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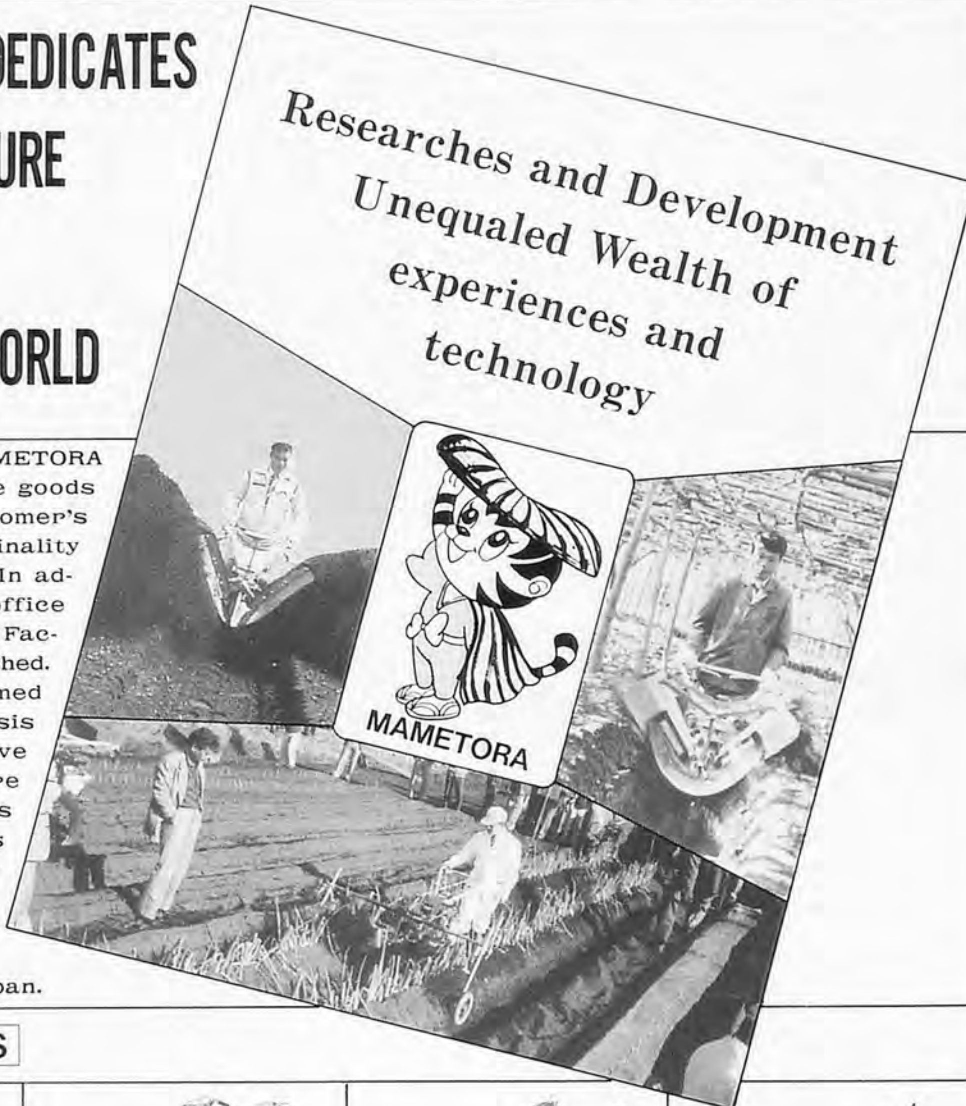

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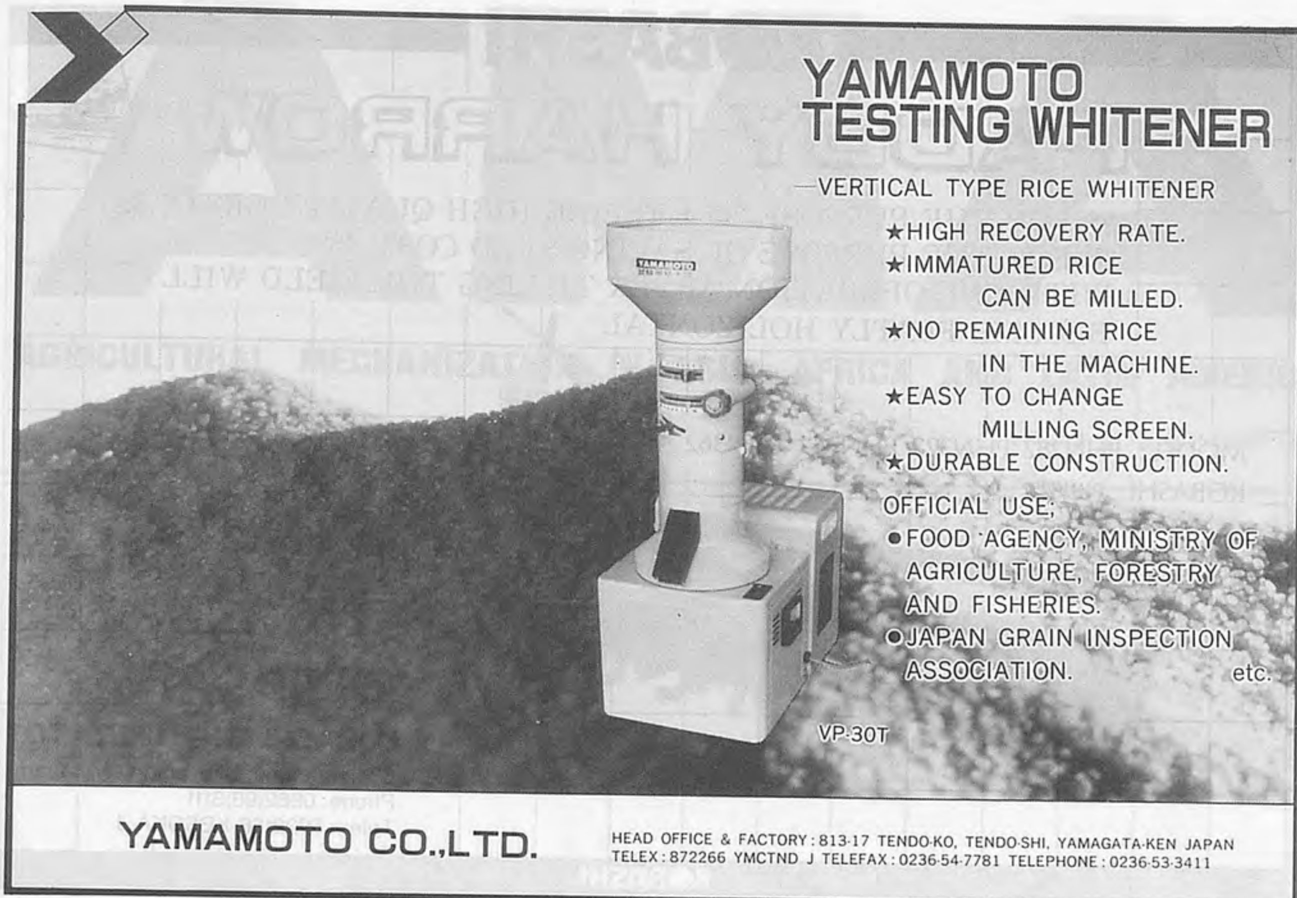
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EDITORIAL

Development vis-à-vis Environmental Protection

Last month's Earth Summit in Rio de Janeiro, Brazil, (officially a United Nations Conference on Environment and Development) was attended by representatives from 120 countries and scores of private entities and businesses. The summit conference, billed as the greatest scale conference in this century, codified regulations on: i) global warming (how to curve emissions of carbon dioxide); ii) Agenda 21 (how industrial nations could help poor nations develop their economies without sacrificing their environments); and iii) biodiversity (how to slow down the loss of endangered species).

In brief, the Rio Declaration drove home the point that: "There can be no economic development without environmental responsibility." To put it bluntly, the issues challenge world leaders and policy-makers to reconcile the dichotomy that: "The global poor go to bed hungry while the excesses of the wealthy go up in smoke."

From where the AMA sees it, economic development indeed must go hand in hand with environmental protection. This is because the logic says that the former is not worth achieving at the expense of the latter. This view is premised on the fact that we, who people this planet Earth, want to live in it comfortably and leave it equally comfortable for the generations to come after us.

The Rio Declaration also implies that on a global basis, the solution to the many problems of agriculture in practically every developing country hinges heavily on the solution to the myriad problems of their environments. To briefly elucidate on this concept, both farm labor and land productivity in developing countries are low due to the operation of the law of comparative advantage, i.e., when neither or both labor and land productivities cannot be increased, efforts are then directed towards expanding farmland areas where resources are available such as hillsides, grasslands and mountain slopes. And when this is the case, cultivation soon gradually creeps farther up — felling trees or otherwise clearing the vegetation that protects the soil's surface. The watersheds soon disappear bringing along destructive floods that damage land productivity even more.

Add to this scenario the fact that unscrupulous loggers in many of the developing countries indiscriminately cut timber leaving behind bald mountains and forests — using heavy machineries that destroy agriculture instead of enhancing agricultural productivity like those that the AMA has since been promoting. This scenario falls under Agenda 21 of the Rio Declaration.

Then as now, AMA advocates the use of agricultural machineries in a timely and appropriate manner as a means of raising agricultural productivity levels which is its primordial aim. The secondary aim is to protect the environment. When both aims are accomplished, it becomes obvious that AMA's motive is not too different from the aim of the Rio Declaration — thanks in large measure to our cooperating editors, contributors and readers.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
July, 1992

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Comparative Performance of Disk Harrow and Sat Haree

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Abstract

The experiment evaluated and compared the performance of a trailed tandem disk harrow and mounted *sat haree* in clay loam soil at moisture content of 6.21% on December 6, 1988 at the Latif Experimental Farm, Sind Agriculture University, Tandojam.

The implements were powered by Ford-6610 diesel tractor and tested at second low gear, third low gear and fourth low gear speeds.

Travel reduction increased with the increase in field speed. The travel reduction was greater for disk harrow in all speeds. The field capacity, soil volume disturbed, fuel consumption and drawbar pull were greater for the *sat haree* at all the speeds selected for the study.

Farmers are interested in good seedbed and to plow large area in a short period. It is, therefore, recommended that the *sat haree* be used as primary tillage implement for seedbed preparation.

However, the use of disk harrow for rocky and root-infested soils is recommended because it rolls over the obstacles.

Further detailed studies under different soil types, environments and crops should be conducted to evaluate the performance.

Introduction

The disk harrow ranks close to the moldboard plow in importance as a tillage implement in Pakistan. Heavy duty disk harrows are used for primary tillage for controlling weeds, cutting up and mixing stubble or cover crops in the soil. Lighter units are often used in seedbed preparation subsequent to plowing.

Blades on disk harrows are concave, usually representing the section of hollow spheres. The action of concave disk blades is somewhat similar to the action of a moldboard plow bottom in that the soil is lifted, pulverized, partially inverted and displaced to one side whereas the disk harrow has opposing gangs that move the soil in opposite directions. The disk implement can cut through crop residues, will roll over roots and other obstructions and can be operated in non-scouring soils by using scrapers. The disk provides incomplete coverage of trash which may be either an advantage or a disadvantage depending upon the tillage objectives.

The new implement designed at the Pakistan Agricultural Research Council (PARC) locally named seven *harees* (*sat haree*) consisting of small moldboard plow bottoms bolted to each shank of a heavily built rectangular frame as very prominent and successful implement which replaced the original moldboard plow. It is most commonly used by farmers in Upper Sind. It does a good job of turning over the soil and is effective in retarding weed growth, pulverizes, aerates and loosens the soil, making it more friable and mellow. The *sat haree* is used as a primary tillage implement, consisting of warped surfaces equipped with cutting edges that crumble and invert the soil. This implement gives best residue coverage and superior pulverization under ideal conditions.

A comparative study of tillage implements, disk harrow and *sat haree* was carried out with a view to assessing their performance. The tillage implements performance can adversely be affected by the soil conditions such as soil surface condition, type of soil and moisture available in the soil. The speed of the tractor and skill of the operator also influence the performance of tillage implements. The performance parameters taken into consideration were power requirements, travel reduction, speed of operation, depth of operation, width of operation, field capacity, soil disturbance and fuel consumption.

The objective of this study was to evaluate and recommend an implement that prepares a good seedbed for plant growth. This will also provide a guideline for the farmers in selecting the implement.

Experimental Procedure and Methods

The study was conducted at the Latif Experimental Farm, Sind Agriculture University, Tandojam on December 6, 1988. The variables studied are draft of implements, speed of operation, travel reduction, depth of operation, width of operation, fuel consumption and field efficiency.

All the variables of the implements performance were measured and recorded according to the recommendations of RNAM test code and procedure for farm machinery technical series No. 12, 1983.

The instruments and machines used in the research study were: a Ford-6610 tractor (two-wheel drive), Fiat-480 tractor (two-wheel drive), trailed tandem disk harrow, mounted *sat haree*, stop watch, ranging poles, steel tape (50 m), steel tape (small), soil sampler (core), sample containers, graduated cylinder, half-meter scale, one-meter square farme, physical balance, oven, polythene bags, jericane, dynamometer, camera and pieces of chalk.

Table 1 Specifications of Implements Used

Implement	Width (m)	Specification
Disk harrow	1.83	Trailed type, tandem, 8-disks in each gang, diameter of rear gang disk 60 cm and front gang disk 42 cm. Disk specing 21.5 cm. Vertical clearance 34 cm. Dish of disk of rear gang 7.62 cm and dish of disk of front gang 4.1 cm. Pak made. Fig. 4 shows the disk harrow used in the study.
Sat haree	2.04	7-furrow, mounted, general purpose moldboard, bottom 29 cm, vertical clearance 43 cm, Pak made. Fig. 5 shows the sat haree used in research work.

Machines

The implements used in the research study are described in **Table 1**. All the implements were standard field machines. The implements were powered by a Ford-6610 diesel tractor.

Data Collection

Speed of operation—The speed was calculated from the time required for the tractor and implement to cover the distance of 50 meters between the assumed line connecting two poles on opposite sides AC and BD (**Fig. 1**). The stop-watch was used to record the time of travel of tractor and implement for three gear speeds.

Width and depth of operation—The working width of an implement was measured by using a steel tape. The width was measured from the furrow wall to the total tilled area at three randomly selected places for each test run.

The working depth was measured with a half-meter scale. The depth was measured from the bottom of the furrow to the surface level of the soil at four randomly selected places for each test run. The operation of *sat haree* is shown in **Fig. 6**.

Travel reduction—The RNAM method of determining the travel reduction was followd which is shown in **Fig. 2**. A simple method in determining the amount of travel reduction was used by making a chalk mark on the drive wheel of the tractor and a distance to the tractor travelled in 10 revolutions with no load (A) and with load (B) was measured. The travel reduction was calculated by using the formula:

$$TR\ (\%) = \frac{A - B}{A} \times 100 \quad (1)$$

where,

T_R = Travel reduction, %
A = Distance travelled with no load, m
B = Distance travelled with load, m

Field capacity and soil disturbance—The field capacity was determined by tilling an area of 50 m long and 25 m wide for each speed. The time lost at corners was also recorded. The field capacity of the selected implements was calculated in hectares per hour by using the Hunt's formula (1977):

$$C = \frac{SWE}{10} \quad (2)$$

where,

C = Field capacity, hectares per hour
S = Speed of operation km/h
W = Width of implement, meters

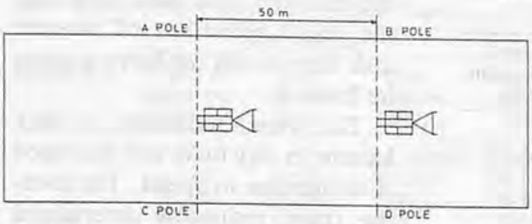

Fig. 1 Measuring operating speed.

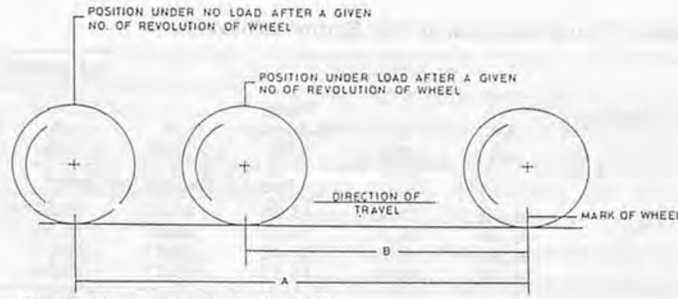

Fig. 2 Measurement of wheel slip.

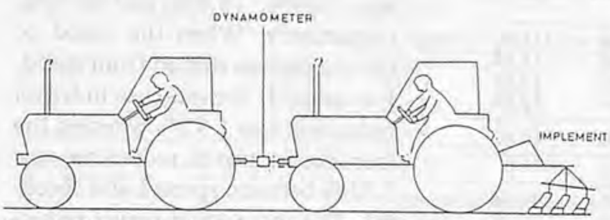

Fig. 3 Measuring of draft for tractor-mounted implement.

E = Field efficiency, decimal

The soil volume disturbed in cubic meters per hour was calculated by multiplying the field capacity with depth of cut and 10000.

$$V = 10000\ CD \quad (3)$$

where,

V = Soil volume disturbed, m^3/h

C = Field capacity, ha/h

D = Depth of cut, m

Fuel consumption and draft measurement—The fuel tank of Ford-6610 tractor was filled to its top level before testing the implements in the test plot of 50 m × 25 m in area. After plowing the test plot, the fuel tank of the tractor was refilled to the same fuel level with 1000 millilitres graduated cylinder. The total quantity of diesel fuel needed to refill the tractor fuel tank to the same mark was recorded and the total time taken to plow the test plot was also recorded. The fuel consumption per hour and per hectare was calculated from the data so obtained. The measurement of fuel consumption is shown in **Fig. 7**.

A hydraulic pull type dynamometer was attached to the front of the tractor on which the implement was mounted. Another auxiliary tractor was used to pull the implement mounted tractor


Fig. 7 Method of measuring fuel consumption.

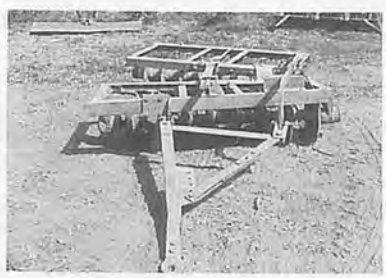
Fig. 4 Trailed tandem disk harrow used in research study.

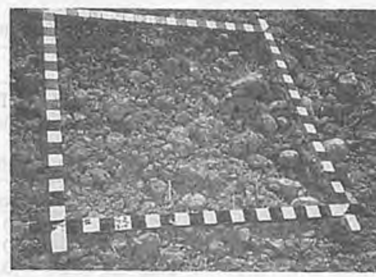
Fig. 8 Land plowed by sat haree at speed-I.


Fig. 5 Mounted sat haree used in research study.


Fig. 9 Land plowed by sat haree at speed-II.


Fig. 6 Sat Haree in operation.


Fig. 10 Land plowed by sat haree at speed-III.

Table 2 Travel Reduction of Disk Harrow and Sat Haree

Replication	Disk Harrow			Sat Haree		
	A* (m)	B* (m)	Travel Reduction (%)	A (m)	B (m)	Travel Reduction (%)
			Speed-I (Second low gear)			
1.	46.00	37.60	18.26	44.82	39.30	13.31
2.	45.80	38.31	16.35	44.09	38.95	11.66
3.	46.35	38.74	16.42	45.25	38.37	15.20
4.	46.41	38.81	16.37	45.27	38.34	15.30
Average	46.05	38.58	16.85%	45.85	38.74	13.61%
			Speed-II (Third low gear)			
1.	44.98	36.00	19.96	45.80	38.45	16.09
2.	45.10	37.20	17.52	46.38	39.40	15.04
3.	45.27	36.83	18.64	45.50	38.85	14.61
4.	44.80	36.30	18.97	45.75	39.34	12.08
Average	45.03	36.58	18.77	45.86	39.00	14.45
			Speed-III (Fourth low gear)			
1.	44.45	35.12	20.98	44.29	36.90	16.68
2.	44.51	35.44	20.37	44.23	37.10	16.12
3.	44.50	35.74	19.68	44.23	36.94	16.48
4.	44.58	35.69	19.94	44.30	37.50	15.34
Average	44.51	35.49	20.24	44.26	37.11	16.15

A* = Distance travelled without load. B* = Distance travelled with load.

Table 3 Field Capacity of Disk Harrow and *Sat Haree*

Replication	Disk Harrow				Sat Haree			
	Field speed (km/h)	Width of operations (m)	Field machine efficiency (%)	Field capacity (ha/h)	Field speed (km/h)	Width of operation (m)	Field efficiency (%)	Field capacity (ha/h)
			Speed-I (Second low gear)					
1.	3.96	1.79		0.567	3.50	2.04		0.633
2.	3.85	1.80		0.554	4.10	2.08		0.742
3.	3.96	1.75	80	0.554	4.02	2.06	87	0.720
4.	3.90	1.76		0.549	4.90	2.03		0.689
Average	3.91	1.77		0.555	3.88	2.05		0.696
			Speed-II (Third low gear)					
1.	4.45	1.85		0.666	4.24	2.15		0.756
2.	4.67	1.88		0.711	4.60	2.10		0.802
3.	4.70	1.83	81	0.697	4.80	2.13	83	0.848
4.	4.50	1.99		0.725	4.50	2.16		0.806
Average	4.58	1.88		0.699	4.53	2.13		0.803
			Speed-III (Fourth low gear)					
1.	5.10	2.05		0.815	5.85	2.14		0.976
2.	5.40	2.04		0.859	5.16	2.17		0.873
3.	5.20	2.03	78	0.823	5.47	2.16	78	0.921
4.	5.35	2.02		0.842	5.50	2.13		0.913
Average	5.26	2.03		0.835	5.49	2.15		0.920

through the dynamometer. The auxiliary tractor pulls the implement mounted tractor with the rear tractor in neutral gear but with the implement in the operating position (Narayanrao and Verma 1982 and RNAM 1983). The draft was recorded in the measured distance of 50 m as well as the time taken to traverse it. On the same field, the implement was lifted from the ground and the rear tractor was pulled to record the idle draft force. The difference gave the draft of the implement. The measurement of the draft is shown in **Fig 3**.

Results and Discussion

Travel Reduction

The travel reduction affected the traction efficiency of the pulling machine. The data regarding the travel reduction of tandem disk harrow and *sat haree* is given in **Table 2**.

The travel reduction of disk harrow in clay loam soil increased with increase in speed. The average travel reduction determined for speed-I, speed-II and speed-III was 16.9%, 18.8% and 20.2%, respectively. When the speed of the tractor was shifted from speed-I to speed-II the increase in travel reduction was 1.92% whereas the increase in travel reduction was 3.35% between speed-I and speed-III. The increase in travel reduction was 1.45% when the tractor speed was switched over from speed-II to speed-III.

The travel reduction increased with the increase in speed of the pulling machine in the case of *sat haree* also. The average travel reductions at speed-I, speed-II and speed-III were 13.6%, 14.5% and 16.2%, respectively. When the speed of the tractor was accelerated from speed-I to speed-II, a slight increase in travel reduction (0.9%) took place. However, the difference in travel reduction between speed-I and speed-III was 2.54% whereas the travel reduction was 1.79% between speed-II and speed-III.

Greater travel reduction was recorded at all speeds while plowing the field with tandem disk harrow.

Field Capacity

The data on field capacity of the disk harrow and *sat haree* show that greater area is tilled as the speed of the disk harrow is accelerated from lower gear to higher gear speed. At second low gear speed (speed-I) the field capacity varied from 0.549 to 0.567 ha/h. The average field capacity was 0.556 ha/h. At third low gear speed (speed-II), the field capacity ranged from 0.666 to 0.725 ha/h. On average, the field

Table 4 Soil Volume Disturbed by Disk Harrow and *Sat Haree*

Replication	Disk Harrow: Depth of operation (m)	Disk Harrow: Field capacity (ha/h)	Disk Harrow: Soil disturbed (m^3/h)	Sat Haree: Depth of operation (m)	Sat Haree: Field capacity (ha/h)	Sat Haree: Soil disturbed (m^3/h)
			Speed-I (Second low gear)			
1.	0.115	0.567	652.05	0.14	0.633	886.2
2.	0.126	0.554	698.04	0.13	0.742	964.6
3.	0.12	0.554	664.8	0.135	0.720	972.0
4.	0.123	0.549	675.27	0.136	0.689	937.04
Average	0.121	0.555	672.54	0.135	0.696	939.96
			Speed-II (Third low gear)			
1.	0.115	0.666	765.9	0.11	0.756	831.6
2.	0.11	0.711	782.1	0.12	0.802	962.4
3.	0.105	0.697	731.85	0.13	0.848	1102.4
4.	0.11	0.725	797.5	0.125	0.806	1007.5
Average	0.11	0.699	769.34	0.123	0.803	975.97
			Speed-III (Fourth low gear)			
1.	0.105	0.815	855.75	0.1	0.976	976.0
2.	0.1	0.859	859.00	0.1	0.873	873.0
3.	0.10	0.823	823	0.105	0.921	967.05
4.	0.10	0.842	842	0.11	0.913	1004.3
Average	0.101	0.835	844.93	0.104	0.920	955.09

Table 5 Fuel Consumption of Disk Harrow and *Sat Haree* (Area of test plot: 50 m × 25 m)

Replication	Disk Harrow: Speed km/h		Width of operations (cm)		Depth of operation (cm)		Fuel consumed ℓ/h	Sat Haree: Speed km/h		Width of operation (cm)		Depth of operation (cm)		Fuel consumed ℓ/h
	Obs*	Mean	Obs*	Mean	Obs*	Mean		Obs*	Mean	Obs*	Mean	Obs*	Mean	
							Speed-I (Second low gear)							
1.	3.96		1.79		11.50			3.50		2.04		14.00		
2.	3.85	3.91	1.80	1.77	12.60	12.10	8.16	4.10	3.88	2.08	205	13.00	13.52	9.25
3.	3.96		1.75		12.00			4.02		2.06		13.50		
4.	3.90		1.76		12.30			3.90		2.03		13.60		
							Speed-II (Third low gear)							
1.	4.45		1.85		11.50			4.24		2.15		11.00		
2.	4.67	4.58	1.88	1.88	11.00	11.00	9.27	4.60	4.53	2.10	213	12.00	12.25	10.42
3.	4.70		1.83		10.50			4.80		2.13		13.00		
4.	4.50		1.99		11.00			4.50		2.16		12.50		
							Speed-III (Fourth low gear)							
1.	5.10		2.05		10.50			5.85		2.14		10.00		
2.	5.40	5.26	2.04	2.03	10.00	9.75	10.22	5.16	5.49	2.17	215	10.00	10.37	11.2
3.	5.20		2.03		9.50			5.47		2.16		10.50		
4.	5.35		2.02		9.50			5.50		2.13		11.00		

* Observations.

capacity at this speed was 0.699 ha/h. The field capacity at fourth low gear speed (speed-III) ranged from 0.815 to 0.859 ha/h. The average field capacity at this speed was 0.835 ha/h. The field efficiencies of disk harrow at speed-I, speed-II and speed-III were 80%, 81% and 78%, respectively.

