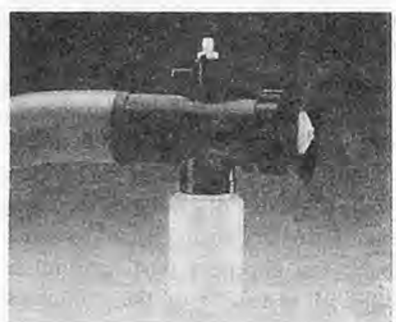

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Please refer to an article stating the formation of Asian Association for Agricultural Engineering that appeared at page 107 of AMA Winter 1991 issue. Readers are advised to use this form for membership application.

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BOOK REVIEW

Australian Tractors
Indigenous Tractors and Self-Propelled Machines in Rural Australia

(Australia)

By Graeme R. Quick

Rural Australia has some of the largest and most labour-efficient farms in the world. A well-equipped wheat farm can produce a tonne of wheat with a labour input of less than one man-hour. Tractors are an essential part of that scene. The average Australian farm has at least two tractors.

Isolation, environmental extremes, shallow soils, a minimum of government assistance, and widely-fluctuating economic circumstances over the years have forced farmers to operate at high levels of efficiency.

Since the earliest days of settlement, the well-being of the rural economy has been dependent on its ability to export. Agricultural commodity exports have been the backbone of the nation's economy.

Australian farmers have always been prepared to adapt technologies to their needs and to participate in the development of suitable machines in order to compete with the rest of the world.

Mechanization has been a cornerstone of production agriculture. The tractor is the modern symbol of farm mechanization.

This book is the story of *Australian* tractor makers and their machines. It is intended to put into perspective such questions as: How extensive was the indigenous tractor industry? How did it get started? Was the industry of any national consequence? Where did horse or steam power fit into broadacre farming? Did Australian tractor makers contribute to world-wide tracctor developments? Where is the industry heading?

The story of the 40 or so makers of tractors and self-propelled agricultural machines detailed here also may evoke fond memories among those who have put in some time "down on the farm."

Size: 28 × 22 cm, pp.167, soft-cover. Price A$24.00/US$20.00

Principal distributors

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North America:

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Studies on Farm Mechanization for Direct Seeding Culture in the Muda Area, Malaysia
MADA/TARC Cooperative Study (Dec. 1988 – Dec. 1990)

(Malaysia)

by Yutaka Kanetani

This report presents the results obtained from the collaborative studies on "Farm Mechanization for Direct Seeding Culture in the Muda Area" between Muda Agricultural Development Authority (MADA), Malaysia, and Tropical Agriculture Research Center (TARC), Japan, for two years, from December 1988 to December 1990.

Rice cultivation system in the Muda area has been changing rapidly from transplanting culture to direct seeding culture since the 1980s. With the increase in the planting area of direct seeding culture, many problems have occurred in the recent ten years. As regards to farm mechanization, some technical problems such as tillage, weed control and seeding were pointed out.

In the situation mentioned above, the author was sent to establish the suitable farm mechanization on direct seeding culture in the Muda area.

This study has also been carried out as one of the major collaborative project studies entitled "Improvement of Production Systems under Direct Seeding Culture in the Muda Area" together with four other researchers of TARCX, including an Agronomist, agricultural civil engineer, agricultural economist and a weed scientist.

In order to establish suitable mechanization techniques for direct seeding in paddy rice farming, agricultural machinery studies and field work surveys were carried out.

The following topical subjects are also described in this report:

1. Efficient surface water drainage techniques using an auger trencher with the objective of improving establishment of seedling in wet seeding culture
2. New drill seeding technique using a power tiller pull-type Prototype seeder for wet seeding culture
3. Drill seeding (Row seeding) using a Rotary drill seeder with up-cut rotary tiller aimed at improving soil pulverizing and establishment of seedling in dry seeding culture
4. Weeding method in direct seeding culture by means of Prototype 6-row weeder equipped with engine
5. Paddy rice drying methods by means of Prototype dryer with the objective of improving rice quality in post-harvest.

Size: 26.5 × 19 cm, pp.101, soft cover

Published by Tropical Agriculture Research Center, Japan (TARC)

Muda Agricultural Development Authority, Malaysia (MADA).

Proceedings of the International Agricultural Engineering Conference and Exhibition Bangkok, Thailand, December 3-6, 1990

(Thailand)

Edited by V.M. Salokhe and S.G. Ilangantileke

The International Agricultural Engineering Conference and Exhibition was organized by the Division of Agricultural and Food Engineering of the Asian Institute of Technology, Bangkok, Thailand from December 3-6, 1990. The primary objective of this International Conference was to bring together scientists, engineers, researchers and experts in agricultural engineering for formal presentation and discussion on topics of relevance in the coming years and towards the 21st century.

The proceedings of this conference contain one hundred and sixty seven technical papers contributed by scientists from over twenty five countries. The proceedings contain a total of 1497 pages divided into four different volumes as below.

Vol. I: Farm Power and Machinery
Vol. II: Post Harvest Technology and Biotechnology
Vol. III: Soil and Water Engineering
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The proceedings are now available for sale. The cost of one set of proceedings (4 volumes) is US$110 (inclusive of mailing charges). Please order your set with payment by Cheque or Bank Draft in favour of "Asian Institute of Technology" and mail it to:

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Biomass Handbook

(U.S.A.)

by O. Kitani and C.W. Hall

Excessive consumption of various energies in modern life have created global environmental problems. Modern sciences and technologies must overcome such problems and develop environmentally sustainable systems for energeis and productions. As one of sustainable energies, the use of biomass has been studied for more than 15 years. Biomass is primarily produced by plant photosynthesis and, therefore, mainly deposited as organic substances of plant in forests, pastures, and cultivated lands. The total amount of biomass in the earth is surprisintly large and the energy accumulated in biomass is far more than that of ultimate petroleum deposit in the earth. As biomass is produced by carbondixide and water, there is no net increase in carbondixide in the air even after it is burned. In addition, it is a renewable resource.

Biomass Handbook presents current progress in all biomass studies.

The first chapter deals with fundamental studies on photoshythesis, nitrogen and carbon cycles, and solar energy. Also biomass products such as algae and trees are included in the first chapter. Particularly, the discussion on the fast-growing tree plantation is interesting as the technology can be adopted for the absorption of carbondioxide in the earth.

The second chapter describes biological, mechanical, and chemical conversions of biomass. Some of the processes are economically promising for the development of biomass industries.

The third chapter illustrates the utilization of biomass for food, feed, and fuel. Also, environmental protection, energy efficiency, and economic feasibility are discussed in this chapter.

Newly emerging technologies are examined in the fourth chapter. Protoplast fussion, gene manipulation to acquire resistances to environmental stresses, bioreactor, artificial photosynthesis, and bioelectric cell are mentioned as potential candidates for future technological development of biomass utilization.

Statistics of various biomass resources, and also chemical and physical properties of these resources are presented in the last chapter of the book. These statistics and properties will be valuable information for industries and research organizations to assess the potentiality of biomass.

Some over hundred experts participated in writing various parts of the Biomass Handbook. The Handbook is comprehensive and covers all the fields of biomass utilization. It is a good reference for biomass researchers to review current progress of biomass utilization. Also, this is a good reference book for graduate students who wish to initiate their research in an area of biomass, as they can obtain a full knowledge of biomass research at present.

Size: 29 × 22 cm, pp.1024, hardcover.

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