At second low gear speed (speed-I) the field capacity of the *sat haree* ranged from 0.633. to 0.742 ha/h or an average of 0.696 ha/h. The field capacity at third low gear (speed-II) was recorded from 0.756 to 0.848 ha/h or an average of 0.803 ha/h. At fourth low gear speed (speed-III), the field capacity varied from 0.873 to 0.976 ha/h or an average of 0.92 ha/h. The field efficiency of the *sat haree* at speed-I, speed-II and speed-III was 87%, 83% and 78%, respectively. The land plowed by the *sat haree* in speeds-I, II, and III is shown in **Figs 8, 9** and **10**.

It is concluded that in both cases the field capacity increased by switching the tractor to high gear speed. However, the field machine efficiency at higher speeds descreased because of overlap of tilling operation by the disk harrow and *sat haree* due to carelessness of the operator or lack of skill.

Soil Volume Disturbed

The soil disturbance is the function of field capacity and depth of implement operation. The data regarding the soil volume disturbed by disk harrow and *sat haree* is shown in **Table** 4.

At speed-I (second low gear) the soil distrubance ranged from 652.05 to 698.04 m^3/h or an average of 672.54 m^3/h. At speed-II (third low gear) the soil disturbance varied from 731.85 to 797.5 m^3/h or an average of 769.34 m^3/h. At speed-III (fourth low gear) the soil disturbance was from 740.7 to 859 m^3/h or an average of 813 84 m^3/h.

At second low gear speed (speed-I) the soil volume disturbed by the *sat haree* ranged from 886.2 to 972 m^3/h or an average of 936.96 m^3/h. At third low gear speed (speed-II) the volume disturbed ranged from 831.6 to 1102.4 m^3/h or an average of 975.97 m^3/h. At fourth low gear speed (speed-III) the soil disturbance ranged from 873 to 1004.3 m^3/h or an average of 955.09 m^3/h.

In total, the *sat haree* disturbed more soil than did the disk harrow in all three speeds.

Fuel Consumption

The fuel consumed by disk harrow and *sat haree* for each speed was recorded for an area of 50 m × 25 m (**Table 5**). At speed-I, the fuel consumed by the tractor in disk harrowing was 8.16 ℓ/h; 9.27 ℓ/h at speed-II; and at speed-III the fuel consumed was

Table 6 Draft Requirement of Disk Harrow and *Sat Haree*

Replication	Disk Harrow					Sat Haree				
	Depth of plow (cm)	Width of plow (cm)	Total draft (kN)	Draft per meter of width (kN/m)	Unit draft (N/cm²)	Depth of plow (cm)	Width of plow (cm)	Total draft (kN)	Draft per meter of width (kN/m)	Unit draft (N/m²)
					Speed-I					
1.	11.50	179	9.231	5.157	8.027	14.00	204	11.121	5.451	7.943
2.	12.60	100	9.933	5.518	7.883	13.00	208	10.008	4.811	7.698
3.	12.00	175	8.936	5.106	7.446	13.50	206	10.898	5.290	8.072
4.	12.30	176	8.236	4.679	6.696	13.60	203	10.996	5.417	8.085
Average	12.10	177	9.084	5.115	7.513	13.60	205	10.776	5.242	7.949
					Speed-II					
1.	11.50	185	9.562	5.167	8.315	11.0	215	10.341	4.809	9.400
2.	11.00	188	8.229	4.377	7.481	12.0	210	10.896	5.188	9.080
3.	10.50	183	9.117	4.982	8.683	13.0	213	9.674	4.542	7.441
4.	11.00	199	8.881	4.463	8.074	12.5	216	9.895	4.581	7.916
Average	11.00	188	8.947	4.747	8.138	12.25	213	10.201	4.78	8.459
					Speed-III					
1.	10.50	205	8.001	3.903	7.620	10.0	214	9.452	4.417	9.452
2.	10.00	204	9.452	4.633	9.452	10.0	217	0.119	4.663	10.119
3.	9.00	203	10.784	5.312	11.982	10.5	216	9.579	4.435	9.123
4.	9.50	202	8.001	3.961	8.422	11.0	213	9.858	4.628	8.962
Average	9.75	203	9.059	4.456	9.369	10.37	215	9.752	4.474	9.4

10.22 ℓ/h.

The comparison shows that for the *sat haree*, at speed-I, fuel consumption was 9.25 ℓ/h, 10.42 ℓ/h at speed-II and 11.2 ℓ/h at speed-III.

It is evident that both disk harrow and *sat haree* required more fuel per hour due to accelerated engine speed.

Draft of Implements

Total draft, draft per meter with unit draft of both test implements are given in **Table 6**. The draft was measured at three tractor sppeds (Ford-6610 tractor) in clay loam soil.

At speed-I the draft of disk harrow ranged from 8.24 to 9.93 kN or an average of 9.08 kN. At speed-II the draft ranged from 8.23 to 9.56 kN and averaged 8.95 kN. At speed-III, the draft ranged from 8.00 to 10.78 kN and averaged 9.06 kN. At speed-II the draft was greater than at speed-I. When the speed-I was changed to speed-II, the increase in draft was 1.5%, the increase in draft was 0.27% by changing the speed from speed-II to speed-III. However, the increase in draft at speed-I to speed-III was only 1.25%.

The data at speed-I show that the draft ranged from 10..008 to 11.121 kN and averaged 10.576 kN; at speed-II, it ranged from 9.674 to 10.896 kN and averaged 10.201 kN; and from 10.119 to 10.858 kN or an average of 10.502 kN. For the *sat haree*, the draft was greater at spped-I than at speed-II and speed-III.

It is concluded that the draft of disk harrow and *sat haree* was increased as the speed was increased.

Conclusions and Recommendations

In all three field speeds, the travel reduction of the disk harrow was greater than that of the *sat haree*, but plowed more area than did the former. The machine efficiency and soil volume disturbed was greater for the *sat haree*. However, greater volume of fuel was consumed by the Ford-6610 diesel tractor while operating the *sat haree*. The latter required greater draft than disk harrow.

The findings of the present study suggest that the *sat haree* should be used to replace the disk harrow as it produced more pulverization and clean seedbed. The use of the *sat haree* is also recommended in weed-infested field because it inverts the weeds completely into the soil. The use of the harrow is recommended for soils infested by roots and rocks because it rolls over these obstacles. It is also suggested that detailed research be carried out in different soil conditions, environment and soil moisture levels.

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Efforts to Mechanize Seeding and Planting Operations in Pakistan

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Abstract

Traditionally most of the crops in Pakistan are sown/planted manually by broadcasting, *kera* or *pora* method which results in poor crop stand and low yields in comparison to their potentials. Certain efforts have been made so far for the development of seeding/planting machines in the country in order to overcome the causes of low yields. These efforts include the development of multi-crop seed-cum-fertilizer drill, sugarcane planters and sugarcane set cutter, testing of multi-crop planter and the development of test rig for evaluating the metering units. The current status of these efforts are described in this paper.

Introduction

Pakistan's land area is about 80 million ha of which 20.6 million ha is cultivated. Irrigated area is about 76% of the total cultivated area. Currently, agriculture contributes over 26% to the national income and provides employment to 54% of the total labour force. Three-fourths of the country's exports directly or indirectly are agriculture-based.

Currently, there are 4.0 million Pakistani farmers of which 75% farmland area is less than 5 ha each and account for only 33% of total farmlands. Out of 13 million people employed in agriculture, more than 8 million are farm tenants. The general income level of farm labour is approximately Rs. 5000/year (1).

The use of agricultural machinery has been realized by the farmers in Pakistan during the last two decades due to labour shortage and introduction of high yielding varieties. The population of operational tractors in 1988 was estimated at 189,000. The use of other farm machines such as mould-board plow, disc harrow, rotavator, seeding equipment, etc. is limited to progressive farmers in the cotton/wheat and rice/wheat belts.

The locally manufactured drills are mostly for seeding and are mono-crop (cotton or wheat). These are not properly designed for accurae metering and placing of seeds. **Table 1** shows the seeding and planting equipment manufactured in Pakistan during 1985-88. The imported drills are multi-crop and have provision for fertilizer application. These drills are very precise in metering and placing of seeds and fertilizer but are very expensive. These drills cost up to Rs. 40,000 ($2300) per unit as compared to local seed drills being sold at prices ranging from Rs. 5000 to 10,000 (US $300-600). This paper presents the efforts made to mechanize seeding/planting operations in Pakistan.

Table 1 Seeding and Planting Equipment

Name of Implement	1985	1986	1987	1988
Cotton drill	1018	922	968	1016
Cotton planter	12	10	10	11
Groundnut drill	10	20	25	15
Potato planter	85	97	101	110
Rabi drill	795	657	689	723
Seed drill	2580	2933	3079	3202
Sugarcane planter	—	—	—	8

Source: Journal of Science, Technology and Development Vol. 8 No. 2, 1988 pp: 24 (1).

Crop Sowing Practices

In Pakistan, traditional seed placing methods are still in vogue. In the case of cereals, pulses and oil seed crops the use of *kera* (dropping of seeds manually in a furrow opened by a *desi* plow) and *pora* (dropping of seeds through a funnel shaped tube attached behind a *desi* plow) is more common in *barani* areas as there is not enough moisture on the soil surface and farmers have to place seeds to a depth of 8 cm or more in the soil.

Conventional practice of hand-broadcasting the seeds on the soil surface is very common in irrigated areas. The field is plowed either before or after broadcasting and is planked finally. This results in poor germination due to placement of seeds at insufficient soil moisture conditions and seed consumption by birds. The old farmers, expert in even broadcasting are becoming scarce. The young generation is reluctant of doing this operation. The result is that increase in crop yield is not satisfactory despite the availability of better high yielding varieties, higher fertilizer input and better water management and pest control practices. Therefore, it can be said that these conventional practices are one of the reasons for low crop production of cereals, oil seeds and pulses in the country.

Conventional sugarcane planting comprises of furrow opening, placing of sets and covering them. Furrows are opened by tractor-operated or animal-drawn ridger or animal-drawn *desi* plow. Sets in the ridger-opened furrow are placed manually and remain bare for sometime. The sets are then covered manually or by planking. This whole planting operation can take a few days to complete. In furrows made by desi plow, sets are immediately placed and covered manually or by planking. The two major planting factors which cause reduction in cane yield are low seed rate and delayed covering.

Design and Development Efforts

Multi-crop Seed-cum-fertilizer Drill

In Pakistan, wheat is planted after rice on 2 million ha. It is one of the common cropping patterns in the country. Wheat sowing is delayed in rice areas if land is prepared after havesting rice. There is mostly enough moisture available for direct seeding of wheat in rice fields. Therefore, the need was felt in evolving a seeding machine which can sow wheat in rice fields without land preparation or zero tillage (2).

Four units of Aitchison drill were imported from New Zealand in 1984. Aitchison is a tractor-rear-mounted drill (**Fig. 1**) comprising mainly of seed and fertilizer hoppers, depth control wheels, sponge feed metering mechanism, infinitely variable speed gear box to vary seed rate from zero to maximum and inverted "T" furrow openers. The drill's sowing width is 2.4 m and requires a 45 kW tractor.

A soft and resilient sponge rotates against a specially shaped groove of seed metering plate. It envelopes the seed irrespective of shape and slowly pulls it down the groove where it is released and dropped down the seed tube. (**Fig. 2**). The seed agitator is used only with larger seeds to avoid bridging of the seeds around the entry point in the groove.

The fertilizer system is designed for use with well granulated fertilizer. There are two lines of feed cups, front for fertilizer and rear for seed. In each line, the feed cups are evenly spaced at 15 cm apart. The spiral delivery tubes are flexible in nature in order to compensate for the furrow opener's impact when operated in no-till field.

These drills were extensively used for sowing wheat on untilled rice stubble fields. Direct drilling of wheat has been compared with conventional sowing at 42 sites in the past four years (3). Direct drilling saved 100% cost involved in land preparation and overall saved 87% of the total cost of sowing wheat compared to the conventional method. **Tables 2** and **3** show the economic comparison of direct drill with farmer practice and deep tillage, respectively, for wheat cultivation (3).

These drills have shown promising results by sowing wheat on time and eliminating land preparation time and cost. In order to ensure availability of these drills at low cost, the FMI collaborated with M/s Descon Mechanical Products for their local manufacturing. The FMI has also shared in the development cost of jigs, fixtures and dies with financial assistance from RNAM.

The sowing width of the drill has been reduced from 16 to 12 rows (2.4 m to 1.8 m) to match

Fig. 1 Aitchison Drill (rear view).

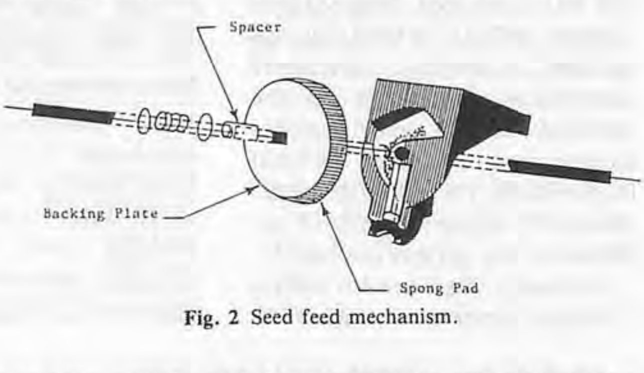


Fig. 2 Seed feed mechanism.

Table 2 Economic Comparison of Direct Drill and Farmer Practices for Wheat Cultivation

Operations	Cost (Rs./ha)	
	Direct drill	Farmer practice
Land preparation		
6 Cultivations @ Rs.75/ha	—	450.00
3 Plankings @ Rs.50/ha	—	150.00
Planting		
2 Cultivations and 1 planking		200.00
Drilling	125.00	—
Broadcasting	—	25.00
Total	125.00	825.00

Note: Cost advantage of direct drill over farmer practice = Rs. 700
Benefits of direct drill through early planting
(20 days(avg) at 30 kg/day/ha = 600 × 2 ..... = Rs.1200
Total benefit .... = Rs.1900

Source: Wheat Programme, NARC, Islamabad (3).

Table 3 Economic Comparison of Direct Drill and Deep Tillage for Wheat Cultivation

Operation	Cost (Rs./ha)	
	Direct drill	Deep tillage
Land preparation		
1 Mould-board flow	—	240.00*
1 Rotavator	—	173.00*
Planting		
1 Drilling	125.00	81.00*
Total	125.00	494.00

Note: Cost advantage of direct drill over deep tillage = Rs. 369
Benefits of direct drill through earlier planting
20 days @ 30 kg/day/ha = Rs.1200
Total benefits = Rs.1569

* Crop maximization Programm, PARC, Islamabad (3).
Source: Wheat Programm, NARC, Islamabad.

the popular 37 kW tractor available in the country (4). Fifteen units of these drills are being manufactured locally for their field demonstration for sowing of wheat, rice, chickpea, sunflower, etc.

Sugarcane Planting

Efforts have been made to mechanize sufarcane planting operation. A few suger mills, research institutes and progressive farmers imported sugarcane planters mainly from Australia for their own use of for custom hiring. The Millat Tractors Ltd. also imported two planters from Australia. Most of the imported planters were not found suitable under local conditions. The Agricultural Mechanization Research Institute (AMRI), Multan and Farm Machinery Institute (FMI), Islamabad started working on development of machines for mechanization of sugarcane planting in the country during 1982-83.

AMRI Sugarcane Planter

The AMRI has developed a sugarcane planter (5). The planter is mounted behind the tractor with three-point linkage and is powered through the tractor PTO shaft (**Fig. 3**). It is a three-row planter with 76 cm row spacing and plants single sets in a row. The length of sets is 46 cm. The sugarcane stalks are fed vertically through feeding chutes. The canes are dropped manually into the chutes which guide the cane towards the cutters and also provide support for effective and positive cutting and shearing of canes. The planter can plant 53000 to 87000 sets per ha. It saves 80 man-h otherwise required for set cutting. It costs approximately RS. 770 per ha which is 43% less than indigenous planting. For planting 1 ha of cane, 5.82 h are required. It is now locally manufactured by Bodla Industries, Mian Channu.

FMI Sugarcane Planter

The Farm Machinery Institute first imported a set planter from India. This planter was extensively tested in 1983 at a farmer field near Sahiwal. After some successful modifications it was named as FMI Sugarcane Set Planter (6). Cut sets are loaded to this machine (**Fig. 4**). Two feeding crew sitting on the fertilizer boxes pick two sets from the hopper, one in each hand and drop them in to the chutes which deliver these to the furrows at the rear of the furrow openers. It is a two-row machine with row

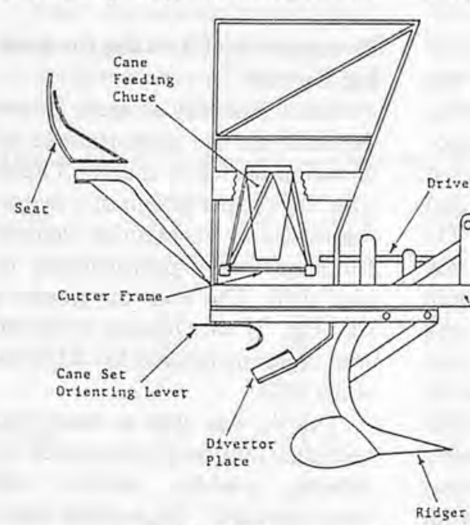


Fig. 3 AMRI sugarcane planter.

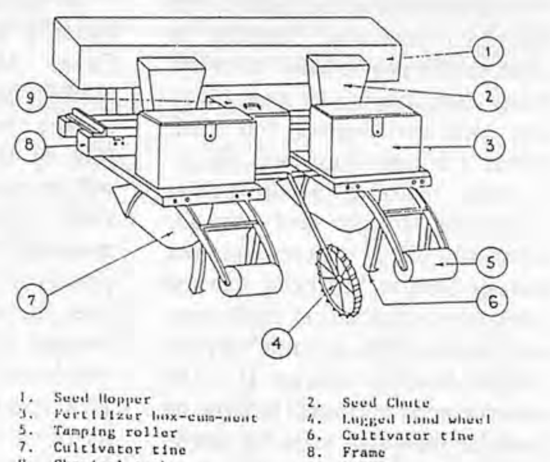


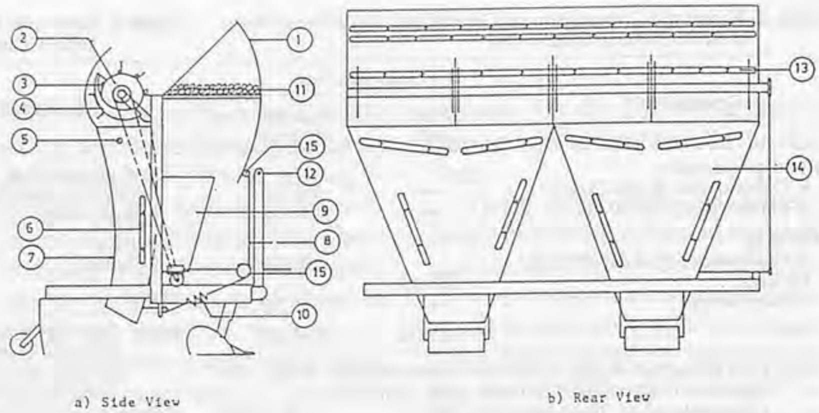
Fig. 4 FMI sugarcane set planter.

spacing of 91 cm and can plant single or double sets in a furrow at a depth of 30 cm. The planter needs 3.8 h to plant 1 ha when planting double sets in a furrow and saves 50% of the labor needed for manual planting. The planting cost was estimated at Rs. 305/ha in 1983.

Efforts were made at the FMI to incorporate the set cutting unit with this planter. The objective was to eliminate the labor needed for set cutting. The planter of this kind was developed (7). Whole canes were loaded horizontally into the hopper. A person standing on the rear of the planter pushes the canes into the cutting unit which cut a cane into four pieces (**Fig. 5**). These pieces are then transferred to the furrow bottom through the chutes. The planter was throughly tested during 1985 spring planting. It was found much suitable when the canes were straight enough while the performance was not satisfactory when the canes were crooked (8). At the same time it was found very difficult to obtain straight canes from the existing commercial varieties.

It was hypothesized that earthing-up can stop the cane lodging which will ultimately result in a reduction of its crookedness. Some experiments were conducted at the Sugar Crops Research Institute, Mardan to explore the possibilities of everything cane lodging by deep plowing and earthing-up but their effect was not significant (9).

After realizing the difficulties of getting straight seed cane for successful use of the cutter planter the set planter has been selected for commercialization until some straight varieties or some ways to control lodging emerge. It is the extreme need to control lodging by possible means at least for growing seed cane. The trend is non-existing to grow cane for seed purpose only which may be helpful in many ways. Few units of the set planter were supplied to the farmers and sugar mills during 1987-88. It is now locally manufactured by M/s Bhatti Industries, Main Channu.



1. Seed hopper
2. Finger wheel
3. Cane in cutting
4. Cutter blade
5. Cane set entering to chute
6. Cane set at end of chute
7. Seed Chute
8. Hoppér height control system
9. Fertilizer box
10. Tension Spring
11. Cane in hopper
12. Linkage point
13. Cane in finger wheel
14. Turning of cane in chute
15. Rope pulley

Fig. 5 FMI sugarcane cutter planter.

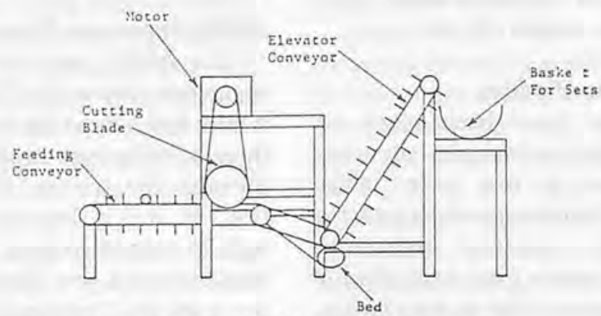


Fig. 6 First prototype of FMI sugarcane set cutter.

FMI Sugarcane Set Cutter

A stationary sugarcane set cutter is being developed at the Farm Machinery Institute, NARC, Islamabad. The first prototype has been fabricated (**Fig. 6**). It is tractor-mounted and will be operated by tractor PTO shaft. The whole cane is put manually on a horizontal chain conveyor. At the other end and over the conveyor chain are suspended four circulating cutters which revolve at high speed (1600-1700 rpm). As the cane moves to its other end with the conveyor passing the cutters, the cane is cut into four pieces of 0.4 m length which fall on the ground. The unit was tested during the February, 1990 planting season. It is expected that one man can cut 30000 sets in an hour with this machine.

Testing and Evaluation Efforts

Development of Test Rig for Seeding Devices

The uniformity of seeds in row depends on the performance of metering device of a drill. Therefore, the proper design of a metering device is an esential element for satisfactory performance of seed drill. The FMI developed a rig (**Fig. 7**) to evaluate different seed metering devices for different seeds (10).

The rig was used to determine seed distribution performance for wheat, paddy, millet and rape/mustard. Depending upon the agronomic requirements of

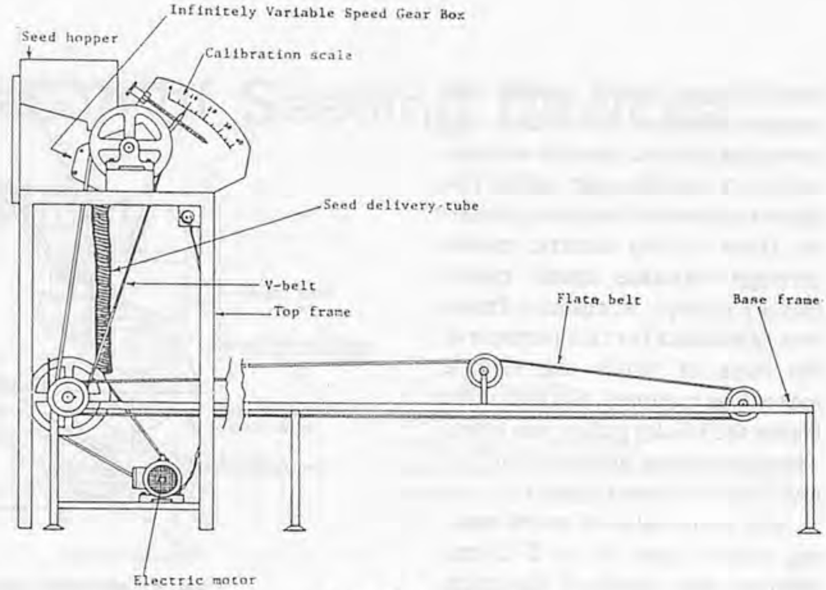


Fig. 7 Test rig.

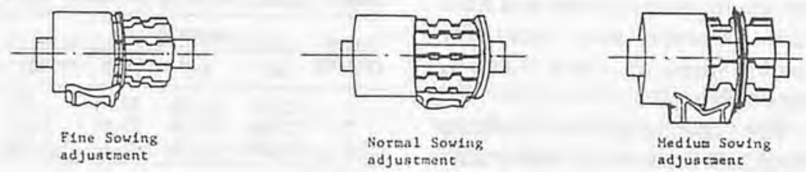


Fig. 8 Universal seed wheel.

these crops, the time required to deliver 100 grams of seeds with single row at three travel speed, i.e., 3.68, 4.5 and 5.4 km/h was calculated with the following formula.

Time required to deliver 100 g of seeds (seconds)

$$= \frac{3.6 \times 105}{\underset{(kg/ha)}{\text{Seed rate}} \times \underset{(cm)}{\text{Row spacing}} \times \underset{(km/h)}{\text{spped}}}$$

The seed distribution data was analysed to estimate the mean, standard deviation and coefficient of variation. The results shown in **Table 4** using universal seed wheel metering device (**Fig. 8**) indicate that the coefficient of variation is low at the speed of 4.5 km/h, for wheat, paddy and rape seed than achieved at 3.7 and 5.4 km/h. This shows that 4.5 km/h was a suitable drill speed for drilling these three crops. In the case of sponge type metering device, 3.7 km/h travel speed was found most suitable for wheat and paddy drilling (**Table 5**) .

The coefficient of variation was observed low for millet and rape seed using both the sponge and universal seed wheel metering devices at the speed of 4.5 km/h.

Gaspardo Planter

The Gaspardo pneumatic planter (model SP 520) was used to investigate the effect of travel speed on plant spacing uniformity (11). The metering mechanism of the planter utilizes a combination of air, gravity and PTO power to select the seed and place it in the soil. Each planting unit (each row) is equipped with a vacuum distributor inside of which the seed plate is mounted. The seed plate of different diameter and different number of holes along its periphery can be used for different seedsizes. Planting distance is obtained by putting the proper sprockets on the gear box axle and drive wheel.

The seed distribution data was recorded by three methods.

1. Laboratory evaluation;
2. By removing the furrow openers, running the tractor at desired forward speed and allowing the seeds to be dropped on prepared/leveled soil surface; and
3. After germination.

Fig. 9 shows the experimental set up for laboratory evaluation. The drive to the vacuum fan was provided by a 10 hp electric motor. For the purpose of attain-

Table 4 Seed Distribution with Universal Seed Wheel

Crop	Ground speed (km/h)	Avg. no. of seed per meter linear length	SD	CV
Wheat	3.7	31.0	0.19	2.94
	4.5	37.0	0.27	4.93
	5.4	34.0	0.33	5.35
Paddy	3.7	130	0.10	6.68
	4.5	153	0.13	9.91
	5.4	148	0.11	7.87
Millet	3.7	139	0.14	9.73
	4.5	123	0.08	5.20
	5.4	110	0.20	11.11
Rape seed	3.7	63	0.17	5.35
	4.5	68	0.12	3.97
	5.4	76	0.19	7.30

Table 5 Seed Distribution with Sponge Feed Device

Crop	Ground speed (km/h)	Ave.no. of seeds per meter linear length	SD	CV
Wheat	3.7	30	0.31	4.69
	4.5	36	0.14	2.56
	5.4	38	0.21	4.0
Paddy	3.7	111.0	0.19	10.67
	4.5	111.2	0.12	6.80
	5.4	116.0	0.17	9.85
Millet	3.7	97	0.08	3.88
	4.5	136	0.11	7.97
	5.4	107.4	0.23	12.2
Rape seed	3.7	71	0.22	7.71
	4.5	76	0.11	4.36
	5.4	67	0.18	6.0

ing different travel speeds, the ground wheel of the planter was rested on the two parallel wooden rolls (8.5 cm diameter each). The drive to these rollers was provided from 1.0 hp electric motor through variable speed pulley (Micky pulley). A separate frame was fabricated for this purpose at the base of which the electric motor was mounted. On top of the frame the Micky pulley was fixed. The planter was operated for 5, 7 and 9 km/h travel speeds.

The mean value of speed spacing varied from 19 to 27.5 cm, whereas the standard deviation varied from 4.43 to 12.62. The maximum value of mean and standard deviation was found for planter speed of 7 and 9 km/h, respectively.

The coefficient of varieties which is a measure of uniformity of spacing was minimum for 5 km/h (**Table 6**) indicating that the spacing was more uniform when the planter was operated at 5 km/h.

The missing seed percentage varied from 2 to 14% with minimum at the speed of 5 kg/h (**Table 7**). The number of double seeds varied from 3% to 9% for 5 km/h and 9 km/h travel speeds, respectively, in the case of test methods 2 and 3. But in the case of laboratory evaluation the maximum and minimum number of doubles were 5 km/h and 7 km/h, respectively.

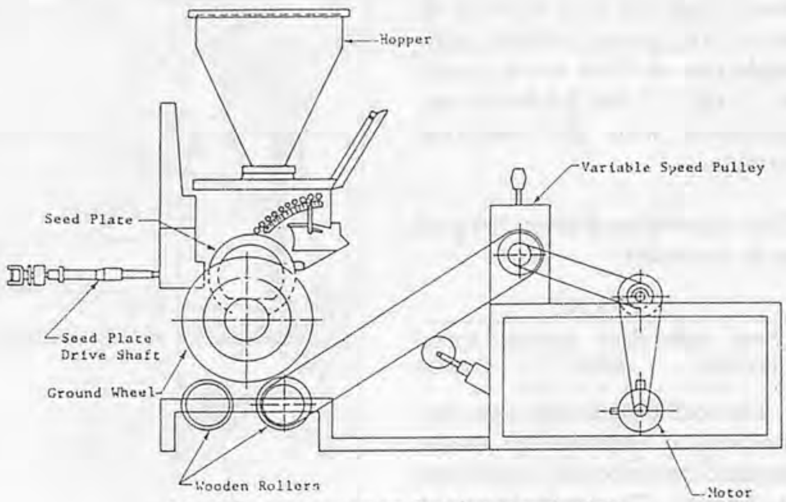


Fig. 9 Laboratory set-up for planter evaluation.

Table 6 Mean, Standard Deviation and CV for Various Travel Speeds

Speed (km/h)	Average			SD			CV		
	M1	M2	M3	M1	M2	M3	M1	M2	M3
5	22.67	19.88	22.41	5.33	4.43	8.62	0.23	0.22	0.38
7	27.56	19.04	21.91	9.48	6.25	9.83	0.34	0.33	0.45
9	24.39	21.94	23.3	7.30	2.7	12.62	0.30	0.40	0.54

Table 7 Percentage of Missing and Doubles for Various Planter Speed

Travel speed (km/h)	Method 1		Meshod 2		Method 3	
	Missing (%)	Doubles (%)	Missing (%)	Doubles (%)	Missing (%)	Doubles (%)
5	4	17	2	4	9	2
7	9	9	3	8	14	3
9	7.5	7.5	11	9	11	8

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Field Evaluation of Seeding Devices for Finger Millet

by
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Abstract

Five seed drills: Birsa seed-cum-fertilizer drill, Gujarat State Fertilizer Corporation seed-cum-fertilizer drill, Eenatigorru ridger seeder and Ragi seeder with broadcasting as control were tested for finger millet (*Eleusine coracana*) in three rainy seasons (1987 to 1989). Their performance was compared based on the relative effect of different parameters. The calculated overall performance indices based on the weights given to various parameters and ratings assigned on their measured values indicated that the Gujarat State Fertilizer Corporation seed-cum-fertilizer drill was best for lateritic soil of Orissa.

Introduction

The state of Orissa is situated in the north-eastern section of India and extends over a geographical area of 15.54 million ha between 17°50' and 20°30' N latitude and the median of 81°31' to 87°38' E longitude. The present population of the State has been estimated at 28.6 million. About 38.55% of the area is under cultivation. Agriculture of the State mainly depends on rainfall which includes more than 70% of the cultivable area. The annual average rainfall is about 1500 mm of which 80% occurs during the period of the south-west monsoon. Effective rainy days vary between 70 and 90.

Paddy is the major crop and is vulnerable to dry spells. The average yield is very low. Finger millet is the second best cereal grown in Orissa due to its resistance to moisture stress and does not need very precise climatic conditions for its culture. About 5.75% of area both in rainy and winter is planted to this crop. As timeliness of operation and precise placement of seed and fertilizer are some of the important factors in dryland agriculture to obtain satisfactory plant stands, it is necessary to test the seeders developed by various dryland centres of the country to select the best one that suits the lateritic soil of Orissa. Details of the soil properties are given by Senapati et al (1988) where the seed drills were tested.

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Table 1 Details of Seed Drills

Treatments	Seeding device	No. of opener	Adjustability of opener	Weight of seeding device with beam (kg)
T_1	Birsa seed-cum-fertilizer drill	One	Fixed	20.5
T_2	Gujarat State Fertilizer Corporation seed-cum-fert. Drill	Two	Adjustable	18.0
T_3	Eenatigorru	Three	Fixed	26.6
T_4	Ridger seeder	Two	Adjustable	18.6
T_5	Ragi seeder	Five	Fixed	27.5
T_6	Local plough (for broadcasting)	One	Fixed	15.6

Experimental Seed Drills and Treatments

Five seed drills were used in the test. Broadcasting and covering by local plough was taken as another treatment for comparison. Details of the seed drills are given in **Table 1**.

The field trials were conducted on the plot of a net area of 50 m^2 (10 m × 5 m) laid out in a randomized block design with three replications. The land was prepared by a tractor-drawn plough. Farm yard manure of 50t/ha was added during land preparation. Finger millet (cv *Dibyasingh*) was sown at the rate of 10 kg/ha and fertilizer was added at the rate of 30 kg N, 13 kg P and 19 kg K/ha. The field trial continued over three years in rainy seasons from 1987 to 1989.

Parameters

Eleven selected parameters (**Table 2**) were broadly considered important to distinguish the performance of the seed-cum-ferti-drills (Mayande, 1989). A weight for each parameter is given based on its contribution in achieving the functions expected of the seed-drill.

Rating of Parameter

The observations recorded for each parameter were given a rating depending on their importance within the value range of the observation. The value (minimum/maximum/optimum) that indicates the best performance was given the highest rating. The rating for each parameter are given in **Table 3**.

Table 2 Seed-drill Performance Parameter and Weights

Parameter	Weightage (Wi)
Draft	0.20
Field capacity	0.20
Plant spacing uniformity	0.10
Plant population per ha	0.05
Field efficiency	0.05
Cost of operation per ha	0.05
Facility for simultaneous placement of seed and fertilizer	0.05
Depth of placement (a) desirable	0.05
(b) undesirable	0.00
Row width adjustability	0.05
Labour required for operation	0.04
Yield	0.01
Total	1.00

Table 3 Rating of Parameter

Parameter	Range value	Rating (R_i)
Draft (kg)	< 60	1.00
	61 — 80	0.90
	81 — 100	0.70
	> 100	0.50
Ffield capacity (ha/h)	> 0.35	1.00
	0.25 — 0.35	0.90
	0.20 — 0.25	0.80
	0.15 — 0.20	0.60
	< 0.15	040
Uniformity coefficient (fraction)	⩾ 0.80	1.00
	0.75 — 0.80	0.80
	0.70 — 0.75	0.70
	0.65 — 0.70	0.50
	< 0.65	0.30
Plant population	Optimum ± 5%	1.00
	Optimum ± 10%	0.80
	Optimum ± 20%	0.60
	Optimum ± 20% <	0.40
Field efficiency, %	⩾ 80	1.00
	75 — 80	0.90
	70 — 75	0.70
	65 — 70	0.50
	65	0.30
Cost of operation (Rs/ha)	< 200	1.00
	200 — 300	0.80
	300 — 400	0.60
	> 400	0.40
Facility for simultaneous placement of seed and fertilizer	Yes	1.00
	No	0.00
Depth of placement of seed and fertilizer	Optimum	1.00
	Optimum ± 20%	0.70
	Optimum ± 20% <	0.50
Row width adjustability	Yes	1.00
	No	0.00
Number of labour requirement for operation	1	1.00
	2	0.80
	3	0.60
Yield (kg/ha)	Optimum	1.00
	< Optimum	0.90

Performance Index Model

On the basis of weights given the various parameters and rating of each parameter based on its qualitative importance, the following model was used to determine the overall performance index:

$$OPI = W_i R_i \quad \ldots\ldots\ldots\ldots (1)$$

where,

OPI = overall performance index of the seed-cum-fertilizer drill

W_i = Weight of ith parameter

R_i = Rating of ith parameter based on its observed/

calculated values

Results and Discussion

The animal draft power of each seeder was measured using a hydraulic dynamometer. The minimum and maximum instantaneous pulls experienced by the machines during the operation were also recorded (**Table 4**). The ridger seeder needs maximum animal draft power of 74 kg as it has wide type and long share for placement of seed below the soil surface. In the case of broadcasting, the land was ploughed by local plough and the draft measured was 45 kg.

The depth of seed and fertilizer placement was measured randomly at more than 10 locations in each plot for each seed drill and the average values are given in **Table 5**, along with the number of labourers and bullocks required to operate the machine. The Birsa seed-cum-fertilizer drill placed the seed and fertilizer at depths of 6.5 cm and 8,2 cm, respectively. The ridger seeder did not have the facility for placement of fertilizer. It was observed that the optimum placement of seed varied between 2.5 cm and 3.0 cm for finger millet crop under lateritic soil condition.

Field capacity is the field coverage per hour. It was observed that the field coverage by the bullocks with the particular seeder remained almost equal during three seasons. Field efficiency of each machine had been estimated considering the time loss in turning, filling seed and fertilizer in hoppers and short term failure of machine during operation. As the Regi seeder (T_5) of Bangalore Dryland Center is a five-row machine, it covered the highest area of 0.11 ha/h. On the other hand, it showed the lowest field efficiency because of more time spent in turning. The field efficiency of other seeders ranged between 70 and 75% (**Table 6**).

Uniform placement of seeds in the line is one of the important factors which affects the crop growth and, consequently, yield as this depends on the precise design of the metering device of the seed drill. Using the equation given by Senapati et al (1988), the uniformity coefficient for each seed drill was determined and shown in **Table 7**.

Plant population in row per meter length, grain yield and cost of sowing are presented in **Table 8**. The cost of operation of each seeder was estimated considering the fixed and variable costs. The cost of operation calculated was more or less equal for each seeder during three seasons and, therefore, the average values in term of Rupees per ha are given in **Table 8**. In the case of broadcasting, the plant population given in **Table 8** is per square meter.

On the basis of weights given the various parameters and ratings assigned on their measured values, the overall performance index of each seed drill was estimated (**Table 9**). As the parameter value is within the same range, its rating value has been the same over three years' observation.

Table 4 Draft Power Requirement of Seeders

Treatment	Draft (kg)				Instantaneous pull (kg)	
	1987	1988	1989	Average	Minimum	Maximum
T_1	47.6	48.1	48.5	48.1	45.0	75.0
T_2	58.8	59.5	59.3	59.2	45.0	80.0
T_3	65.4	66.4	64.1	65.3	55.0	90.0
T_4	73.8	75.2	73.5	74.2	60.0	90.0
T_5	48.8	50.3	50.7	49.9	45.0	60.0
T_6	42.7	47.4	45.0	45.0	42.0	53.0

Table 5 Depth of Seed and Fertilizer Placement and Number of Labourers and Bullocks Required for Operation

Treatment	Placement of seed (depth in cm)				Placement of fertilizer (depth in cm)				No. of Labourers	No. of bullocks
	1987	1988	1989	Average	1987	1988	1989	Average		
T_1	6.9	6.5	6.2	6.5	8.7	8.3	7.6	8.2	2	2
T_2	5.1	5.3	5.1	5.2	6.5	6.7	5.6	6.2	3	2
T_3	3.0	3.1	3.0	3.0	4.5	4.6	3.4	4.2	3	2
T_4	5.3	5.5	5.3	5.4	—	—	—	—	3	2
T_5	1.5	2.1	2.2	1.9	2.5	3.1	3.2	2.9	3	2
T_6	1.0	1.1	1.2	1.1	1.0	1.1	1.2	1.1	1	2

Table 6 Field Capacity and Field Efficiency of Seed Drill

Treatment	Field capacity (ha/h)	Field efficiency (%)			
		1987	1988	1989	Average
T_1	0.0294	70.1	72.3	74.2	72.2
T_2	0.0454	74.3	72.4	69.0	71.9
T_3	0.0714	69.1	68.2	71.3	69.5
T_4	0.0435	70.3	73.1	74.2	72.5
T_5	0.1111	60.4	61.3	59.5	60.4
T_6	0.0500	71.4	70.7	70.3	70.8

Table 7 Seed Uniformity Coefficient (%)

Treatment	Year			Average
	1987	1988	1989	
T_1	51.2	50.8	50.6	50.9
T_2	50.5	50.2	50.0	50.2
T_3	51.1	50.6	50.1	50.6
T_4	53.4	52.1	52.9	52.8
T_5	43.6	44.2	40.2	42.7
T_6	62.7	58.7	67.7	63.0

Table 8 Plant Population, Grain Yield and Cost of Sowing

Treat-ment	Plant population (per meter-row length)				Yield (q/ha)				Cost of sowing (Rs/ha)
	1987	1988	1989	Average	1987	1988	1989	Average	
T_1	73	210	200	161	9.12	14.55	16.10	13.25	202.64
T_2	192	237	209	213	12.50	18.05	16.00	15.51	192.94
T_3	248	351	231	277	15.75	24.15	19.85	19.91	124.60
T_4	147	232	140	173	10.37	15.85	15.05	13.75	197.57
T_5	176	256	193	208	14.25	20.05	17.50	17.26	81.90
T_6	308	301	320	310	14.00	17.00	13.00	14.70	118.00

Table 9 Estimationn of Overall Performance Index

Parameter	Weight factor (W_i)	Treatments											
		T_1		T_2		T_3		T_4		T_5		T_6	
		Rating factor (R_i)	W_iR_i	Rating factor (R_i)	W_iR_i	Rating factor (R_i)	W_iR_i	Rating factor (R_i)	W_iR_i	Rating factor (R_i)	W_iR_i	Rating factor (R_i)	W_iR_i
Draft	0.20	1.00	0.20	1.0	0.200	0.90	0.180	0.90	0.180	1.00	0.200	1.00	0.200
Field capacity	0.20	0.40	0.08	0.40	0.080	0.40	0.080	0.40	0.080	0.40	0.080	0.40	0.080
Plant spacing uniformity	0.20	0.30	0.06	0.30	0.060	0.30	0.060	0.30	0.060	0.30	0.060	0.50	0.010
Plant population	0.10	0.40	0.04	0.40	0.040	0.40	0.040	0.40	0.040	0.40	0.040	0.40	0.040
Field efficiency	0.05	0.70	0.035	0.50	0.025	0.70	0.035	0.70	0.035	0.30	0.015	0.70	0.035
Cost of operation	0.05	0.80	0.040	1.00	0.050	1.00	0.050	1.00	0.050	1.00	0.050	1.00	0.050
Facility for simultaneous placement of seed and fertilizer	0.05	1.00	0.050	1.00	0.050	1.00	0.050	1.00	0.050	1.00	0.050	0.00	0.000
Depth of placement	0.05	0.50	0.025	0.50	0.025	1.00	0.050	0.50	0.025	0.50	0.025	0.50	0.025
Row width adjustability	0.05	0.00	0.00	1.00	0.050	0.00	0.00	1.00	0.050	0.00	0.000	0.00	0.000
No. of labour required for operation	0.04	0.80	0.032	0.60	0.024	0.60	0.024	0.60	0.024	0.60	0.024	1.00	0.040
Yield	0.01	0.90	0.009	0.90	0.009	0.90	0.009	0.90	0.009	0.90	0.009	0.90	0.009
$\Sigma\ W_iR_i$	(performance index)		0.571		0.613		0.578		0.603		0.553		0.489

Conclusion

Considering the factors taken for the evaluation of seeding devices, the overall performance indices were calculated (**Table 9**). The analysis of results indicates tha the Gujarat State Fertilizer Corporation Seed Drill (**Fig. 1**) had the best performance on the field as it had the highest performance index value of 0.613 followed by the Ridger seeder of Hissar (OPI = 0.603). Although Eenatigorru of Anantpur Centre had shown consistently the highest yield over three years, it secured the third position on the basis of its overall performance.

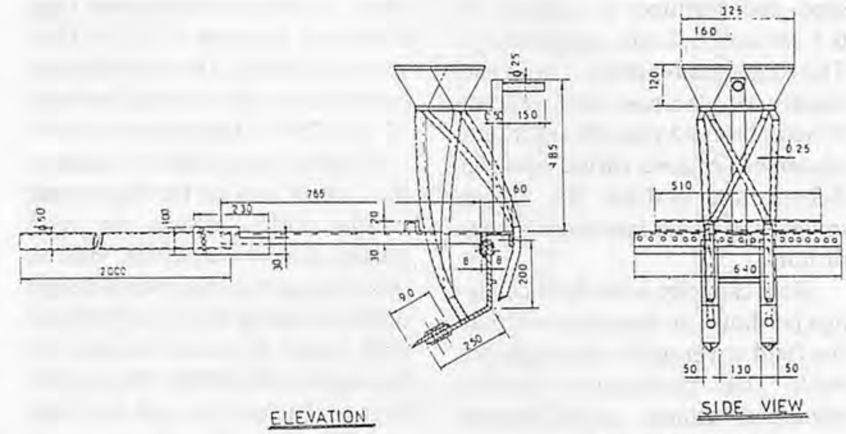

Fig. 1 GSFC seed-cum-fertilizer drill.

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Development of a Basin Lister Actuated by Tractor's Hydraulic System

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Abstract

Basin listing is a proven moisture conservation measure for dry tracts. The designed basin listing attachment actuates the tractor's hydraulic system to lift and lower a mounted ridger at regular intervals, and thus forms basins of 3 m length and 1 m spacing. The hydraulic system's response for the operation was analyzed using an onboard microcmputer and the operating speed optimized to 3.5 kph. An observation trial to ascertain the effect of basin listing on soil moisture retention was made, against a control treatment. Two to 4 per cent of more moisture was retained in the basin listed treatment for the first three weeks after rainfall.

Introduction

Land and water resources are limited, hence their wise use is imperative. This is especially so for countries where the population pressure is on the increase. Dry farming, as it is presently understood, is the profitable production of crops without irrigation on lands, which receive rainfall annually of 500 mm or less. It is important in dry farming to conserve moisture in order to make it available to crops being sown. Basin listing is one of the proven methods of moisture conservation, especially for black soils if bund forming is not practised. It is the creation of multitude of small basins as an effective way of moisture conservation.

Review of Literature

Meelu et al reported that 10 mm of additional soil moisture stored above 14 cm in 1m-deep profile gave an additional yield of 1.1 quintals/ha. Hyle et al concluded that basin tillage is effective in allowing sufficient time for infiltration of the impounded rain water. It is reported that power tiller-operated basin lister treatment resulted in 10% increase in cotton yield.

Various designs of mechanical basin listers are available which use linkages and cams to periodically lift the furrow forming lister bottoms of the ground to form interrupted furrows or basins. The newly developed equipment is an attachment to the tractor and uses the tractor's hydraulic system to do the basin listing with a mounted ridger plough.

Materials and Methods

Principle of Operation

The basin listing operation is accomplished by lifting the mounted ridger through the hydraulic control of the tractor at a regular time interval. A cam and follower assembly as shown in **Fig. 1** is used to derive motion from the right hand rear wheel of the tractor. The cam which is mounted on the wheel bolts, oscillates the hinged follower that is bolted to mudguard. The follower's axis is accommodated in a pipe boss to provide the hinging action and the follower is spring

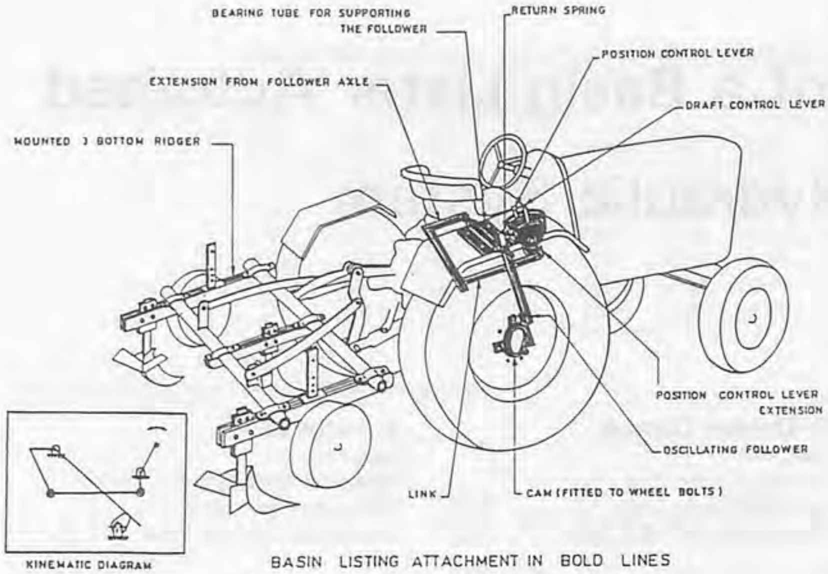

Fig. 1 Tractor-operated basin lister.

loaded. The movement imparted to the follower is transmitted through this axis and a set of levers to the tractor's position control lever. The cam's rise and dwell are so designed that for each rise, the position control lever is moved to the 'lift' position and during dwell to the 'down' position. The cam has a dwell angle of 240° during which period the three-point links retain the implement in working position, i.e., for 240/360 = 67% of the distance travelled by the tractor for one wheel rotation. When the follower is tracking the cam's rise, the implement is raised to leave a break in the furrow being formed. This periodical rise and fall of the implement forms interrupted furrows as basins. While turning in head lands, the basin listing could be stopped by simply holding the position control lever from following the cam. As the spring preload on the mechanism is very light in the order of only 30N, the driver can easily hold the lever from being actuated. The tractor's position control lever is extended from its bottom to accommodate the linkages and is so provided not to hinder the normal operation of the lever, on detaching the linkages.

Optimization of Tractor Speed

It was observed that the delay in the hydraulic system's response to the position control lever, posed a problem in the system's working at high speeds. In order to test the system's response, an onboard computer was used.

A software was developed for an 8085-based microcomputer kit, to count the delay between the instant the lever is thrown to the lift position and the instant the implement completely emerges out of the ground from a ploughing depth of 250 mm. The flow chart of the programme is presented in **Fig. 2**.

An ordinary linear potentiometer connected like a voltage divider senses the movement of the tractor's lower links, as an angular displacement transducer. The transduced DC level is passed on to an ADC interface and digitalized by the programme calling a subroutine for analog to digital conversion.

The main programme first checks for a hardware debounced high bit from a microswitch sensing the position control lever's throw to 'lift' position. The programme then initializes and loads the 8253 timer's counter '1' and starts counting a 1 kHz clock pulse from a 555 timer. The

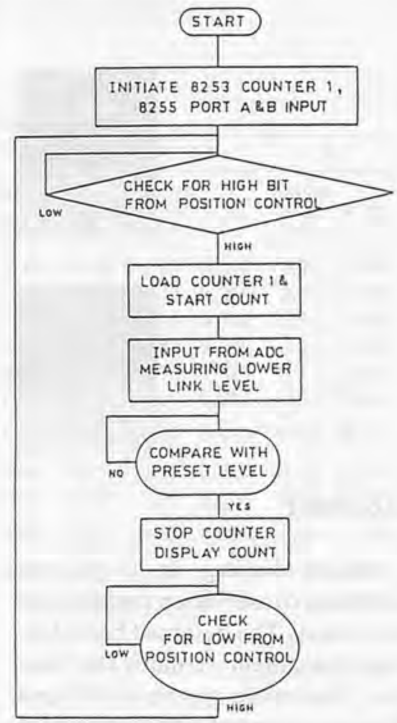

Fig. 2 Flow chart of software measuring time delay.

programme receives the digital equivalent of the implement's position relative to the ground and compares it with a pre-defined level at which the implement emerges from the ground completely. The counting is continued until the two values match. The time required for the hydraulic system to respond to the position control lever is thus counted and the result is converted to m.sec time is displayed in the LED panel.

The control response of the hydraulic system of a B247 International tractor was thus observed in two selected gears at the same throttle setting. The average observations are presented below:

Speed	Average delay of the system to respond to the position control lever
5.0 kph	820 milli.sec
3.5 kph	850 milli.sec

The total time available for the system to lift and lower back the implement is only 33% of the time taken by the tractor to cmplete one revolution of the rear wheel. This works out to be 930 milli.sec and 1550 milli.sec (for a traction wheel diameter of 1.25m) for 5 kph and 3 kph speeds, respectively. The available time for an operating speed of 5 kph is very much closer to the response time of 820 milli.sec required by the hydraulic system. Therefore, it indicates the inability of the system to respond sufficiently to form the basins. But the data shows clearly that a 3.5 kph operating speed works satisfactorily, since the available time for the system to respond is more.

Performance of Basin Lister

An observation trial on the performance of the basin lister in comparison with a conventionally ploughed plot was conducted. The device was operated in a plot measuring 40 m × 40 m at the optimised speed of 3.5 kph and basins were formed. In total, 600 basins were thus formed of which 200 were measured and the data recorded. The basin lengths varied from 287 cm to 305 cm and spacing from 95 to 103 cm which is not significantly varying from the designed value of 300 cm length and 100 cm spacing.

The soil moisture levels were recorded at regular weekly intervals after the day of the rainfall. Soil moisture at 0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm depth zones of the soil were measured using a neutron probe moisture meter.

The soil moisture status at different depth zones for both treatments are presented in **Fig. 3**.

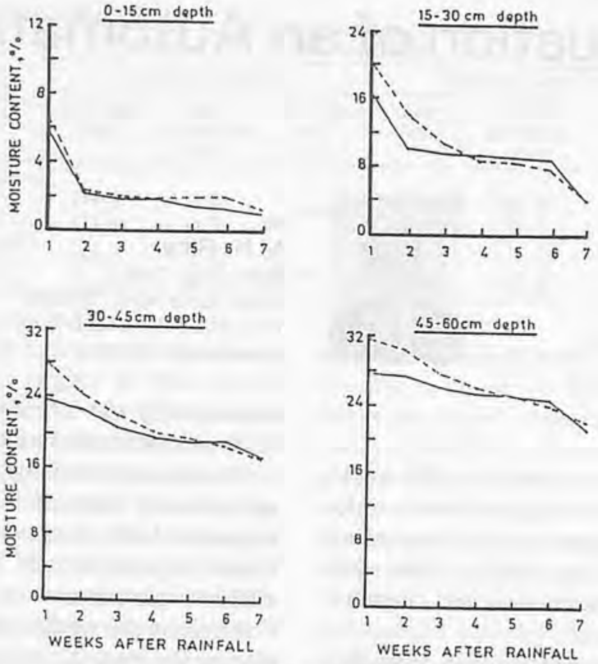

Fig. 3 Pattern of moisture retention.

Results and Discussion

The pattern of moisture retention in **Fig. 3** clearly indicates that the water conserved in the basin listed treatment is greater by 2 to 4% than that of the control, in all depth zones of the soil profile except the surface zone. There is no significant variation in the surface zone because it is exposed to higher evaporation rate.

The moisture status in the other three zones indicate that the retention is greater for the first three weeks after the rainfall. This moisture would thus help the crop to withstand wilt during acute shortage of rainfall in dry tracts.

Conclusion

The newly developed tractor-drawn basin lister has the improved design of actuating mechanism. It eliminates the need for an exclusive implement and can use a conventionally available mounted ridger itself for basin listing also.

The response of the hydraulic system through which the machine works, was tested with an onboard microcomputer. The speed of basin listing was optimized to 3.5 kph based on the results obtained.

From the observation trials conducted on the machine, basin listing showed 2 to 4% greater moisture retention than that of a conventionallly ploughed plot. The moisture retention is substantially greater for the first three weeks after the day of rainfall.

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Evaluation of an Automatic Depth Controller

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Abstract

Accurate control of the working depth of agricultural implements is one means of increasing crop yields, saving fuel and improving fertilizer and chemical application.

The automatic depth controller model DCU-3 was purchased, and tested for ease of installation, adjustment of operation, safety and reliability. Measurements were taken and observations were made to determine the effectiveness of this electronically controlled hydraulic system intended for maintaining constant implement depth in varying field conditions and tractor forward speeds. The standard statistical parameters (mean, standard deviation, coefficient of variance and variance ratio) were used to analyze the data.

Introduction

Resourceful farm management is becoming a major consideration in today's turbulent economic climate. The farmer uses the latest technical means to increase the profitability of his farm's operation. As the cost of equipment, overhead, fuel and chemicals rises, today's farmer must be prepared to increase the efficiency of the agricultural production process. The consistent results produced by modern equipment may be enhanced by the introduction of electronic control circuits.

The proper working depth of agricultural implements is an important factor in any farm operation but also one of the most difficult parameters to control. Controlling the seeding depth and placing the seed at a proper depth is the most important parameter of the planting operation. Optimum seeding depth is generally viewed as the desired goal for all crop establishment systems. Accurate control of working depth of tillage implements is also very important and will result also in better fuel economy. Improvements of fertilizer and chemical application is very essential for having more yields from any crop.

The objective of this study is to determine the degree of improvement in the performance of the John Deere 940 S-Tine cultivator that was used behind John Deere 250 spray cart by using automatic depth controller.

Background

General Description

Fig. 1 shows the major components of the Microtek Automatic Depth Control System which was developed to maintain constant implement depth in varying field conditions.

This device is an electronically controlled hydraulic system which was consists of three gauge wheels mounted on the implement, an electro-hydraulic solenoid directional control valve located between the tractor remote hydraulic valve and the implement, an electronic depth monitor and an automatic depth control box mounted in the tractor cab.

DCU-3 depth control console consists of knobs and rocker switches. These include power switch, depth dial zero adjustment screw, field condition selector, list time adjustment screw, wheel sensor zero adjustment screw, wheel sensor select switches (L, C, R), wheel sensor indicator lamps, deviation meter display, control valve operation indicators, display dampening dial, implement adjustment dial, up and down adjustment screws, implement response dial and mode switch. This automatic depth controller can be used on tractors equipped with either open or closed center hydraulic systems. This can be achieved by using open or closed center electro-hydraulic solenoid operated directional control valve.

Fig. 1 Major components of the Microtek Automatic Depth Control System.

The pressure and tank ports are connected to the tractor hydraulic remote lines while the two outlet ports are connected to the implement depth cylinder. The gauge wheels have been adjusted at the factory for implements having a height of 71.12 cm and are designed for use on implements with frame heights ranging from 6.60 to 8.64 cm. The gauge wheels should be adjusted so that the bottom of the tire on the gauge wheels are 2.54 to 5.10 cm below the shovels on the cultivator. A potentiometer measures changes in the angle between the trailing arm and the implement frame as the implement depth changes. Each sensor is equipped with a compression spring to apply adjustable ground force and a shock absorber for dampening. The sensors are mounted on the implement frame with U-bolts supplied, to accommodate square tubing ranging in size 7.5-10.2 cm.

Materials and Methods

The automatic depth controller was installed on a three section John Deere 940 S-tine field cultivator, and was pulled by John Deere 4250 Tractor. The depth controller was operated for 30 hours while applying herbicide at Wilmar Acres Ltd., Centerville, Kings County, Nova Scotia.

The unit was evaluated for quantity of work, ease of installation, ease of operation and adjustment, and operator safety. Throughout the tests, comparisons were made to the uncontrolled cultivator.

Results and Discussion

Working Depth Uniformity

The ability of the Microtek depth controller to maintain a uniform working depth was good. The depth control process arbitrarily begins at the depth sensing wheels. As the sensor wheels follow the contour of the field, the potentiometer measures changes in the angle between the trailing arm and the implement frame as the implement depth changes and constantly send depth information in the form of electrical signals to the control console. The Microtek electronic circuitry determines if the measured angle is within tolerance of the desired depth. If not, the electronic circuitry determines whether it must energize either "A" or "B" solenoid of the hydraulic valve and to what extent. The hydraulic valve will then direct and proportion oil flow to the appropriate end of the implement pistons to raise or lower the implement.

The cultivator with the controller maintained a more uniform working depth in fields with varying soil hardness than cultivator without controller as shown in **Table 1**.

Table 1 Working Depth Result

Conditions	Working depth					
	With controller			Wihtout controller		
	Av. depth (cm)	Std. deviation (cm)	Variance ratio F	Av. depth (cm)	Std. deviation (cm)	Variance ratio F
Field hardness						
Soft soil	(11.1)	(4.9)	0.93	(12.9)	(6.4)	34
Hard soil	(11.4)	(4.8)		(9.8)	(6.7)	
Ground speed						
(4.8 km/h)	(10.7)	(9.5)	6.9	(12.2)	(13.1)	1.26
(8.0 km/h)	(11.4)	(7.9)		(12.7)	(16.3)	

Depth Control Effectiveness

The function of a depth controller is to maintain the implement at a constant depth when conditions such as soil hardness, ground speed or field topography vary.

The Microtek depth control system was used predominantly for controlling cultivator depth during normal herbicide application.

In addition to using the Microtek in herbicide application, special field plots were prepared for the purpose of determining controller effectiveness. The test plot preparation work consisted of preworking a number of strips across a soft summerfallow and hard summerfallow soils with two different travel speeds.

Depth control effectiveness was determined both by observing its performance during normal field operation and by comparing the working depth of the cultivator with and without the controller. Working depth measurements were taken across the width of the machine. Maintaining this constant implement depth will result in a uniform average working depth.

The average working depth did not change significantly due to variations in soil hardness when the Depth Control System was used on the cultivator. However, without the controller, large changes in the average working depth occurred ranging from 19.8 to 12.9 cm. **Fig. 2** represents a typical histogram that illustrates the distribution of working depth of the cultivator with or without the controller. SAS computer program was used to calculate and plot the results. This histogram shows that with the controller system little change in working depth of the cultivator was observed as compared to the change observed without the controller. The tallest vertical bar occures at a depth of 12 cm in both frequency distributions. However the 12 cm bar with the controller is as big as 3 bars at depths 9.6, 10.8 and

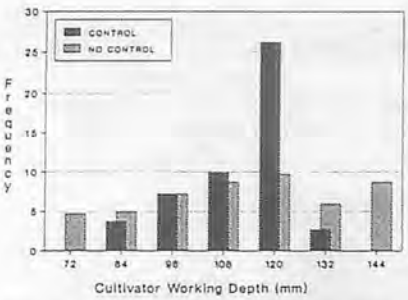

Fig. 2 Frequency distribution of data obtained at different soils vs working depth.

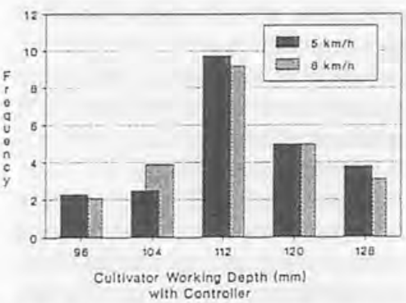

Fig. 3 Frequency distribution of data obtained at different speeds vs working depth.

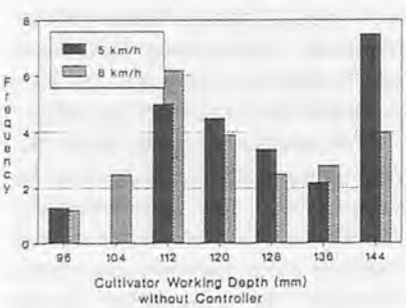

Fig. 4 Frequency distribution of data obtained at different speeds vs working depth.

12.0 cm combined without the controller.

The histograms in **Figs.** 3 and 4 shows that the average working depth did not change significantly due to variations in ground speed with or without the depth control system. However, the results shown in **Fig.** 3 were obtained from tests conducted in a soft, loose field.

Ease of Installation

A bracket was fabricated to mount the electro-hydraulic solenoid valve on the rear frame member of the John Deere 4250 tractor. The value could also be mounted on the implement hitch.

The Microtek gauge wheels were easily mounted on the frame of 940 S-tine John Deere cultivator. One gauge wheel was mounted on each of the three sections of the cultivator. Electrical cables were strapped to the implement frame and using plastic cable ties.

Ease of Operation and Adjustment

The calibration of the system was relatively easy and did not take more than 15 min. The calibration was done when the tractor was operated with the implement in an open level field at normal operating speeds and conditions. Zero adjustment screw was adjusted to calibrate the depth dial reading to correspond with the actual implement working depth. Display dampening dial was set for changes in depth caused by irregularities in surface conditions. The dampening was adjusted to obtain a smooth reading of the deviations meter. The up and down adjustment screws were adjusted to equalize the up and down implement corrections for a particular implement adjustment. During the test field condition selector was set to work in the average range. The implement adjustment dial was set to adjust the implement in 0.6 cm corrections during the test. Although during the first try, calibration procedures seemed to be difficult, they became quite easy and simple for an experienced operator.

The microtek automatic depth control unit could be used on tractors equipped with either open or closed center hydraulic systems. The maximum flow capacity of the solenoid valve was 82 L/min for open center systems and 109 L/min for closed center systems.

The automatic depth controller was considered advantageous for use with the John Deere 250 spray cart where visibility of the cultivator was obstructed by the tank. The depth control system provided the operator with an indication of working depth. The Microtek depth control system was considered safe for field and transport use if normal safety precautions were observed. In moist conditions, soil would build up on the gauge wheels, resulting in change in depth readings.

Conclusions and Recommendations

The ability of the depth controller system to maintain a uniform working depth was good. The cultivator with the controller maintained a more uniform working depth in fields with varying soil hardness than cultivator without controllers. Occasionally, however, the response of the sensor was inadequate. In fields with heavy or lumpy trash cover, the depth controllers system would sense the lumps and over compensate. Large variations in depth sensor readings cause the depth control system to alternately raise and lower the implement beyond acceptable limits.

It is recommend that there should be more efforts to encourage research institutions and industry to carry out and pursue high technology research and development on agricultural problems in general and produce products to help solve those problems, especially the problem of precisely maintaining working depth. With precision depth control a uniform germination, optimum utilization of fertilizer, more effective chemical weed control, and improved yields can be achieved.

(Continued on page 33)

Design and Construction of An Around-the-tree Cultivator

by

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Abstract

Weeding and mixing manure with soil around trees are considered fundamental orchard practices in Iraq and play a very important role together with other factors in increasing productivity.

Hand weeding and manure-soil mixing are common practices still followed by the majority of farmers in Iraq because trees in orchards are not uniform in rows, thus the use of modern mechanization is impossible.

The around-the-tree cultivator described in this paper was designed and constructed at the Farm Mechanization Department, College of Agriculture, University of Baghdad, Iraq.

Introduction

Weeding is a very important factor for increased crop production. Weeds directly reduce yield by competing with the trees in respect of space, water and nutrients[8]. They also adversely affect the micro-climate around the trees, harbour diseases and pests, increase the cost of production and lower the quantity and quality of crop production[5, 6].

Winkler et al[10] demonstrated that the amount of water loss by transpiration from weed around the vine tree is much more than the water lost by evaporation from the cultivated soil.

An essential feature of all permanent systems of farming is the return to the soil of the nourishment taken from it by crops that are removed. This is commonly done by the application of farmyard manure[4]. Unlike major cultural operations in farming, weeding and fertilization cannot be mechanized in Iraqi orchards because using cross cultivation among trees is not possible as the trees are not uniformly spaced. That is why hand weeding is the most common method of weed control that requires a very high labour input. Often several weedings are needed to keep the trees weed-free and, consequently, increases the cost of production.

For the above reasons, an around-the-tree cultivator was designed and constructed at the Agricultural Mechanization Department, College of Agriculture, University of Baghdad to meet the requirements of weeding and mixing the manure with soil around the trees. In order to prevent uprooting and severe damage to trees from cultivation, weeds close to the trunks are not controlled because the effective cultivation encountered by the cultivator is 30 cm away from the trunks.

Materials and Method

The three main parts of the around-the-tree cultivator are frame, transmission and cutting blades.

Frame

The procedure in building the frame was as follows:

1 A part of an old moldboard plow frame containing the lower link of the two lower attachment points and the headstock of the upper attachment point.
2 A 3 mm plate (70 × 35 cm) was welded at the lower part of the three point attachment frame to accomodate a gear-box at the front and a supporting plate of 60 mm in height and 120 mm in width at the rear.
3 Two holes of 25 mm each were drilled through the rear supporting plate to hold two spindles which act as pivots to the moveable wings.
4 The two spindles were welded in their places in the holes.
5 Two hollow square bars of 70 mm each were chosen for making a hexagon frame of two parts (wings).

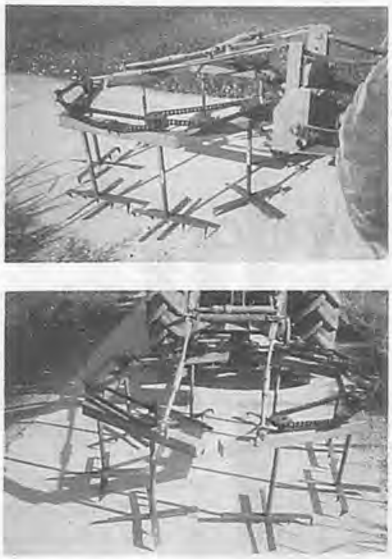

Fig. 1 Around-the-tree cultivator (cover removed). a) side view, b) rear view.

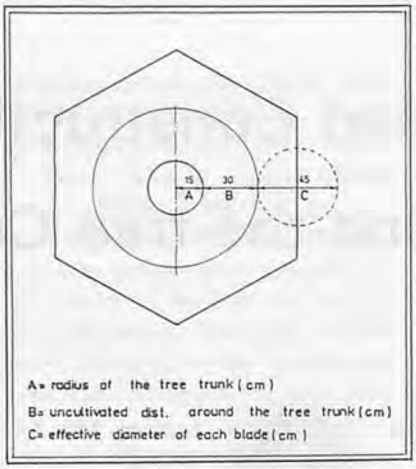

Fig. 2 Calculating the cultivated area around the tree.

Since the diameter of the tree trunk is estimated not to exceed 30 cm, the distance between the center lines of the facing lines was set at 135 cm. This would also allow an uncultivated ribbon of 30 cm wide around the trunk. The effective diameter of each blade was 45 cm.

The cultivated area around the tree was as follows (**Fig. 2**).

$15+30+45=90$ cm radius of the outside circle;

$15+30=45$ cm radius of the inner circle;

$0.9^2 \times 3.14=2.54$ m^2 outer circle area;

$0.45^2 \times 3.14=0.64$ m^2 inner circle area; and

$2.54-0.64=1.90$ m^2 the cultivated area.

6 Five holes of 25 mm were drilled in each wing. A bushing with an inner diameter of 18 mm was fitted in each hole. The length of the front bushing is 7 mm, the same height of the hole in the wing bar. This bushing acted as part of the wing pivot. The other four holes which were 47 cm apart from each one to its neighbours were fitted with bushing of 20 cm in length to accommodate the four rotating shafts on each side which ended with cutting blades. This length is essential in preventing the possible swinging of the shafts.
7 It was found that the two spindles were capable of carrying the two wings, but as safety feature, two adjustable carrying bars were fixed between the headstock and the rear of each wing.
8 The carrying bars were used to hold the hydraulic cyclinder which opens and closes the wings. A heavy-duty spring was used to assist in closing the wings.
9 The upper, outer and inner sides of the cultivator were protected by an adjustable cover. This safety feature also prevents the scattering of soil away due to centrifugal force.

Transmission

1 A gearbox was chosen with a splined shaft to fit the tractor pto shaft of 540 rpm. The gearbox was fitted on the carrying plate in a manner that the driven shaft was in an upward position which was supplied with a double star wheel to transmit power to both wings through chains. The reduction ratio of the gearbox was 3:1 to reach the cutting blades at 180 rpm which is the average speed of a rotator blade[(4)].
2 A double star wheel was fitted at each spindle, one of them to receive power from the gearbox and, the other, to deliver it to the shaft wheel. The spindle star wheel had a ball bearing inside it to act as a transmitting power and ease the opening and closing of the wings without restriction.
3 A double star wheel was fitted to each rotating shaft except the rear one. The later was fitted with a single star wheel because it receives power only without delivering it. Each wheel was fitted on the shaft by means of a pin in a hole through the wheel and the shaft.
4 Chains were used to transmit power between the star wheels and an adjustable wheel or pad was used for tensioning the chain.
5 The shaft was perpendicular and went through the bushing. The length of each shaft was 60 cm. A changeable bushing of 5 cm was fitted over the shaft between the lower side of the fixed bushing and rested over a notch on the shaft. In this way, the changeable bushing which is affected by the upward force can be replaced when worn rather than the entire shaft.
6 The lower end of each shaft has a square cut to accommodate the cutting blade for easy replacement. The shaft end had a thread and nut to fix the blade.

Cutting Blades

Each shaft ended with a cross cutting blade of 45 cm in cutting diameter. The width of the blade was 5 cm and had a square hole suitable to the square cut of the shaft. One part of the cutting blade ended with 5 cm downward sharpend bent. Five tines were welded on the bottom side of this part. The other part of the cutting blade comprised of an S-shaped bent plate with sharpened edge on the direction of rotation to facilitate easy cutting of soil slice which acts as a downward force when the slice rises over the blade and easy penetration into the soil.

Testing Procedure

The stability of the equipment and proper function of parts were tested by upward and downward movements and by driving the pto shaft, respectively. Then the equipment was lifted upward, the wings were opened, the tractor was backed toward a tree (**Fig. 3**), and the wings were closed around the trunk of the tree (**Fig. 4**).

Future testing—It is hoped that the cultivator will be further tested during the following months to facilitate a comparison between the conventional method of cultivation and machine cultivation by studying three parameters: speed of operation; cost of cultivating a tree and efficiency.

Fig. 3 Opening the wings and going toward the tree.

Fig. 4 Closing the wings around the tree.

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Evaluation of an Automatic Depth Controller

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Energy Use in Irrigated Agriculture in A Developing Country — A Ghanaian Experience

by
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Abstract

The practice of intensive irrigated agriculture is fairly new in Ghana spanning a period of a little over a quarter of a century. The ability to cope with a host of variables that go into running a viable irrigation scheme is now taking roots at both management and farmers' level. This paper attempts to analyze the energy input-output relationship on a typical 2089 ha sugarcane and rice irrigation project at Asutsuare in Ghana where the main sources of energy are electricity from the National Grid and petroleum fuels. The study concluded that the energy use pattern on the project leaves much to be desired in the face of mounting energy cost and the many varied cultural practices the farmers have to cope with.

Introduction

The escalating energy costs affect the Ghanaian community in several ways. Nearly all petroleum energy used in Ghana is imported and nearly all the dollars spent on energy are exported. Petroleum oil imports take one-third of the total export earnings of the country. This causes a decrease in local activity due to foreign exchange constraints.

The unprecedented energy consciousness that has gripped the world during the early seventies started with the three-fold increase in petroleum price in 1973. Energy crisis developed during this period because of the increasing demands for commercial energy sources.

In Ghana, field machinery and tractors are essential for the operation of irrigated farm lands. Power and machines have been the amplifiers which enable farmers to conduct their agronomic work in an adequate and timely manner. Ghana as a developing country is pursuing a more selective and appropriate mechanisation policies than in the past. The energy crisis has given a cue to the country to adopt a more rational approach to the use of scarce capital and foreign exchange resources for agricultural mechanisation.

It is recognized that it would be disastrous in many respects if the high cost of farm energy should slow down its use in a developing country like Ghana where the need for increased food and agricultural production is essential. In these circumstances the more efficient use of farm machinery is imperative. The relative importance of rainfed agriculture is high compared with irrigated agriculture.

Widespread deforestation and environmental degradation evidenced in irrigated project areas in Ghana have placed sustainability high on the agenda (Bobobee, 1985). Priority has become not just sustainable agriculture, but sustainable livelihoods based on agriculture. Population projections indicate that in Ghana, rural areas will have to support a much larger population with more people living in fragile environments.

It has been a common feature for irrigation practices not to be accepted immediately by farmers. This often leads to inefficient use and operation of the irrigation schemes. In the drought prone areas of Asutsuare (the study area), irrigation makes it possible to cultivate more than one crop a year with higher yields and to supplement rainfall deficit during the dry season.

The primary purpose of this study was to assess the energy consumption (both electricity and petroleum fuel) on the project and to compare it with the potential energy derivable from agricultural products—ethanol and rice—, and wastes-bagasse, rice straw and rice husk. Two other objectives of the study are:

1. to determine what conversion technology methods are being

used, so as to provide a background information for public agencies and farmers on the proper management of energy in agriculture, especially the environment controlled agriculture and efforts at promoting energy conservation awareness and savings, 2. to help farmers and management of irrigation projects conserve energy and, therefore, save dollars in order to remain competitive in the Ghanaian economy, to improve the efficiency of energy use at the community level by encouraging few or no cost energy conservation measures, thereby reducing the amount of energy dollars leaving the community through high utility bills.

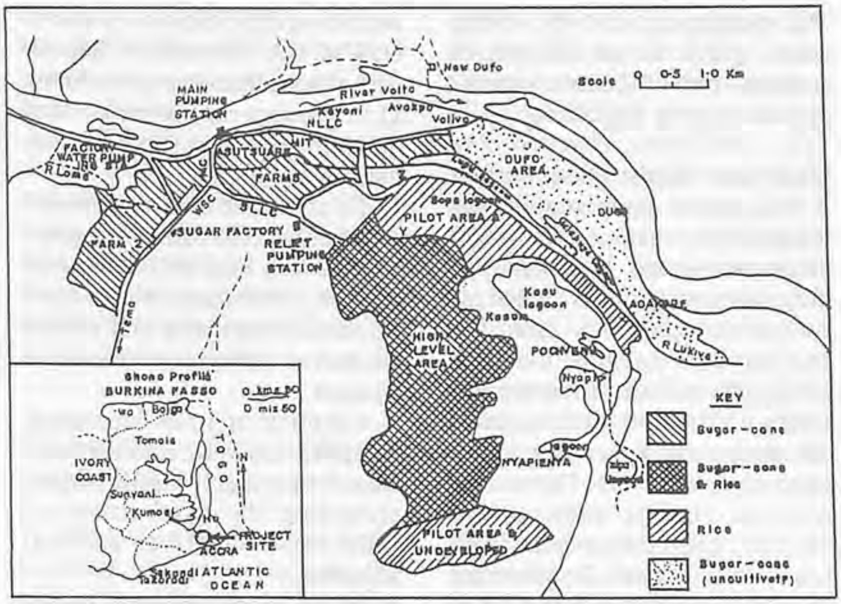

Fig. 1 Ghana profile showing the Asutsuare Irrigation Scheme, location of rice and cane cultivation.

The Study Area

The project area is shown in **Fig. 1**.

The total developed land planted to rice after the collapse of sugarcane production in 1983 is approximately 2089 ha. The causes of the collapse are outside the scope of the present paper.

At the heart of the whole project is the main pumping station with installed capacity of 4.25 m^3/s. There are five MF50-50 Kirloskar pumps from India, and these are primed by 165 kW motors each. The pumps are arranged in parallel and discharge into a 9,900 m^3 butyl lined reservoir.

The Northern Low Level Canal (NLLC) and the Main Canal (MC) **Fig. 1**; have head regulation comprising a triple-gated arrangement consisting of Neypric Avio guard gate, Neypric Avio constant downstream water level gate and a radial regulating gate. Maximum capacities of the gate are 2.8 m^3/s and 8.0 m^3/s for NLLC and the Main Canal, respectively. A separate siphonic spillway with 1.22m diameter pipe discharges directly from the reservoir into the Volta River. The Main Canal is 1275 m long and links the pump head reservoir with the regulator group serving the Southern Low Level Cannal (SLLC) and the Western Section Canal (WSC) through a 325 m rectangular flume.

The SLLC has no control or measuring structures. Flow into the WSC is controlled by a 0.76 m diameter gated pipe culvert which passes under the Asutsuare Estate road. The SLLC has approximately 2.1 m^3/s discharge and is 5822 m long while the NLLC has a discharge of 1.42 m^3/s and is 5675 m in length. The NLLC and the WSC used to serve the sugarcane farms exclusively while the SLLC serves part of the sugarcane farms at Farm 3.

The NLLC serves MIT, 293 ha, and is supposed to feed the undeveloped Dufor area 324 ha, and the WSC serves Farm 2 of 332 ha.

The SLLC serves a total area of 1451 ha divided into Farm 3, 230 ha; Pilot Area A, 491 ha; and High Level 730 ha. The total area at Pilot Area A, (491 ha) is served by two laterals (Y and Z) of the SLLC. Lateral Y is 3423 m in length and has a capacity of 0.57 m^3/s. It has a command area of 196 ha. Lateral Z is 6635 m long. A 0.62 m^3/s capacity feeds 11 sub-laterals and has a command area of 295 ha. Each sub-lateral serves a block varying in size between 21 ha and 37 ha. Each block, or, in some cases, a pair of blocks has a small night storage reservoir. Field distribution is effected by concrete division boxes with wooden checks. Field channels are either breached to admit water into the fields, or, in some cases, siphon and pipes are built through the bunds.

Surface Irrigation of Rice and Sugarcane

Generally, the controlled irrigation comprising pump irrigation and large scale gravity flow irrigation are practised in the study area.

Table 1 Volume and Cost of Irrigation Water

Year	Volume (Mm^3)	Cost (US$)
1986	17.6	112986
1987	17.8	34249
1988	17.8	9931

The decreasing cost of lifting water is due to the increase in exchange rate of the local currency (cedi) to the US dollar.

High Level Re-lift Pump Station

This re-lift pump station was designed for 4 pumps each of 850 litres per second capacity. The duty pump set (2 units) discharges 1.70 m^3/s against a head of 15.5 m, into a 1.0 m diameter manifold of an approximate length of 500 m terminating at a discharge basin and compensation reservoir downstream. The storage reservoir has a capacity of 3063 m^3. The flow is regulated by four sluice gates. Downstream flow is controlled by three 1.2 m wide Romijin Wirers. The canal length is approximately 5645 m and its discharge capacity is 1.75 m^3/s. It has a command area of 730 ha.

Energy Use

The commercial energy use pattern on the project is depicted in **Figs. 2** and **3** showing the energy utilized and the cost involved. The average yearly cost of petroleum energy used is around US$ 218/GJ, while that of electricity used in lifting irrigation water is US$ 20/GJ. This means that the cost of petroleum energy is almost 11 times more expensive than that of electricity energy supplied from the National Grid.

To offset the cost of commercial energy in the form of electricity bills and high petroleum fuel costs, it is envisaged that farmers would use more crop and animal residues as fertilizer or fuels when possible.

Adoption of straw incorporation practices will create opportunities for profitably raising output, promoting the development of skills and altering cultural attitudes.

In the many farming households in the study area, there is virtually no tradition of mixed farming. Crop and animal wastes have neither been used as a non-commercial fuel nor as fertilizer. Agricultural modernization in the form of environment controlled irrigation has, therefore, proceeded directly to energy intensive chemical fertilizer, because fertilizer have become cheap through heavy government subsidy. Chemical fertilizer presents advantages of concentration, portability, and adaptability to different soil conditions and crop requirements. The maintenance of soil fertility in the non-irrigable areas depends on practices like shifting cultivation, fallowing, crop rotation and cash cropping, especially with N-fixing legumes.

Farm Machinery

The main aspect of petroleum fuel consumption in the project is in the use of motor vehicles and farm machinery. The contributions of power-operated farm machinery to irrigated agriculture in the study area are:

1. Effective performance of heavy operation such as deep ploughing, land levelling and seeding on heavy clay soils.

2. Speedy performance of crucial operations such as tillage and planting at right time so that yields are increased and losses due to pests or weather are reduced (FAO, 1983).

In addition to the high cost of petroleum fuels, poor planning and management often lead to half the fleet of tractors being idle while the other half are operated below capacity. Spare parts are also difficult to come by.

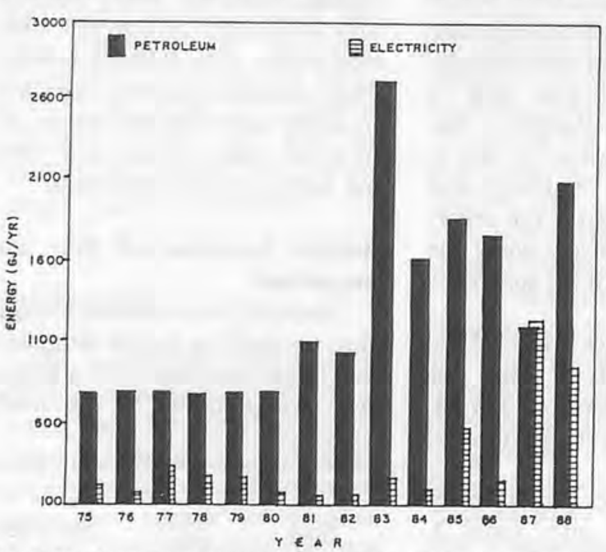

Fig. 2 Yearly commercial energy consumption on the Asutsuare Irrigation Project based on technical conversion factors used by Hunt, D.R. 1977 and Schmidt and Bodansky 1973.

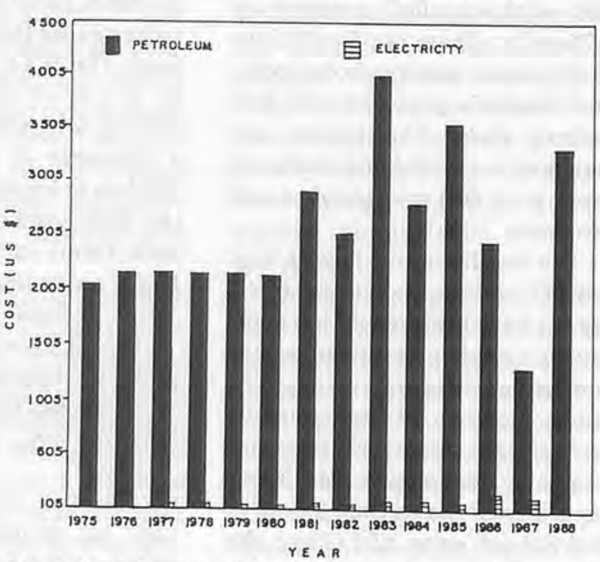

Fig. 3 Cost of commercial energy on the Asutsuare Irrigation Project.

Human Power

Labour requirements of the project involve, at times, manual broadcasting of seed and fertilizer, weed control by hand-picking, farm sanitation (bund weeding and clearing of water ways), harvesting (manual cutting and threshing), drying and winnowing. The effectiveness of machines and human power sources have been increased by combined use. Whereas mechanized power is best for tilling, levelling and seeding, human power is best for weeding, knapsack spraying and harvesting. Mechanization in the irrigation project complements rather than replaces human labour.

Solar Energy and Grain Drying

Form the works of Gowell and Agarwalla (1981) and current studies going on at the Mechanical Engineering Department of UST, Ghana, on solar radiation within the tropics, and considering ideal conditions, several areas in Ghana enjoy a good deal of solar radiation with insolation levels around 2500 kWh/m^2/yr. There is a heavy reliance on solar energy by the rice farmers in drying their grains after harvest.

Simple forms of solar rice drying take place in the fields on concrete platforms, tarpaulins and polythene sheets. The simplest method of solar drying is placing the grains on a dark surface, which absorbs incident radiation more readily than a light surface.

Wind Power

The main use of wind power on the Asutsuare project by the farmers is in the drying and winnowing of their grains to remove chaff and foreign matter. Grains at harvest usually have moisture content of 20-30% which needs to be reduced to 12-11.5% before storage.

As the moisture content must be reduced just before storage, during the process these grains are exposed to dirt contamination, to over-heating and to fungal and bacterial attack.

Rice drying is carried out during a few months of the year and the use of elaborate driers may not be economical. But some relatively inexpensive simple alternative drying equipment may be justifiable by the improved quality of the food products.

Observations and Recommendation

The project which was set up in the 1960s had demmonstrated the possibilities of successful crop raising under irrigated conditions. The total recoverable biomass fuel energy produced on the Asutsuare project over the years is shown in **Fig. 4**.

Apart from ethanol which can be used as petroleum fuel substitute, although traditionally being used in Ghana as an alcoholic beverage and bagass which has seen little utilization as a boiler fuel in the sugar factory, the bulk of the other biomass materials are not utilized in any form whatsoever. Ethanol produced on the project, if used as fuel, has a considerable energy content compared with that of both petroleum fuel and electricity combined. The average yearly energy content of ethanol produced is seen to be almost 11 times that of both petroleum and electricity used in the project. For bagass which has seen very little utilization on the project, its energy contents as a fuel compared to the total utilized energy is in the ratio of 53:1. This is an enormous amount of renewable energy which has been very seriously under-utilized. This is a classical example of "poverty in the midst of plenty". The combined energy content of rice husk and straw produced on the project is, on the average, twice the total energy supplied by both petroleum fuel and electricity.

As pointed out earlier, this potential source of energy is also left unused on the project, and this typifies the picture at the national level of biomass utilization.

It is recognized that data available are not sufficient to quantify accurately the overall energy resources and requirements and the impact of cost derived from

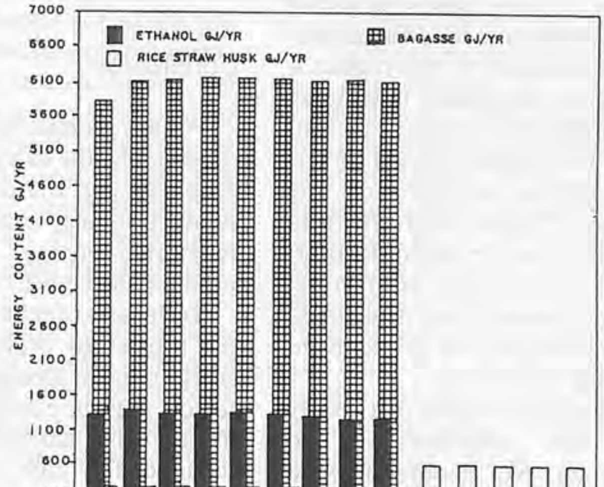

Fig. 4 Biomass production on the Asutsuare Irrigation Project based on technical conversion factors derived from many sources, including Benz and Kuttner 1987, FAO 1978, and National Research Council 1983.

energy sources in the socio-economy of the areas. An aspect of the long term measures involves intensive (renewable) energy investigation to measure the various parameters in the field and in the households.

The lack of consistent data on the interaction of energy input-output has limited research and extension personnel in generating needed information necessary to increase efficiency of energy utilization. Agricultural productivity per hectare is low in the country because of the lack of price incentives and shortage or high cost of fuel to mechanize production and move crops to market. This reminds one that to sustain the long term productivity potential of the land for agriculture increased funds are necessary. There is considerable risk that by the time energy effects upon third world agriculture become apparent, the process will be difficult to change, the study believes. There is a good reason for pin-pointing what the changes could be and doing something about them in advance to head off the damage.

The share of irrigated crops in the total volume of crop production in the study area is projected to rise. What needs to be particularly emphasized in this respect is that, given the already low energy husbandry of the project environment, the negative impact of further actions accelerating the process of waste recovery from biomass resource cannot be postponed too far into the furture. Energy concerns should be directly integrated into the development planning framework.

The study observes that energy form and versatility are also important. No amount of wind energy, for example, will propel a tractor in the field. Electricity probably has the most versatile range of applications. Liquid fuels are usually more readily transported, stored and used than solids or gaseous fuels. Sugarcane is one of the best crops for the production of alcohol fuel. It has the considerable advantage of a long history of cultivation and processing on the project and bagass from the cane provided more than enough boiler fuel for a distillery.

The importance of renewable energy is growing as it becomes increasingly evident that fossil fuel supplies are finite, politically vulnerable and can pose considerable environmental pollution problems. The key to overall economic improvement through alcohol production is the availability of capital and management both of which have been available in the project area through the establishment of the Ghana Sugar Estate Limited Factory, in the 1960s.

Research is underway to more completely characterize energy use in the Ghanaian irrigation systems. Solar grain drying wind energy for cleaning and winnowing and human energy consumption are examples of current projects.

Conclusion

For any biomass-to-fuel project to be viable, the energy in the fuel produced and the attendant by-product should exceed the non-renewable energy required to produce and convert the biomass.

Technical capability exists in the project to produce positive energy returns, though many other factors must be considered. These include the amount of water required for high crop yields, length of growing and harvesting seasons, the practicality of storage, capital and processing costs, and the potential for yield improvements.

The availability of large amounts of biomass in the project area or of undeveloped lands capable of producing it suggest the long term possibility of subtituting biomass-fuels for petroleum fuels in this area.

The study believes that energy balances alone do not provide the basis for potential for increasing rural employment and replacing imported petroleum fuels. Although available evidence suggests that the overall results may be beneficial, experience with biomass fuels is too limited to permit unequivocal conclusion.

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Experimental Verification of Impact Cutting Energy Estimated through Mathematical Modelling

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Abstract

A mathematical model was developed to estimate the impact cutting energy required in harvesting forage crops by rotary mower. Laboratory experiments were also conducted to verify the developed model for maize harvesting. A strong correlation were found between the mathematical model and experimental results, though the impact cutting energy determined from the experimental results were always less than that found from the developed model. Using this mathematical model, the power requirement of a rotary mower can be determined effectively with the help of physical parameters of the forage crops to be harvested by the machine.

Introduction

Rotary mowers are generally used in harvesting forage crops and grasses. They are simple and sturdy in construction, with less wearing parts and, therefore, the frictional power loss is minimum. The working speed and field capacity of the machine is high and there is provision for mowing, windrowing and spreading operations by the same machine with simple attachments.

In designing a rotary mower, it is essential to determine the impact cutting force/energy required to cut the crop at recommended speed of operation. According to Fisher (1967) the energy requirement for impact cutting of a crop depends on type, variety, stalk diameter, maturity and moisture content of the crop and sharpening angle of the cutter edge. The durability of the blade is also important because if any soft materials is used for the purpose, the edge becomes dull very fast. The same thing occurs in the case of hard material, too, if the sharpening angle is very small. The energy requirement for cutting the crop stem increases as the sharpening angle is increased. Hence, for efficient trouble-free operation, an optimum sharpening angle should be adopted and then the power/energy requirement for harvesting can be determined (Miller, 1968 and Chattopadhyay, 1988).

Considering the above factors, a mathematical model was developed and its effectiveness was evaluated through experimental methods in controlled laboratory condition.

Materials and Methods

Development of Mathematical Model for Impact Cutting

The different notations used in the model are given below:

- L Total height of plant, m
- h Height at which cutting is done, m
- F Maximum force required to cut stalk, N
- r Radius of stalk to be cut, m
- y Length co-ordinate along stalk, m
- X Deflection co-ordinate perpendicular to plant stalk
- X(h) Deflection at height 'h' where cutting takes place
- f Force distribution function w.γ.t. penetration, N
- K Cutting force required for unit penetration up to centre of plant stalk

In this model, the stem of the crop was considered as a uniform cantilever beam fixed at the ground in which only inertial and benching effects are considered (McRandel and McNulty, 1977). It is assumed that the cutting force 'f' increased linearly up to the centre of the stem and then remains constant up to the end of cutting. The slope of the curve indicates the amount of force required per unit penetration inside the stem (**Figs. 1(a)** and **1(b)**).

If V = Velocity of the blade at the point where it cuts

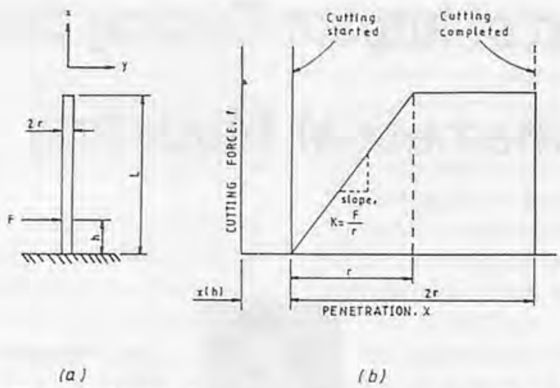

Fig. 1 (a) Model of crop stem as uniform cantilever fixed at the ground; (b) Model of force distribution as the blade penetrates the stem.

the stem, and

t = time required to cut the stem completely after bending it to the amount X(h),

then the penetration inside the stalk is given by (Vt − X(h)) and the blade makes contact with the stem at t = 0.

The maximum cutting force is given by

$$F = K\left(\frac{Vt - X(h)}{2}\right) \quad \ldots\ldots (1)$$

The segment of the stalk of length (L − h) is separated from the parent plant during harvesting. Hence, mass of the segment cut is (L − h) *p*, where *p* is the linear density of the stem in kg/m. It is assumed that the mass (L − h) *p* is concentrated at the point of impact, then,

$$F = (L-h)\,p \times \frac{d^2x}{dt^2} \quad \ldots . (2)$$

(Since, Force = mass × acceleration)

Now, from equations (1) and (2),

$$F = \frac{K}{2}\,(Vt - X(h)) = (L-h)p \times \frac{d^2X(h)}{dt^2} \text{ or, } \frac{d^2X(h)}{dt^2} + \frac{K}{2(L-h)p}\,(X(h) - Vt) = 0 \quad \ldots\ldots (3)$$

Equation (3) can be solved by using Laplace transformation which gives

$$X(h) = V\left(t - \left(\frac{2(L-h)p}{K}\right)^{1/2} \times \sin\left(\frac{K}{2(L-h)p}\right)^{1/2} t\right) \quad \ldots\ldots (4)$$

Cutting is completed when (Vt − X(h)) becomes equal to 2r, therefore

$$Vt - X(h) = 2r \quad \ldots\ldots (5)$$

Equating eqn. (4) and (5), and rearranging, it yields

$$t = \left(\frac{2}{K(L-h)p}\right)^{1/2} \sin^{-1}\left(\frac{2r}{V}\right) \times \left(\frac{K}{2(L-h)p}\right)^{1/2} \quad \ldots\ldots (6)$$

The corresponding stalk velocity $\dot{X}(h)$ is obtained by differentiating equation (4) w.r.t. t. Now from eqn. (6) and $\dot{X}(h)$ comes to

$$\dot{X}(h) = V - \left(V^2 - \frac{4r^2K}{2(L-h)p}\right)^{1/2}$$

The work done in accelerating the plant up to the time of cutting is equivalent to the bimitic energy imparted to the mass of displaced segment (L − h)*p*. Hence, energy required (Wa) to accelerate the plant is given by,

$$Wa = \frac{1}{2}\,m\left(\frac{dx(h)}{dt}\right)^2 = \frac{1}{2}\,(L-h)pV^2 \times \left(1 - \left(1 - \frac{2r^2K}{V^2(L-h)p}\right)^{1/2}\right)^2$$

The static shearing energy (W_S) is given by the area enclosed by the curve in **Fig. 1(b)**.

$$W_S = \frac{3}{2}\,Fr$$

Hence, the total impact cutting energy (W) is obtained by summing up the accelerating energy and static shearing energy, i.e., $W = W_a + W_S$

$$= \frac{1}{2}\,(L-h)pV^2\left(1 - \left(1 - \frac{2r^2K}{V^2(L-h)p}\right)^{1/2}\right)^2 + \frac{3}{2}\,Fr$$

From the above eqn. it is observed that as the cutting velocity 'V' increases, the accelerating energy as well as total impact cutting energy decreases provided that the other variables of the equation remain constant.

Experimental Determination

In the laboratory, the impact cutting energy was determined at different rpms of the rotary cutter by measuring the cutting torque with the help of a torque transducer.

Experimental Set-up

The following experimental set-up was used to determine the energy requirement for impact cutting in controlled laboratory condition (**Fig. 2**).

The rotary mower blade was fixed on the horizontal plane and was driven by a flexible shaft which received power from a variable speed motor through V-belt power transmission and bevel gear system. The rpm of the rotary blade was varied with the help of a variable speed motor. A torque transducer was placed in between the flexible shaft and the power source which sensed the torque when rotary cutter was overcom-

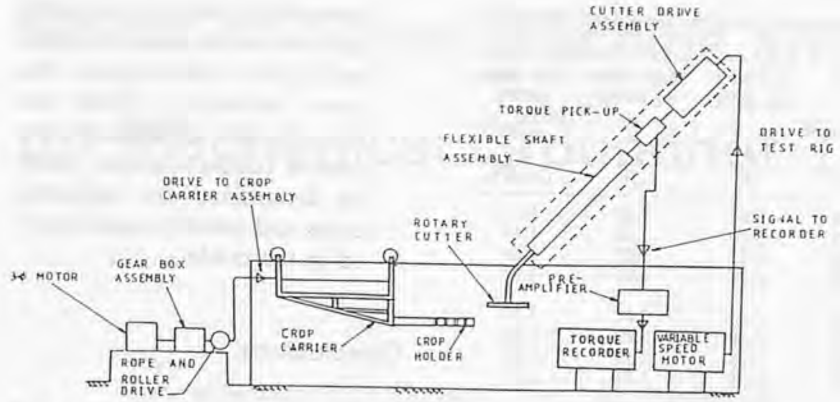

Fig. 2 Experimental set-up showing different components and instrumentation.

ing the cutting resistance offered by the plant stalk. This cutting torque was recorded on the chart of torque recorder. The actual time taken in the cutting process was determined from the pre-selected chart speed of the torque recorder.

The crop was fed to the rotary cutter with the help of a plant holder fixed on a trolley which could be moved backward and forward by a gear mechanism driven by a 10 hp induction motor.

Results and Discussion

Impact Cutting Energy from Mathematical Model

The impact cutting energy from the developed mathematical model was determined by using different physical parameters of the crop (maize). The value of the constant K was determined by measuring the shearing force from the Instroh Testing Machine for the same sharpening angle of the blade.

The estimated impact cutting energy per unit cross-sectional area required for maize stalk at 72% moisture content using the developed mathematical model is given in **Table 1**.

For a particular sharpening angle, as the cutting velocity decreased, the impact cutting energy per unit cross sectional area increased. The data indicate that the estimated cutting energy from the mathematical model were increased by 36.7 to 50.4% when the cutting velocity decreased from 13.82 m/s to 5.03 m/s.

As the sharpening angle of the blade was increased, the requirement of impact cutting energy per unit cross-sectional area also increased. At 13.82 and 5.03 m/s cutting speed the impact cutting energy per unit cross sectional area increased by 51.9 and 45.7%, respectively, when the sharpening angle was increased from 15° to 30°. However, at lower sharpening angles, the rate of increase was very slow as compared to higher sharpening angles.

Impact Cutting Energy from Laboratory Experiment

The experimental observations on the requirement of impact cutting energy by rotary cutter at different cutting velocity and sharpening angle is given in **Table 2**.

The impact cutting energy per unit cross-sectional area increased by 19.0 to 29.1% when cutting velocity was decreased from 13.82 to 5.03 m/s for the sharpening angle range of 15° to 30°. At 13.82 and 5.03 m/s cutting speed the impact cutting energy per unit cross-sectional area increased by 52.3 and 47.7%, respectively, when the blade sharpening angle was increased from 15° to 30° in steps.

The impact cutting energy determined from the experimental results was always less than that found from mathematical model. This was mainly due to the error in determining the actual contact time required to cut the plant stalk which was needed to compute the impact energy. This has occurred due to the limitation of the torque recorder which could not measure very small contact time due to comparatively lower chart speed. Hence, instead of actual contact time, theoretical contact time was considered on the assumption that the plant was stationary while cutting the plant stalk and thereby the bending effect was neglected. Hence the theoretical contact time was obviously less than actual contact time and, therefore, the experimental results were showing considerably less impact cutting energy per unit cross-sectional area.

Correlation Between Impact Cutting Energy Determined from Mathematical Model and from Experimental Observations

A straight line relationship was found between the estimated impact cutting energy from the mathematical model and that of observed from the laboratory experiment. The relationship is given by:

$E_i = 2.019 \quad E_c = -0.593;$
$R^2 = 0.92$

The value of correlation coefficient ($R^2 = 0.92$) indicates that there was a strong correlation between the mathematical model and experimental results and predicted impact cutting energy with the help of the model were fairly accurate although some correction factors are required to improve the accuracy.

The accuracy of the model can be further increased by taking the

Table 1 Estimated Impact Cutting Energy for Maize Using the Developed Mathematical Model at 72% m.c.

Sharpening angle B (degreee)	Corrected stalk dia d (cm)	Cutting velocity V (m/s)	Shearing force F (N)	Accelerating energy W_a (J)	Static shearing energy W_s (J)	Total impact cutting energy per unit C-S E_i (J/cm²)
15	1.84	13.82	249.63	0.05	3.44	1.31
	1.85	10.44	270.95	0.10	3.76	1.43
	1.80	7.54	294.30	0.23	3.97	1.65
	1.80	5.03	313.90	0.77	4.24	1.97
19	1.61	13.82	259.66	0.04	3.01	1.50
	1.70	10.44	270.95	0.09	3.45	1.56
	1.61	7.54	294.30	0.18	3.55	1.83
	1.63	5.03	304.11	0.55	3.72	2.05
22	1.62	13.82	267.54	0.04	3.25	1.59
	1.59	10.44	289.62	0.09	3.45	1.78
	1.65	7.54	313.90	0.22	3.88	1.92
	1.70	5.03	333.50	0.78	4.25	2.22
26	1.65	13.82	276.45	0.05	3.42	1.62
	1.63	10.44	298.95	0.09	3.65	1.79
	1.70	7.54	323.70	0.25	4.13	1.93
	1.60	5.03	343.30	0.72	4.12	2.40
30	1.52	13.82	312.09	0.05	3.56	1.99
	1.60	10.44	326.95	0.11	3.92	2.00
	1.61	7.54	372.80	0.29	4.38	2.29
	1.45	5.03	372.80	0.69	4.05	2.87

Table 2 Impact Cutting Energy Determined from Experimental Observations

Sharpening angle B (degree)	Corrected stalk dia d (cm)	Cutting velocity V (m/s)	Cutting torque T (N-m)	Impact cutting energy per unit C-S area E_c (J/cm²)
15	1.84	13.82	27.46	0.86
	1.85	10.44	28.45	0.93
	1.80	7.54	29.43	1.04
	1.80	5.03	31.39	1.11
19	1.61	13.82	27.46	0.99
	1.70	10.44	28.45	1.02
	1.61	7.54	29.43	1.16
	1.63	5.03	30.41	1.19
22	1.62	13.82	29.43	1.05
	1.59	10.44	30.41	1.16
	1.65	7.54	31.39	1.21
	1.70	5.03	33.35	1.25
26	1.65	13.82	30.41	1.07
	1.63	10.44	31.39	1.17
	1.70	7.54	32.37	1.21
	1.60	5.03	34.33	1.37
30	1.52	13.82	34.33	1.31
	1.60	10.44	34.33	1.30
	1.61	7.54	36.29	1.44
	1.45	5.03	37.28	1.64

following points into consideration.

i) The experiments conducted on Instron Testing Machine have established that the shearing force does not vary linearly with the penetration of the blade which was assumed in developing the model in the present study. The exact behaviour is represented by an exponential relationship. Based on this fact, the force constant should be computed and incorporated in the model.

ii) In the present model, the maximum shear force was assumed to occur at the centre of plant stalk is not always true. The exact locations, based on experiments conducted on Instron Testing Machine, could be determined for different crops and suitably incorporated in the model.

Conclusions

On the basis of the above equations and experimentally evaluated information, the functional components and the prime mower can be designed. Following the above design procedure, a rotary disc type mower has been designed and fabricated at Indian Grassland Fodder Research Institute, Jhansi and functioning successfully for harvesting berseem, lucerne and oats. In design, the factor of safety of all functional components should be considered carefully according to the variation in crop parameters and the field condition in which the machine is expected to be operated. Since the blades rotate at very high speed, the safety factors should also be considered.

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Effect of Some Machine and Crop Factors on Mechanical Groundnut Threshing

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Abstract

An experiment was conducted at the Rahad Research Station, Elfau for two consecutive seasons on a groundnut combine to investigate the effect of machine factors (pick-up cylinder speed and picking cylinder speed) and crop moisture content on header and tail losses of groundnut.

Statistical analysis showed that pod moisture content has a significant effect on header and tail losses. Losses increased substantially with the decrease in moisture content (delay of threshing). The combine pick-up speed was found to have a significant effect on header losses and a little effect on tail losses. The picking cylinder speed was found to have a decisive effect on tail losses and no effect on header losses.

Introduction

Groundnut (*Arachis hypogae* L.) is an important economic crop in the Sudan. Its average contribution to the total export value in the period 1980-1985 was between 1.7 to 18.6% (Bank of Sudan, 1985). About 15% of the total area under cultivation is irrigated, producing 40% of the total crop (Ishag, 1986). Irrigated groundnut areas in the Sudan is comprised of large government projects (Gezira, Rahad, New Halfa, and Suki) where production is mechanized at various levels. The highest mechanization levels are found in Rahad Project where about 24% of the cultivated area (27,000 ha) is mechanically dug out and about 62% of the area is mechanically threshed (Ibrahim et al., 1986).

Mechanization problems faced by these projects include: lack of spare parts, inadequate training, insufficient workshop equipment, absence of support services, poor management and maintenance of machinery, selection of unsuitable machinery and poor infrastructure (Dawelbeit and Ahmed, 1987).

The objectives of this study were to evaluate the groundnut losses in the threshing operation as affected by crop and machine parameters. Parameters considered were groundnut moisture content (or time from digging), machine pick-up cylinder speed, and picking cylinder speed. Such information should help machinery management staff and operators in performing an efficient harvest operation.

Materials and Methods

The experiment was conducted at Elfau-Rahad Research Station for two consecutive seasons (1985/86 and 1986/87). The mean annual rainfall is about 470 mm, soil is vertisolic with high clay content (50-60%), low organic matter (0.03%), and alkaline pH (8.78-9.4) (Fahal, 1984).

Equipment used included:

1. A Lilliston Model 5500 mounted digger-hasker-windrower with a 1.80 m digging width. This machine digs the plants, lifts them onto the shaker and finally places them on a windrow.

2. A Lilliston Model 1580, trailed (with pneumatic tires), PTO driven groundnut combine. This combine has eight basic operating groups (**Fig. 1**). The combine is manufactured to harvest directly from the windrow, it can be used also efficiently to harvest stacked groundnut. Five basic functions are performed by this combine. These include: pick up and feeding, picking, separation, cleaning, and conveying into a storage tank.

A split-split plot design with four replications was used. In the first season, the main plots were two levels of pod moisture content at two days and five days from digging. The sub-plots were three levels of picking cylinder speeds: 68, 75, and 80 rpm. The sub-sub plots were three levels of pick up

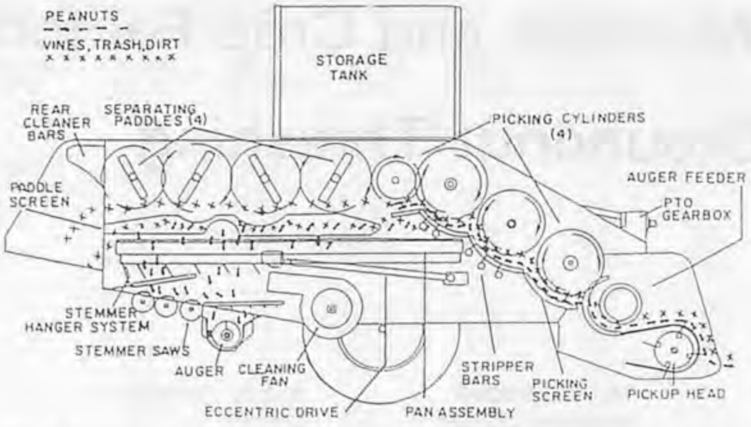

Fig. 1 Cut-away view of a typical groundnut combine (Lilliston, 1980).

cylinder speeds: 69, 88, and 97 rpm. These levels of cylinder speeds represent the high, medium, and low available sprocket combinations. In the second season change had been made on the organization and levels of factors due to some difficulties encountered in the first season. The main plots were two picking cylinder speeds 68 and 75 rpm. The sub-plots were two pick up cylinder speeds 88 and 97 rpm. The sub-sub-plots were four levels of pod moisture content at intervals of zero day, four days, seven days, and ten days from digging. These variables were factorially arranged each with four replications.

Pod moisture content (w.b.) was calculated according to ASAE standards (ASAE, 1984). From each level of moisture content four samples were taken randomly, shelled, and over dried for 6h at 130°C. Soil moisture content was determined using the standard method (oven dried at 105°C for 24 h). Soil samples from five locations of the experimental area were used to estimate the average soil moisture content.

The experimental area was disc harrowed and shaped to ridges 0.80 m wide using a ridger/lister. Planting (var. MH383) was done in the first week of June at a seeding rate of 90 kg/ha using a row planter. A pre-emergence herbicide was used, followed immediately by applying irrigtion water using long furrows. Resowing was done manually after about ten days. Nine subsequent irrigations were applied at fortnightly intervals. Plots were kept weed-free. Digging was performed 145 days from planting. The digger-shaker-windrower was used to dig all the plots at the same time. Digging losses were estimated from ten plots randomly determined from the experimental area, as pods lost in the ground during the digging operation.

Threshing losses estimated were as follows:

a. Header losses: these are pods which are left on the surface of the ground after the combine header pass.

b. Tail losses: these are pods lost with the hay thrown at the back of the combine.

c. Total threshing losses: is the sum of the header losses and the tail losses.

Combine parameters used included pick up cylinder speed and picking cylinder speed.

Results and Discussion

Data collected in this experiment was processed and an analysis of variance was performed. (More details are found in Dafalla, 1988).

Digging Losses

For the first season the mean percent digging losses were 7.7 at a soil moisture content (d.b.) of 21.1%. For the second season, mean digging losses were 8.2% at soil moisture content (d.b.) of 20.2%.

Threshing Losses

The pod moisture content, pick-up cylinder speed and picking cylinder speed affected header, tail and total threshing losses in various degrees.

Pod moisture content—In the first season the moisture content after two and five days from digging were 22.16 and 10.12% respectively. Results showed that header, tail, and total losses increased significantly (5% level) with a decrease in pod moisture content. **Fig. 2** summarizes the results showing that threshing after two days is better than threshing after five days.

Mean pod moisture content (w.b.) for the second season was 36.5. 12.1, 10.0, and 3.9 for zero day, four days, seven days and ten days, respectively. Mean percent header losses increased with a decrease in pod moisture content (**Fig. 5**). Analysis of variance showed highly significant effect (at 1% level). Results showed also that the effect of pods' moisture content was highly significant (at 1% level) on tail losses. The mean percent losses increased with a decrease in pod moisture content. Consequently, total threshing losses increased significantly with the decrease in pod moisture content.

These results are in agreement with those obtained by Bharat et al. (1976) and Young et al. (1982) who concluded that, while the pod

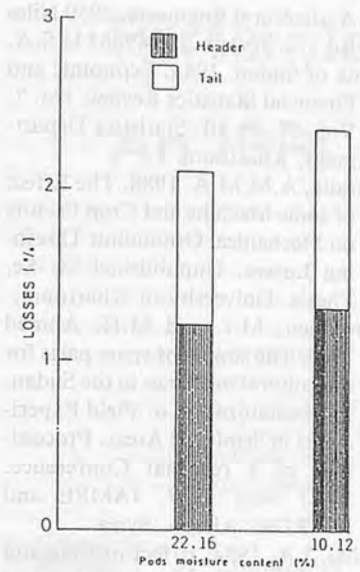

Fig. 2 Effect of pods moisture content on header, tail and total threshing losses, first season.

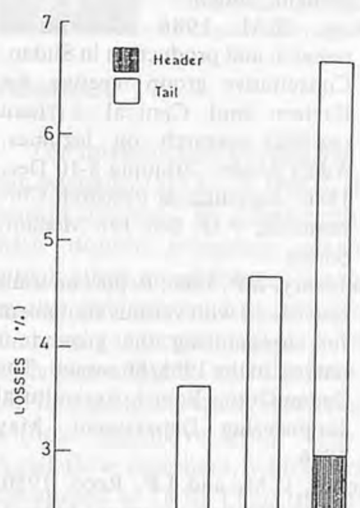

Fig. 3 Effect of pods moisture content on header, tail and total threshing losses, second season.

moisture content is reduced in the windrow, field losses increased with increased exposure in the windrow. This also confirms what

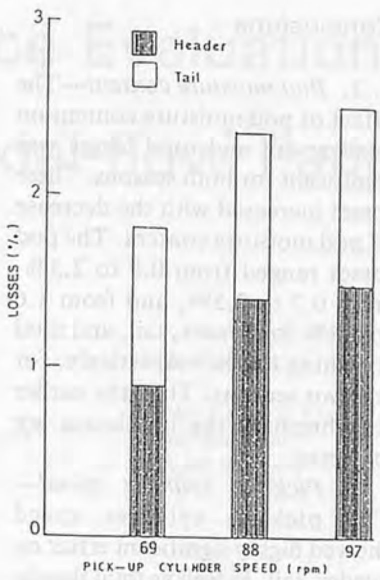

Fig. 4 Effect of pick-up cylinder speed on header, tail and total threshing losses, first season.

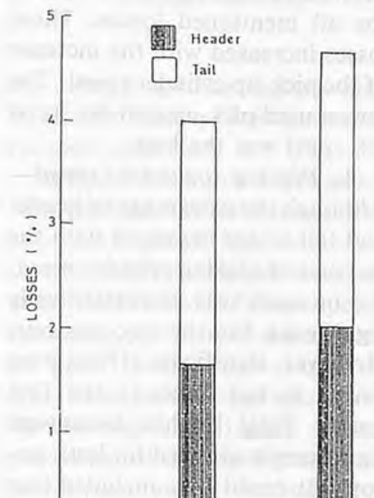

Fig. 5 Effect of pick-up cylinder speed on header, tail and total threshing losses, second season.

Pothecary (1966) stated that with picking by machine the optimum time for good threshing is 2 to 3 days after lifting, further delay meant that the crop became too dry and losses increased.

Pick-up cylinder speed—No significant effects were observed on the effect of pick-up cylinder on tail losses in the first season. However, results showed that the

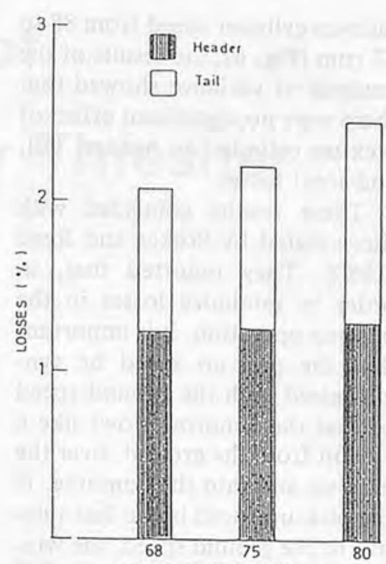

Fig. 6 Effect of picking cylinder speed on header, tail and total threshing losses, first season.

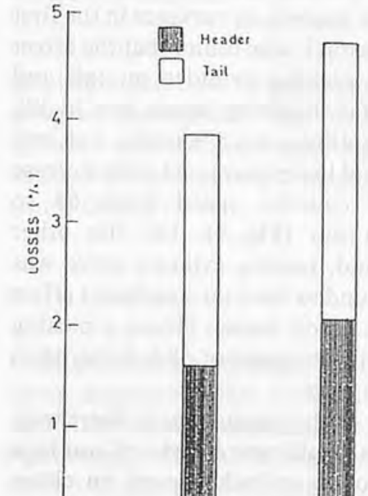

Fig. 7 Effect of picking cylinder speed on header, tail and total threshing losses, second season.

pick-up cylinder has highly significant effect on header losses as well as the total threshing losses. These losses increased with the increase of the pick-up cylinder speed from 69 to 88 to 97 rpm (Fig. 3). Hence, the best pick-up cylinder speed was 69 rpm.

Although there was some increase in threshing losses in the second season with the increase of pick-up cylinder speed from 88 to 97 rpm (**Fig. 6**), the results of the analysis of variance showed that there were no significant effect of pick-up cylinder on header, tail, and total losses.

These results coincided with those stated by Stokes and Reed (1950). They reported that, in order to minimize losses in the pick-up operation, it is important that the pick-up speed be synchronized with the ground speed so that the windrow flows like a ribbon from the ground, over the pick-up and into the combine. If the pick-up speed is too fast relative to the ground speed, the windrow will tear apart and strip the pods from the vines before they enter the combine.

Picking cylinder speed—From the analysis of variance in the first season it was found that the effect of picking cylinder on tail and total threshing losses was highly significant (at 5% level). Tail and total losses increased with increase of cylinder speed from 68 to 80 rpm (**Fig. 4**). On the other hand, picking cylinder speed was found to have no significant effect on header losses. Hence, a picking cylinder speed of 68 is better than 80 rpm.

In the second season there were no significant effects of combine picking cylinder speed on either head or tail losses. However, the percentage of pod losses increased significantly (5% level) with the increase in picking cylinder speed from 68 to 75 rpm (**Fig. 7**).

Interaction among variables—The results of the analysis of variance for interaction among all the variables studied in the experiment at all the levels for the two seasons showed no significance.

Conclusions

1. *Pod moisture content*—The effect of pod moisture content on header, tail and total losses was significant for both seasons. These losses increased with the decrease of pod moisture content. The pod losses ranged from 0.9 to 2.3%, from 0.7 to 2.5%, and from 1.6 to 4.8% for header, tail, and total threshing losses, respectively, for the two seasons. Thus the earlier the threshing the less losses are expected.

2. *Pick-up cylinder speed*—The pick-up cylinder speed showed highly significant effect on header, tail, as well as total threshing losses in the first season. However, in the second season it showed no significant differences for all mentioned losses. These losses increased with the increase of the pick-up cylinder speed. The lowest used pick-up cylinder speed (68 rpm) was the best.

3. *Picking cylinder speed*—Although the percentage of header and tail losses increased with the increase of picking cylinder speed, the increase was not statistically significant for the two seasons. However, significant effects were found in tail losses in the first season. Total threshing losses were significantly affected for both seasons. It could be concluded that the lowest picking cylinder speed used (69 rpm) was the best.

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Performance Evaluation of An IRRI Axial-flow Paddy Thresher

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Abstract

The introduction of high yielding varieties (HYV) of rice in the humid tropics, in combination with double cropping systems which allow an additional harvest in the wet season, has increased the need for mechanical threshers with high capacity and the potential to handle extremely wet paddy without extensive grain losses. Axial-flow threshers, which were developed at IRRI (The International Rice Research Institute) in the 1970s are adapted and widely disseminated throughout Asia. However, there is still need for further improvement. Many users report problems in threshing wet paddy with long straw and others complain of insufficient field mobility. Furthermore, certain thresher models cannot be used for other crops like maize which is, in the tropics, often grown in rotation with rice.

In order to improve the axial-flow concept, the performance of an IRRI axial-flow modular thresher was investigated to determine the influence of drum speed, feed rate, and louver adjustment on grain- and MOG- (material other than grain) separation over the concave length, grain losses, percentage of damaged grain, and power requirement. An inductive crop flow measurement system was developed and used to determine the path travelled by the material inside the threshing unit. A newly developed raspbar threshing drum, which had shown potential for maize shelling in initial test runs, was tested in paddy to improve the multi-crop capability of the thresher.

Evaluation of the crop-flow data helped to improve crop flow and to reduce backfeeding through the feed opening by modifying louver adjustments. The results also showed a big potential to improve the IRRI axial-flow concept by optimizing process parameters like drum speed as well as design parameters such as louver angle or threshing drum design.

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Introduction

High yielding varieties of rice have improved the yield and with their earlier maturing have significantly reduced the vegetative period of the crop. Greater crop intensification and double cropping systems as a result of the introduction of the new varieties have highlighted new problems in post-harvest operations. In double cropping systems the harvest of the first crop is often shifted from the dry season to the wet season with daily rainfalls. Harvesting of the first crop and transplanting of the second crop usually overlap. Threshing equipment with high capacity is needed in the first harvest because the time needed for harvesting and land preparation must be minimized to give the second crop sufficient growing period. Frequent rains during the wet season requires highly efficient threshing operation to take best advantage of the time of the day without rain. Since the new varieties mature unevenly, traditional field drying methods lead to extensive shattering losses. Therefore, HYVs often have to be threshed at high moisture content.

The IRRI axial-flow concept was introduced to the rice producing countries in the early 1970s (Khan, 1986). About 300 000 axial-flow threshers have since been manufactured by an estimated 1 000 manufacturers worldwide (Anon., 1990). Efforts had been undertaken to improve the thresher performance. The closed pegtooth drum, which had been used in the first models, was replaced by an open drum for higher feed rate (Anon., 1978). Ramos (1986) determined the optimum engine size while threshing rice under various crop conditions, and Ilyas (1980) analyzed the effect of design parameters on thresher performance. Nevertheless, the performance of the axial-flow threshers does not satisfy all needs, especially in extreme crop conditions and in terms of portability, as well as multi-crop threshing capability. While threshing wet paddy with long straw the threshers run very roughly and the material tends to accumulate at the end of the drum causing plugging. The available portable models are too heavy to be carried by two persons over long distances on top of the rice level banks. Finally, the multi-crop capability of the pegtooth drum is limited.

Objectives

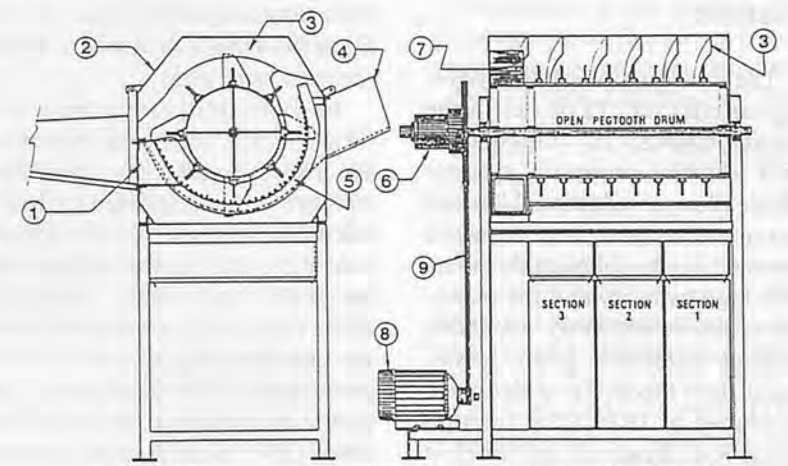
Within the scope of a cooperative research project between IRRIs' Engineering Department and Hohenheim University, the IRRI modular thresher TH11 was chosen for investigating the basic threshing and separation process, power requirement, and the crop movement to provide a database about axial-flow thresher characteristics for further modifications and developments.

Equipment

The axial-flow thresher TH11 **(Fig. 1)** used for the investigation consists of an axial-flow threshing unit which can be mounted on different cleaning systems.

It has an open axial-flow peg tooth threshing drum, a throw-in feed opening, and straw throwing paddles at the end of the drum. The angle of concave wrapping is 202°. In the first half of the concave each fourth round bar was replaced by aggressive square bars to improve the threshing process. In the second half a standard grill made of round bars is used. A semi-hexagonal cover of the threshing cylinder with spiral louvers which support axial crop transport is used for easy fabrication (Anon., 1988). The recommended drum speed is 600-640 rpm which is equivalent to a peripheral velocity of 14-15 m/s. Targeted capacity is 600-800 kg wet grain/h. Additionally, a closed rotor with short raspbars **(Fig. 2)**, which had performed promising in initial test runs using maize earlier was used for testing.

Instrumentation



1 feed opening
2 cover
3 louver
4 outlet
5 concave
6 torque meter
7 straw throwing paddles
8 electric motor
9 v-belt

Fig. 1 The IRRI modular thresher (without cleaning system) with the original pegtooth drum.

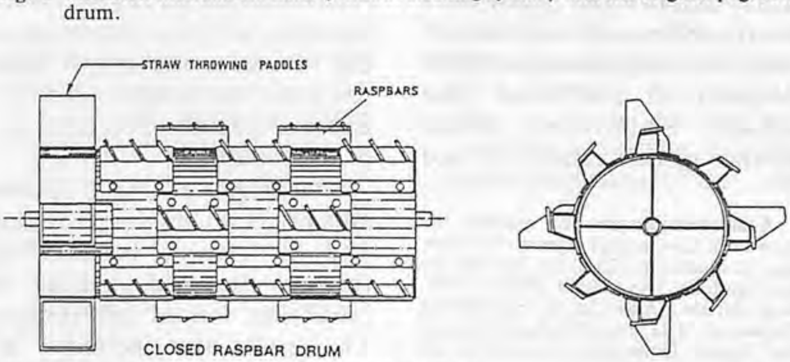


Fig. 2 Closed threshing drum with short raspbars.

For the experiments the thresher was modified as follows: To determine the separation over the length of the rotor, the concave was divided into three equal sections by metal sheets underneath the concave. Section 1 (feed section) covered the concave over the length of the feed opening, section 2 (mid section) and section 3 (outlet section) separated the rest of the concave in two equal parts (**Fig. 1**). Three removable boxes were placed underneath the concave to collect the separated material from each section. A net was used to collect the material ejected from the thresher's outlet.

To determine power requirement, a torque meter was installed instead of the original pulley. A sensor for the drum speed was integrated in the torque meter. The outputs of the torque and drum speed sensors were recorded with a yt-recorder. The unit was powered by an 4 kW electrical motor while different drum speeds were adjusted by different pulley sizes.

An inductive crop movement measuring system developed by Kutzbach (1980) and Wacker (1985) to investigate the crop movement in combines was modified to be used for the investigation. **Fig. 3** shows the basic principle.

Small magnets are used as signal transmitters. To make sure that the magnets have the same physical properties as straw, they are enclosed within a heat-shrinkable plastic sleeve. Additionally, they are attached to the straw with scotch tape. Inside the thresher bars with measuring coils replace parts of the concave in such a way that the open area of the concave is not reduced. Each of the 64 coils is connected to a sensor channel in the display unit. The display unit is equipped with an interface for a data acquisition computer. When a magnet passed a coil-bar while it travels through the threshing unit, a signal is induced in one or more of the measuring coils. Inside the sensor channel the signal is amplified and, if it is big enough to pass the schmitt-trigger, stored in two latches. The display-latch activates a light emitting diode corresponding to the location of the coil for immediate visual control. The data latch holds the signal until it is requested from the data acquisition computer where it is stored on a hard disk for analysis. Several programs for the evaluation and printing of the data were designed and coded.

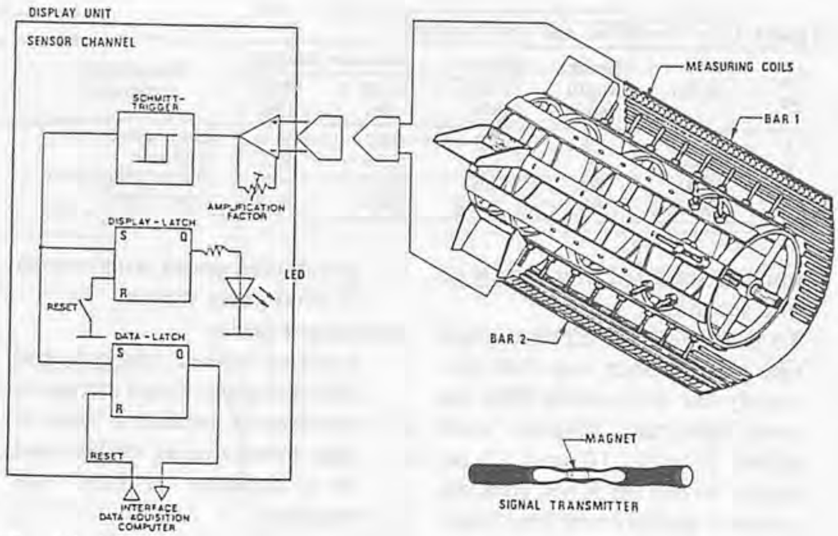


Fig. 3 Inductive crop movement measuring system.

Materials and Procedure

Threshing experiments were conducted at IRRI in Los Baños, Philippines, during the wet season from August to October 1990 (Gummert, 1991). The crop used for the test runs was paddy which was harvested by sickle at the IRRI farm. The extremely high moisture contents (grain 20.6 to 32.1% w.b., (material other than grain) MOG up to 70% w.b.) were typical for the wet season. Since all test runs of a series could not be conducted within a given single day, crop conditions where different for each series of test runs. In **Table 1** the main attributes of the crops used are listed.

The grain/MOG varied within each series of tests because the manually harvested paddy had a variable straw length. Therefore, the total feed rate (metric tons of crop fed per hour) was controlled by the experimental design instead of the output capacity (metric tons grain threshed and separated per hour). For that reason, in this paper, the determined functions for the dependent variables are plotted against feed rate instead of grain throughput (output capacity).

Four series of test runs with seven test runs each were undertaken as shown in **Table 1** to determine the effect of drum speed, feed rate, louver adjustment, and the replacement of the original pegtooth drum by a rasp-bar drum. To be able to compare the results of the series, in each series of test runs a reference setup (600 rpm, 1.4 t/h) was replicated twice using the original thresher configuration.

The duration of the test runs was 20 seconds. Two different feeding procedures were used:

- To determine the effect of drum speed the material needed for a given feed rate was arranged in 20 bundles. Magnets for the crop movement analysis were added to three of the bundles. The

Table 1 Crop Conditions and Test Parameters

Test No.	Variety	Straw length (cm)	MOG/ grain ratio	Moisture content Grain (%)	Moisture content MOG (%)	Independent parameter
1	IR72	53	2.8	32.1	66.9	drum speed
2	IR66	40	1.4	26.6	69.9	feed rate
3	IR70	60	2.6	22.5	64.4	louver adjustment
4	IR66	50	1.8	20.6	56.9	drum design

bundles were fed in intervals of one second.

- To determine the effect of feed rate the thresher was fed constantly for 20 seconds with the same feed rate. Magnets were added after 3, 10 and 17 seconds. In one set of test runs the operator fed different feed rates.

Evaluation

The following evaluation criteria were used to assess the performance of the thresher:

Total feed rate:
Total weight of fed crop in metric tons per hour.

Grain separation:
Percentage of the separated grain weight with respect to the total grain weight.

MOG-separation:
Percentage of the separated MOG weight with respect to the total MOG weight.

Purity:
Percentage of grain of a given fraction with respect to the total weight of that fraction.

Threshing loss:
Percentage of unthreshed and not separated grain with respect to total grain weight.

Separation loss:
Percentage of threshed but not separated grain with respect to total grain weight.

Broken grain:
Percentage of separated broken grains with respect to total grain weight.

Cracked grain:
Percentage of separated internally cracked (fissured) grains with respect to total grain weight.

Dehulled grain:
Percentage of partially or totally dehulled grains with respect to total grain weight.

Damaged grain:
Total of broken, cracked, and dehulled grain. Grain damage is not desired because it leads to high losses during milling and to a decrease of head rice recovery.

Power requirement:
Determined was the net power requirement of the threshing process, including the no load power requirement of the drum.

Specific energy consumption:
Energy consumption per metric ton threshed crop.

The evaluation of the grain- and MOG-separation is shown in **Fig. 4**.

After the test run the samples collected in boxes 1 to 3 were cleaned with an IRRI grain cleaner to determine grain- and MOG-separation over the concave length. The weight of grain received after cleaning the sample collected with the net manually was the separation loss and while cleaning the sample was checked for threshing loss. After mixing the grain of box 1 to 3, grain damage (brokens, cracked and dehulled) was determined visually.

Results and Discussion

General Findings

In **Fig. 5** the functions grain-separation and MOG-separation (determined within the reference test setup) are plotted against position along the length of the concave.

In the feed section of the concave more than 70% of the grain was separated while less than 5% was separated in the outlet section. On the other hand, the percentage of MOG-separation was almost the same in all three sections. As a result of that the purity of the separated material in the boxes decreased rapidly with increasing concave length (from 80% in the feed section to 20% in the outlet section). The total purity in all separated materials was 65%. Threshing loss was not found at most of the test runs. For the recommended operation conditions separation loss was less than 1%.

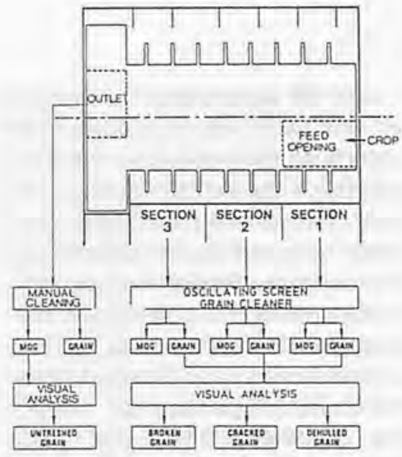


Fig. 4 Evaluation method of the function of separation over the concave length, losses, and damaged grain.

The evaluation of the crop flow data shows that the movement of the crop in axial direction was not continuous. Especially between the drum and the concave, where no leading elements like louvers caused axial transport to the outlet, the crop often moved back axially in the direction of the feed section. The number of revolutions around the drum and the retention time of the crop varied largely within the sets of test runs and even within the individual test runs. The average revolution around the drum was 7.5 and the average retention time was 3.5 seconds. All these effects were caused by the pegteeth which have no leading characteristics — a crop particle struck by a pegtooth can bounce off in any direction, depending on the angle of the struck. Because of the space

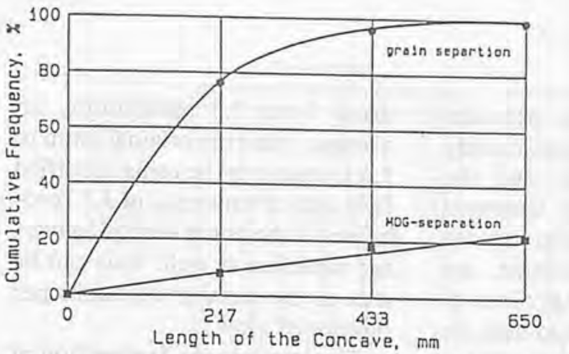


Fig. 5 Grain- and MOG-separation vs length of the pegtooth threshing drum (1.4 t/h, 600 rpm).

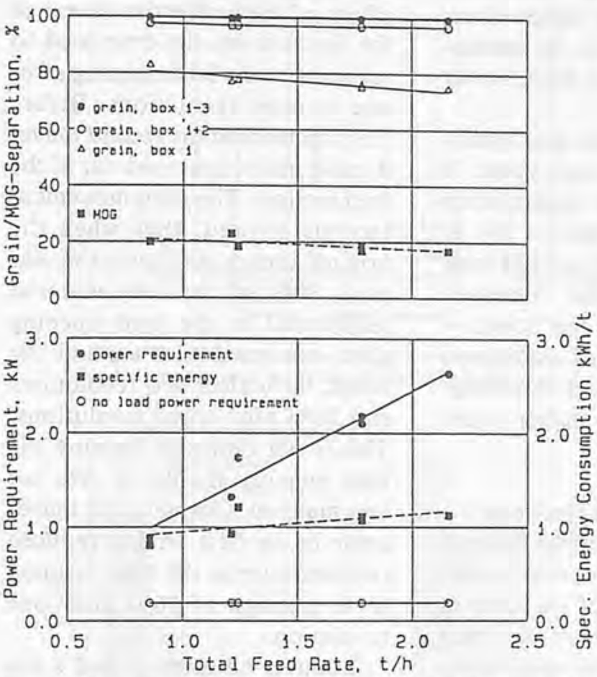


Fig. 6 Effect of total feed rate on grain- and MOG-separation, power requirement and specific energy consumption at a drum speed of 600 rpm.

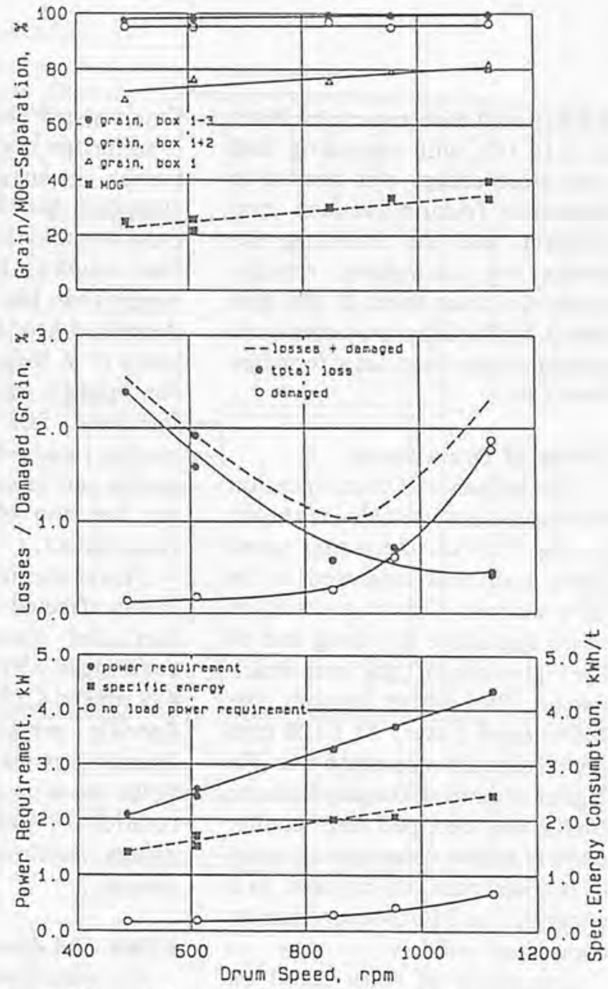


Fig. 7 Effect of drum speed on grain- and MOG-separation, grain loss, power requirement and specific energy consumption at a total feed rate of 1.4 t/h.

between the pegteeth, the relatively large concave clearance, and the big expansion of the concave clearance in the upper part of the thresher, no coherent crop mat moving around the drum was found. Observations of the outlet, where the material was ejected in bunches and not in a continuous flow, verified this assumption. These results are quite different from the findings of Kutzbach and Wacker (1980). In their investigations a crop-mat moving spirally with a constant axial pitch around the raspbar drum of axial-flow combines was determined. That means that crop flow inside an axial-flow thresher equipped with a pegtooth drum differs from crop flow inside an axial-flow thresher with a raspbar drum. Therefore, findings gained from investigating one type of thresher cannot be transferred directly to anohter type.

Effect of Total Feed Rate

The maximum feed rate at a drum speed of 600 rpm was 2.2 t/h which is equivalent to a capacity of approximately 0.7 t/h grain throughput. The distribution of the grain separation shown in **Fig. 6** changes with increasing feed rate. At low feed rates 83% of the total grain was separated in the first section. At higher feed rates grain separation in this section was reduced to 74% while more grain was separated in the second section. However, after the second section a grain separation of 97% was reached at all feed rates. The percentage of separated MOG decreased from 21% at 0.8 t/h to 17% at 2.2 t/h. Separation loss doubled from 0.34% to 0.7%, respectively, because the increased amount of material inside the concave clearance hindered the grain separation.

Feed rate affected power requirement significantly. The function for the investigated range, shown in **Fig. 6**, is approximately linear (correlation coefficient: 0.98). Doubled total feed rate led to 2.5 times higher power requirement. The specific energy consumption increased from 0.9

kWh/t at 0.86 t/h to 1.2 kWh/t at 2.16 t/h, with increasing feed rate more energy was needed to overcome friction between crop material and the threshing elements. No load power requirement at a drum speed of 600 rpm was 0.2 kW. Crop movement and retention time were not affected by feed rate.

Effect of Drum Speed

The influence of drum speed on the dependent variables is shown in **Fig. 7**. With increasing speed more grain was separated in the first section. This is a result of more aggressive threshing and of the higher centrifugal force which forced the grain through the MOG-layer faster. At 1 120 rpm the total grain separation was 2% higher than at 490 rpm. Because MOG was chopped into smaller parts at higher drum speeds, more of it could pass the concave, as a result of that MOG-separation increased as well.

The effect of rotor speed on threshing loss was negligible. Only at 490 rpm a threshing loss of 0.2% could be determined but 50% of these unthreshed grains were immature anyway. Higher drum speeds increased threshing action by more aggressive impact in a way that no significant threshing loss occurred. Separation loss decreased at higher speed because the higher centrifugal force made the grains penetrate the crop layer inside the thresher easier. On the other hand, grain damage, especially dehulled grains, increased progressively, especially beyond 850 rpm. The total of losses and damaged grain was minimum at 850 rpm. If this finding could be proved for other, especially more dry crop conditions — and for traditional varieties with higher threshing forces as well — the drum speed should be increased to 850 rpm corresponding to a peripheral velocity of 20 m/s. Drum speed could be increased even further if an economic study proves the assumption that the financial benefits of increased capacity, and thereby the reduced time required for threshing, are bigger than the monetary loss of decreased head rice yield and the costs of a bigger engine needed for higher drum speeds. The increased fan- and rotational energy required at higher drum speeds can be seen in the increasing function of no load power requirement.

Power requirement was significantly affected by rotor speed. It increased linearly (correlation coefficient 0.99) from 2.1 kW at 489 rpm to 4.35 kW at 1 124 rpm. Specific energy also increased linearly (correlation coefficient = 0.98) as a result of additional rotational-, fan-, and threshing-energy required at higher drum speeds.

Effect of Louver Adjustment

To reduce backfeeding through the feed opening and overthreshing (reappearance of the crop at the feed opening after one turn around the drum) the two louvers in the feed section from the original setup, shown in the developed view in **Fig. 8** left, were replaced by one louver with a steeper angle as shown in **Fig. 8**, middle. (A developed view is one in which the concave is in effect "unwound" to create a plane surface. This approach is used to visualize crop movement and the influence of the guide vanes or louvers). In a third setup, additionally two louvers in the outlet section were replaced by one with a steeper angle **(Fig. 8, right)** to further reduce retention time of the crop. Signal transmitter tracks of typical test runs are drawn into the developed views in **Fig. 8** with dashed lines. Modifications in louver adjustment reduced, in the first place, the number of revolutions around the drum from 7.5 revolutions, on average, using the original setup to 5.5 revolutions the using modified feed section louvers and 4.5 revolutions if the outlet section louvers are modified as well. This can be seen in the number of tracks per developed view.

The tracks in the feed section of the original louver configuration developed view show that, as an effect of the ineffective shape of the first louver, the crop used to reappear at the feed opening after one or more revolutions. Before the crop reached the second louver it could not be conveyed out of the feed section. The crop movement analysis showed, that when the original louver configuration was used, 80% of the crop material reappeared at the feed opening after one revolution around the drum, 60% after two revolutions and 20% after three revolutions. This is not desirable because the feed opening should be free for new material. Changing the louver angle in the first section reduced reappearance at the feed opening to an average of 16% after one revolution.

Loouver adjustment had a big influence on retention time and clearing time because of its effect on the number of revolutions **(Fig. 9)**.

Fewer revolutions resulted in reduced crop density inside the unit. Crop speed increased and time/revolution decreased accordingly. For the same reason, the clearing time needed to empty the thresher after feeding was stopped decreased as well.

Changes of the louver adjustment in the first section increased separation loss from 0.61% to 0.89%. Additional louver modifications in the third section increased separation loss further to 1.06%. On its way through the threshing drum the amount of material decreases with increasing threshing drum length, because the

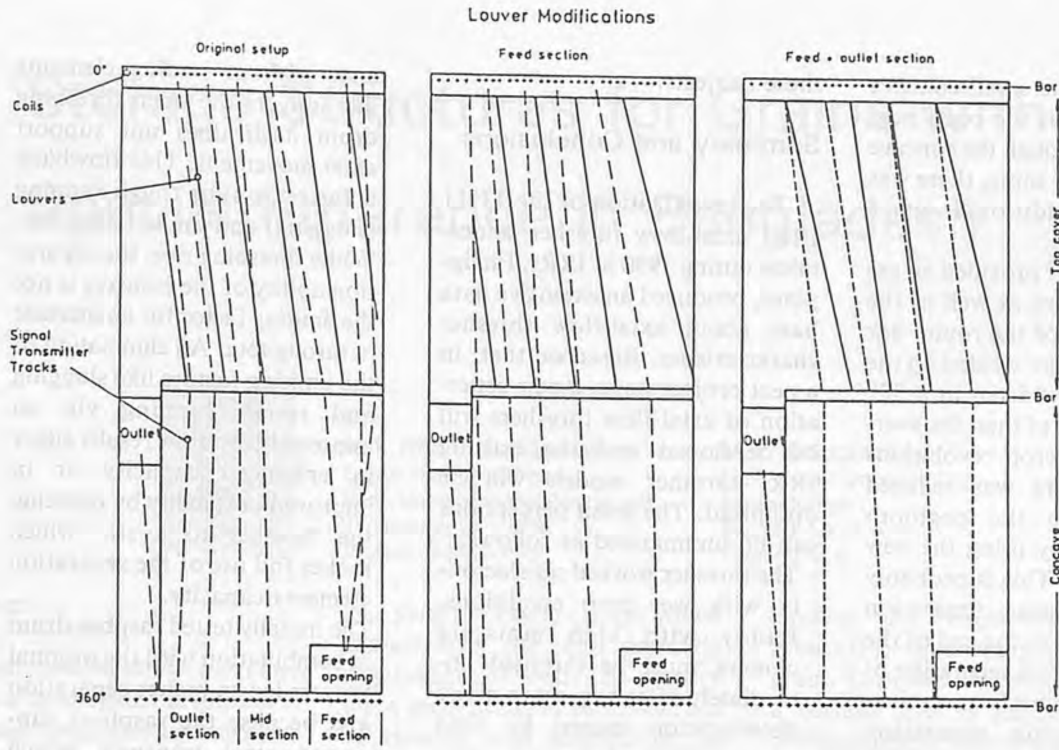


Fig. 8 Developed views with signal transmitter tracks of the original setup, with louver modifications in the feed section and with louver modifications in feed and outlet section.

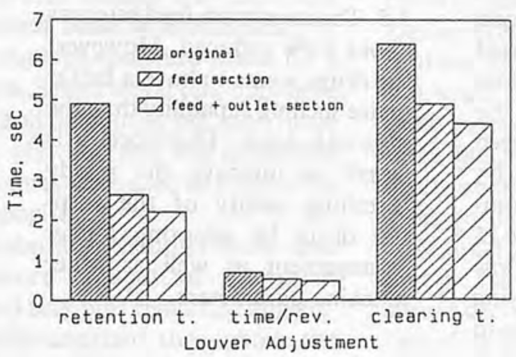


Fig. 9 Effect of louver adjustment on retention time, time/revolution, and clearing time.

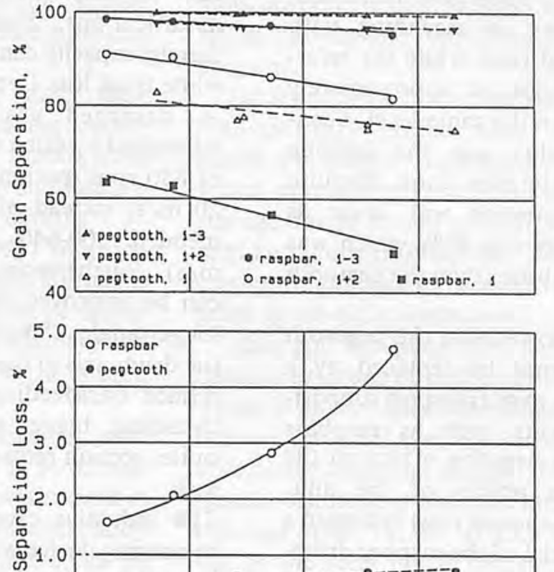


Fig. 10 Effect of the drum design on separation and separation loss.

grain and a portion of the MOG is separated through the concave. Therefore, the louvers could be installed with an increasing angle to the drum axis the greater the distance along the concave. A smaller angle at the feed section would clear the feed opening due to better axial transport and a bigger angle at the end of the drum would cause a high number of revolutions, so that the grain would have enough time to be separated. Generally, separation loss can be kept low easily by using the outlet section louvers to keep the crop longer inside the thresher.

Effect of Threshing Drum Design

The maximum feed rate of the thresher equipped with the new multi-crop drum was determined at 1.9 t crop/h. For reference, pegtooth drum maximum feed rate was at 2.2 t crop/h (Fig. 10). This may be attributed to the fact that by using the raspbar drum, the whole amount of threshing material had to pass the small concave clearance while at the open pegtooth drum. Although the concave clearance was the same, there was considerable additional space between the pegs.

The drum itself provided an axial crop movement as well as the louvers because of the round bar profiles which were welded on the ledges of the new drum in a 30° angle. As a result of that, the average number of crop revolutions around the drum was reduced from 7.5 using the pegtooth cylinder to 3.5 by using the new threshing drum. This is probably insufficient because separation was shifted more to the end of the concave. Total grain separation of the raspbar thresher was equivalent to the grain separation reached after the second section using the pegtooth drum. Accordingly, separation loss increased, its function is ascending with higher feed rates while the reference function is approximately constant on the same level. Separation ability was the limiting factor of the new drum. Because MOG separation was lower as well, purity was 87% which was about 5% better than the pegtooth purity.

This showed that the pegtooth drum cannot be replaced by a drum with axial transport supporting elements such as raspbars without a negative effect on the separation ability of the unit. However, the test runs indicated a big potential of the raspbar drum. Power requirement was the same for both drum types, preliminary tests indicated that multi-crop capability regarding maize seems to have improved, and the problems with insufficient separation can be solved by modifications in raspbar design and louver adjustment. The effects of other machine- and process parameters have not been determined yet. Investigations will be continued on these subjects.

Summary and Conclusions

The investigation of the TH11 IRRI axial-flow thresher undertaken during 1990 at IRRI, Philippines, produced an extensive data base about axial-flow thresher characteristics. Based on that, in a next project stage, a new generation of axial-flow threshers will be developed and the existing IRRI thresher models will be optimized. The main perceptions can be summarized as follows:

- The thresher worked satisfactorily with wet crop conditions. Paddy with high moisture content must be threshed immediately after harvest to avoid deterioration caused by field storage. Nevertheless, the performance of the existing TH11 can be improved by minor modifications. Feed rate and thereby capacity can be increased while total loss (separation loss + damaged grain) can be minimized by using a drum speed of 850 rpm (peripheral velocity 20 m/s) instead of the recommended 600-640 rpm (14-15 m/s). Furthermore, crop flow can be improved by modifying louver angles. Smaller angles to the drum axis in the feed section reduce backfeeding and overthreshing, bigger angles at the outlet section reduce separation loss.
- The inductive crop movement measuring device was successfully used in a rice thresher for the first time. The results show the ability of the system to accurately monitor crop flow inside the threshing unit. Monitoring crop movement with the device showed a big potential for future work. Crop flow inside the threshing unit is not continuous, material can even run back against the axial direction. Especially in the lower concave clearance without leading elements like louvers the open threshing drum itself does not support axial movement. This flowback is the reason for rough running (slugging) and limited capacity.
- While threshing rice, the separation ability of the concave is not the limiting factor for an increase in throughput. An elimination of the limiting factors like slugging and rough running via an improved crop flow results either in enhanced capacity or in improved portability by reducing the thresher to a size which makes full use of the separation elements capacity.
- The initially tested raspbar drum in combination with the original louvers led to higher separation loss because the raspbars supported axial transport which reduced the crop revolutions around the drum from 7.5 to 3.5. The maximum feed rate was about 14% reduced. However, the drum seems to have a better maize shelling capability than the pegtooth drum. Therefore, it is worth to improve the paddy threshing ability of the raspbar drum by adapting louver arrangement as well as other machine parameters.

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(Continued on page 58)

Storage Structures for Grains with Special Reference in Bangladesh

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Abstract

A comparative study was conducted to investigate the influence of storage structures and storage periods on the viability of high-moisture wheat seeds. The storage structures (sealed clay bins and plywood bins) were compared by storing high-moisture wheat for 6 weeks. Sealed metal bin, polythene bag and open (clay bin, polythene bag, plywood box and metal bin) structures were used as control for comparison.

Laboratory studies show that moisture content of grain for sealed clay bins remained approximately constant throughout the six-week period but in the other structures it decreased. On the other hand, the temperature of the grains inside the structures increased slowly during the experiment. The study also shows that for re-wetted grains with 23% moisture content, the viability fell rapidly after 2, 4 and 6 week's storage in the different structures. Among them, plywood boxes gave higher results than others.

Introduction

Rice is the staple food in Bangladesh and wheat is the second most important food crop. The yield per hectare is low which cannot meet the total domestic requirement of food. The country has a great need for economic use of existing food supplies in the form of reduction of loss during storage. Samajpati and Sheikh (1980) reported that the storage loss in different storage godowns is about 20%.

Usually, farmers store their grain in traditional storage structures like *gola*, *dole*, *matka*, steel drum, gunny bag, tin and *jala* for a period of 6 to 12 months.

Mandal et al (1984) reported that the success of grain storage is always dependent on the preservation of its food value, viability and reduction of loss of the stored grain.

Laboratory studies in two seasons in Australia at 30°C and 90-100% relative humidity held in cabinet found that rewetted paddy containing 20% moisture can be satisfactorily stored for 6 weeks at 30°C in sealed glass jars or polythene bags. The grain packed in the containers at the level of 22-50 g/100ml showed no sprouting and mould growth. These conditions produced a modified atmosphere containing 20% carbon dioxide and 10% oxygen within a week due to respiration (Wills et al, 1983).

During storage, the moisture content and temperatuve have great effect on keeping quality of grain. The moisture content above a certain level is necessary for development of micro-organisms.

Figure 1 shows the relationship of storage temperature and grain moisture content to insect heating, fall in viability and fungal heating in grain.

Under poor weather conditions high-moisture grains must be stored for safety. High-moisture grains deteriorate rapidly during storage due to mould growth, insect and mite infestations. This can be minimized by storing the grain in air-tight containers.

Muir and Wallace (1971) compared the storage of high moisture wheat in an air-tight butyl-rubber bin and a typical steel bin during a 12.5-week summer period. The mean moisture content in the butyl bin rose form 19.3% to 19.9%, but in the steel bin it decreased from 17.9% to 17.5%. In the butyl-rubber bin comparative temperature, moisture content and germination percentages at the bottom and top centers of the bin were 13°C and 28°C, 18% and 27.5%; 86% and 0%, respectively.

The actual damage on grain occurs under storage conditions of high humidity above 70% and high temperatures (25-23°C)

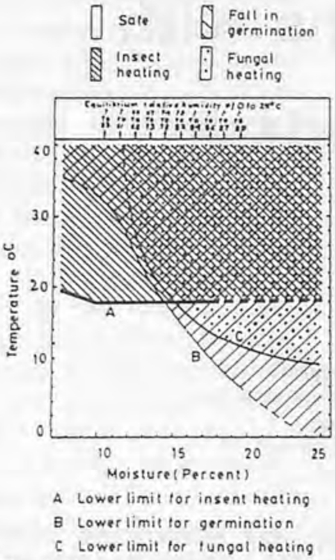

Fig. 1 Values of temperature, relative humidity and moisture content for safe storage, insect and fungal heating and fall in germination.

(Araullo, et al, 1976).

Most of the agricultural commodities always gain or lose moisture from and to ambient air until they are in equilibrium with the relative humidity of surrounding air. **Figure 2** represents the moisture contents and relative humidity equilibrium curves for different crops.

During prolonged rainy period at 85% RH the equilibrium moisture content of paddy is about 15-16%. It is very difficult to dry the grain from a high moisture level to a safe storage level with high drying cost.

In rural areas where electricity is not available, installation of artificial drier is not possible. A possible alternative is to use diesel engine instead of electric motor. However, small farmers cannot afford it. During rainy days people use covered areas and spread the grain for drying. However, by this process moisture cannot be removed quickly enough to prevent fungal growth and the result is not encouraging because the process is to fully depend on ambient conditions, particularly high humidity.

Therefore, in Bangladesh the

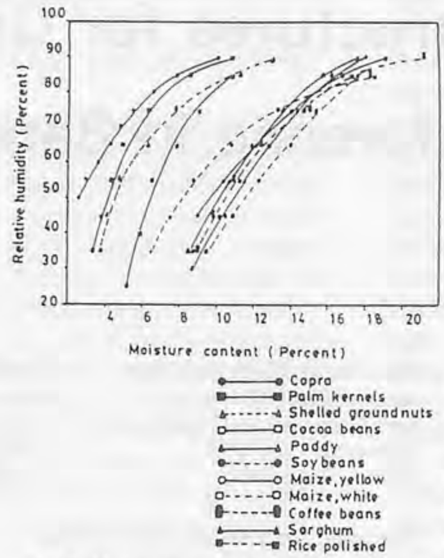

Fig. 2 Moisture content/relative humidity equilibrium curves.

losses mostly occur in *Aus* and *Boro* as the harvest is done during the rainy season.

In Bangladesh clay soil, rice husk and woods are readily available in rural areas. People can build clay-husk bins and wooden bins easily by themselves. A possible short-term alternative to expensive artificial drying is to store the high moisture grain in a modified atmosphere containing high carbon dioxide and lower oxygen levels than normal.

Therefore, the deterioration of high-moisture grain can be minimized by storing the same in the air-tight clay bin or wooden box for a short time. When sunshine is available the high-moisture grain can be dried for long term storage.

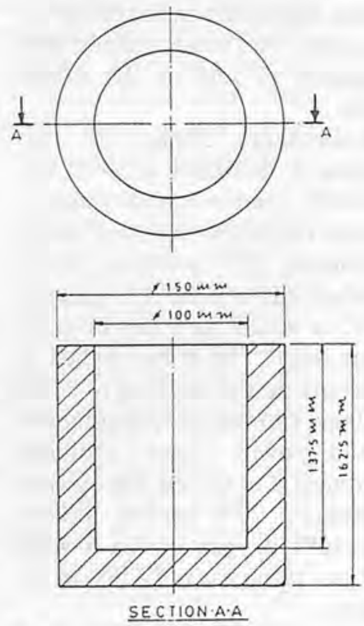

Fig. 3 Sealed clay bin.

Materials and Methods

During the experiment, clay bins, plywood box, metal bin and polythene bags were used as storage structures. The "Norman" variety of wheat was supplied by a seed certifying authority, M.A.F.F. (U.K.). The initial moisture content and germination were 12-6% and 98%, respectively.

The clay bin was made of kaolinite clay and rice husk at a ratio of 8:1 (clay: rice husk = 8.1). The moisture content of the clay bin was 1.66%. The engineering drawing of the clay bin and plywood boxes are shown in **Figs. 3** and **4**. The working seeds were re-wetted to 23% moisture content. Clay bins, plywood boxes, metal bins and polythene bags were filled with wheat seed and stored for 2 weeks, 4 weeks and 6 weeks, respectively. The seeds

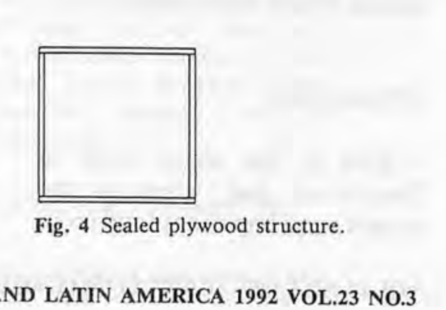

Fig. 4 Sealed plywood structure.

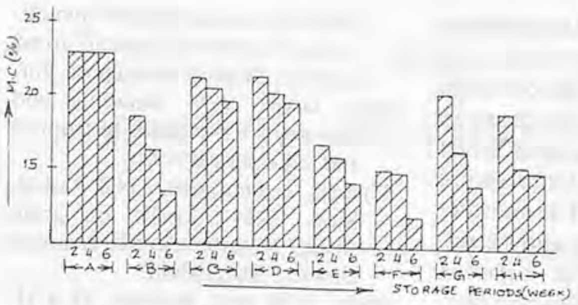

Fig. 5 Moisture content vs storage periods. A — Sealed clay bin, B — Sealed plywood box, C — Sealed metal bin (control), D — Sealed polythene bag (control), E — Open clay bin (control), F — Open plywood box (control), G — Open polythene bag (control), H — Open metal bin (control).

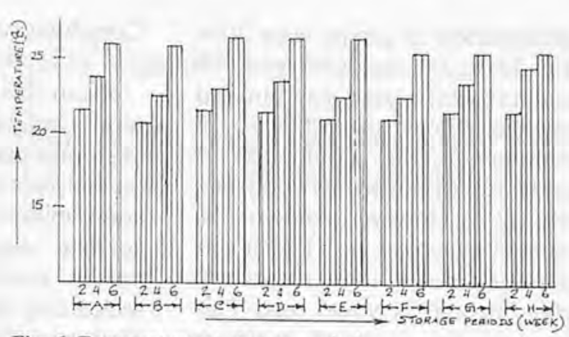

Fig. 6 Temperature vs storage periods.

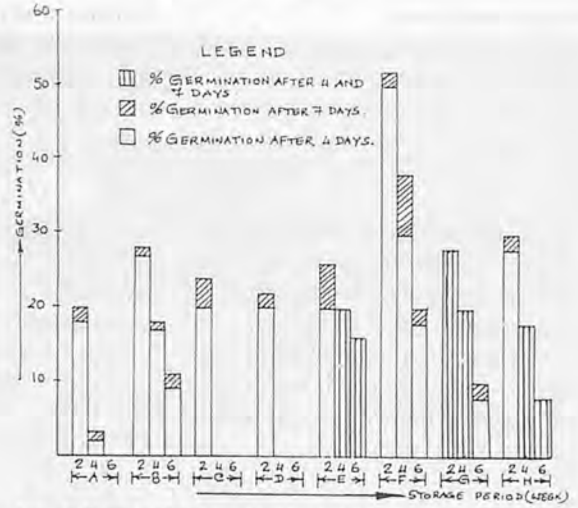

Fig. 7 Germination vs storage period.

were stored in sealed clay bin and sealed plywood box. It was also stored in sealed metal bin, sealed polythene bag, open (clay bin, plywood box, metal bin and polythene bag) structures as control.

The structures were kept in the environmental growth cabinet at 85-90% relative humidity and 25°C temperature.

Results and Discussion

In this experimental investigation, sealed clay bins and plywood boxes were used as main structures. Other storage structures were used for comparison.

The maximum temperature and relative humidity inside the cabinet ranged from 20°C to 30°C and 40% to 80%, respectively. However, attempts were taken to minimize this fluctuation of relative humidity and temperature inside the cabinet during the experiment.

After intervals of two, four and six weeks, the grains were examined from each structure for determination of moisture content, temperature, and viability of seed. The initial moisture content of re-wetted grain was 23%. After six weeks in storage, the grains from all structures lost moisture content.

Fig. 5 shows the relationship between moisture content and storage periods of seeds in different structures. The moisture content of grain for sealed clay bins throughout the storage period was constant (22.67%). Similarly, the average moisture content of grain for plywood boxes were 18.4%, 16.2% and 13.5%, respectively. The moisture loss of grain from sealed plywood boxes was higher than sealed clay bin. However, the plywood boxes absorbed moisture from the grain and released it toward the outside atmosphere.

The moisture content of grain of other control structures varied over the period of storage.

Fig. 6 shows the relationship between temperature and storage periods. The average temperatures of grain for sealed clay bins and plywood boxes were 21.5°C and 20.67°C; 23.67°C and 22.5°C and 26.33°C and 26.33°C for different storage periods. The grain temperatures of sealed clay bins were little higher than that in the sealed plywood box. The figure also shows that as the storage periods increased, the temperature of the grain also increased for different structures. This may be due to high moisture content and higher rate of respiration of grain. After determination of moisture content and temperature of grain, the representative samples were collected for germination test.

Fig. 7 represents the relationship between germination and storage periods. After four days in storage, the average germination of grains were 19% and 27%; 1% and 17% and 0% and 10% for sealed clay bin and plywood box, respectively. At the same time the grain germination of open plywood box (control) was 50%. After seven days, the average germination of grains were 20% and 28%; 3% and 18% and 0% and 11% for sealed clay bin and plywood box, respectively. In comparison, the germination of grain for the open plywood box was 52%. However, some of the control structures gave higher germination result than the sealed clay bin and plywood box. This may be due to quick moisture losses and available oxygen in the latter containers.

The grain in the sealed plywood boxes released moisture towards the atmosphere and obtained oxygen and gave a higher germination results than those in the sealed clay bins.

On the whole, the viability of grain in different structures decreased rapidly with the increase in storage period. This may be due to fluctuation of temperature and relative humidity of air inside the cabinet and higher level of grain filling of the structures.

Conclusions and Suggestions

From this study, the obtained results indicate that the duration of storage period has a great effect on moisture content, temperature and viability of seed. The moisture content, temperature and germination results differ between sealed clay bin and plywood box. However, the plywood structure provides better result than others. Further study is suggested with at least three levels of grain filling into the structure with three levels of storage period for plywood box.

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Developing the Draught Animal Power System in A Structually Adjusting Economy

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Abstract

This paper which adopts the systems approach, deals extensively with the species and breeds of draught animals, the hardware in terms of the various implements and the infrastructural subsystems. The overriding economic and financial advantages of these subsystems over tractorization are also highlighted with particular reference to the Nigerian farming system where small-scale farmers dominate.

The paper concludes that the most profitable agricultural power source for small- and medium-scale farmers is the draught animal power system. The policy relevance includes the urgent need for the introduction and subsequent development of the draught animal power system.

Introduction

The misinterpretation of agricultural mechanization as tractorization and, therefore, the subsequent establishment of highly subsidized public tractor hiring units (PTHU) coupled with other misrepresentations such as the overvalued exchange rate which made tractor and the accompanying implements easily affordable, speculations about the menace of the cattle disease - trypanosomiasis, and the dearth of highly comprehensive supportive research, to mention a few, had aggravated the lack of government support and the almost total neglect of the Draught Animal Power (DAP) system in Nigeria.

The Structural Adjustment Programme (SAP), an economic recovery programme introduced by the Federal Government in 1986, has as one of its key strategies the adoption of a realistic exchange rate. The strategy, apart from causing a sharp increase in the cost of tractors, therefore, making its use uneconomical (1), had created other problems such as incapacitation of tractor owners to maintain them due to lack of and expensive spare parts; inability of government to satisfy the already created tractor services demand brought about by the establishment of the PTHU; and high uneconomic cost of human labour used for various power intensive agricultural operations. These aforementioned problems have, therefore, necessitated a critical and urgent need for the resurgence and consequent development of the DAP system as ruminant livestock production is less affected by SAP due to the requirement of minimal imported inputs and technology (1).

However, the call for the rehabilitation and consequent development of the DAP system which is now inevitable, can only be realistic and deeply rooted after a critical review of the overriding economic and financial advantages of the system over tractorization, especially in a structurally adjusting economy like that in Nigeria. Also, mention should be made of the various developmental problems that should be combated before a full realization of the basic fact that the DAP system is easily affordable within the financial and organizational means of the small-scale farmers who constitute the majority of the farming population.

This paper, therefore, has as its basic intention a systemic review of the DAP system as suggested by Ramaswamy (2) and highlights of its advantages for the avoidance of future failure and neglect in terms of the draught animal, hardware and infrastructural subsystems. The supportive data for the various analyses and pronouncements were collected from a comprehensive survey of farmers in Bauchi State Agricultural Development Project (BSADP) area, an area noted for its DAP system development in Nigeria.

The Draught Animal Subsystem

This subsystem deals extensively with the species and breeds of animals available for draught purposes, sources and availability, age and cost of trained and untrained draught animals, work accomplishments of draught animals and various agricultural operations that these animals can perform. Draught animals are those animals domesticated by man to assist in drawing agricultural implements and vehicles as well as threshing and carrying loads. Apart from these functions, draught animals also provide fertilizer for the soil in the form of manure, yield meat, skin, bones and numerous other by-products of enormous value when slaughtered after their productive life. The popular draught animals in various countries of the world include cattle, buffaloes, horses, mules, donkeys, camels, elephants and yaks (2).

In Nigeria and indeed in the data base, cattle and donkeys are the main species of animals used as power sources. The white Fulani, a relatively docile animal, is the main breed of cattle used as draught animals although the N'dama, Wadara, Adamawa Gudali, Keteku and Shuwa breeds are also used to pull various animal-drawn implements. Donkeys are used for transportation of agricultural inputs and products to and from the farm and/or carrying other non-agricultural materials. These products are usually carried on their backs.

The acquisition of the draught animal, cattle, is usually from the Fulanis, especially during the period of migration to the South for greener pastures. At this period of transhumance, cattle are sold at very low prices, especially those that cannot withstand the migration stress. Farmers who purchase these animals are capable of feeding and taking good care of them as they possess residues of harvested crops. Farmers who are financially incapacitated to acquire draught animals usually hire from other farmers or from the local government authorities. However, hiring of draught animal is not reliable as farmers who possess also utilize them at the same time (time synchronic nature of agricultural operations) and hardly hire out to non-family members due to fear of death of the animals as a result of over-working or maltreatment.

Untrained draught animals are usually purchased at 2 — 3 years of age and later trained until they are large enough to withstand draught rigours. The costs of untrained animals vary widely depending on the age, body size and general health condition of the animal. During the data collection period, (December, 1988) untrained animals were being sold at an average price of ₦1,600* per pair while trained animals cost ₦1,720 per pair. The trained animals, which appreciate in value, are sold after their useful working life; which usually lasts 4-6 years; at an average price of ₦4,000 per pair.

The working life of draught animals depends on the age they start work and various maintenance practices. A well maintained draught animal can successfully last an average of four years before disposal. However, some animals die before the attainment of this work termination age due to overworking, underfeeding and other health hazards. This is a rather serious limitaiton as the death of a member of the pair renders the pair useless until a capable substitute is acquired. With the recommended working hours of 7 a.m. to 11 a.m. and 2 p.m. to 5 p.m. or 6 a.m. to 10 a.m. and 4 p.m. to 6 p.m., draught animals can work for an average of 5 to 6 h a day. It was estimated that a man and a team of workbulls could spend an average of 6 h to plough (ridge) an hectare of farm land, i.e., one day of active work. This estimation, however, depends on the size and age of the workbull team, soil type and conditions of the field.

With the availability of various agricultural implements, draught animals can be utilized for ploughing (ridging), harrowing, weeding along furrows, earthening-up and transportation of various agricultural inputs to the field and farm products to the market. Farmers in the data base, however, utilize draught animals primarily for ridging, earthening-up and transportation.

The Hardware Subsystem

This subsystem encompasses the various aspects of the hardware subsystem which includes the animal-drawn implements with specific attention on the types, uses, acquisition cost, life span and harnessing devices. There are various types of animal-drawn tillage tools-ridging ploughs or ox-ploughs - used for ridging and earthening-up operations. Other types of animal-drawn implements are the ox-harrow for harrowing and weeding along furrows and the ox-carts for transportation purposes. Animal-drawn implements such as trailers, sprayers, mills, and grinders are not widely utilized in the data base. Various models of the ox-plough ranging from the Ransome DY ridging plough, Ransome Emcot S-30 ridger/plough, to the newly improved multipurpose tools which include the *cossul* ridgers, *mekin* ridgers, and *peco* tools now exist. **Table 1** shows the costs of these

* Current rate of exchange is ₦7.94: U.S. $1.00.

Table 1 Costs of Animal-drawn Tillage Tools

Implements	Cost (₦) per unit
Cossul ridger	220
Emcot ridger	200
Mekin ridger	200
Arara tool bar	225
Peco tool	225
Ox-cart	220-250

Source: Bauchi State Agricultural Supply Company and Survey Data, 1988.

implements. The costs of ox-carts vary widely as most are manufactured locally from old car axles and frames.

The working life of animal-drawn implements depends on handling, maintenance and the extent of use. A well-handled and adequately maintained animal-drawn tillage implement would last for a period of 10 years or more but because of shortage of spare parts, most farmers estimated the working life to be about 8 years. Most of the repairs on animal-drawn implements are carried out by local blacksmiths who charge very reasonable prices and also substitute old and spent materials by locally made ones.

Power harnessing is accomplished by passing a rope through the nose of the animals and then tied to the horns. The mouth 'cover' (muzzle) is tied to this rope to prevent animals from devouring the crops on the field during the working period. The yokes, which are made of strong planks, have two holes each at both ends with each hole of the planks separated from the other according to the size of the animals' 'necks' with a small stick in each hole. The agricultural implement is attached to the holes at the free end of the yokes far away from the 'necks'.

Infrastructural Subsystem

This subsystem covers the training of draught animals, feeding, housing, health care facilities and credit provisions for the draught animal power system in the data base. One of the important characteristics any potential draught animal should possess is to be docile so as to settle quickly into the training routine. This routine consists of getting the animals to being led and strengthening their shoulders by dragging logs. There are two methods of training draught animals. However, training usually starts at 2—3 years old when the animals are capable of pulling weights and during the dry season when the rains are about to commence as trained animals are utilized immediately after the first rains.

The first training schedule involves taking the untrained animal to the field to observe the already trained animal while working and to watch the performance of various agricultural operations. Heavy logs, of the same weight as the ox-plough, are tied to the yoke for the draught animals to pull around. Coordination is taught the animals by making them move in straight line or make bends as the case may be. These activities are performed twice a day (morning and evening) for 2—3 weeks depending on how the animals respond to training.

Another training schedule involves coupling an untrained animal to a trained one to work together for sometime. This method, however, may not be feasible for farmers who do not possess trained animals. Farmers who cannot train the animals on their own hire labour, who assist, at an average cost of ₦6 a day. Such farmers may also purchase already trained animals.

Draught animals consume a lot of feeds which generally have little or no cash costs attached to them. These feeds are usually crop residues from the farmers' harvested crops. During the period of heavy use in the data base (late May through July), there is plenty of grazing materials in the area since the rains have begun. Feeds such as groundnut leaves (*Ganyegada*), cowpea leaves (*arawa*), grasses (*chiyawa*), guinea corn stalks (*karandawa*), millet stalks (*karangero*) and wheat offals (*dusa*) are supplied in abundance for animal feeding from the farmers' farms. However, millet stalks (*karangero*) which are harvested during rains and usually wet, are not consumed by most animals. Animals usually graze freely or are turned to Fulani herdsmen by farmers, who graze their cattle throughout the region, as farmers may not have time due to heavy engagement on the farm.

Appetisers, such as potash, (*bakinmada or kanwa*) are usually diluted in drinking water for the animals while farmers who can afford salt licks (*mandanlassa*) serve it to animals also as appetiser. Special houses are not provided for draught animals and are usually kept outside very close to farmers' huts or inside huts formerly used by the farmers. Animals are dewormed occasionally through the advice of veterinary personnel from the Ministry of Agriculture who also treat sick animals when contracted by farmers free of charge. However, necessary drugs are purchased by the farmer himself. Castration is not recommended for draught animals as castrated animals put on unnecessary fats which retard their work accomplishment. Uncastrated animals are, therefore, separated from female animals to prevent mating. Dehorning, which prevents animals from inflicting injuries on each other, is carried out using hot local knives by local blacksmiths. Branding is also carried out for identification purposes. The Cooperative Financing Agency (CFA), one of the affiliates of BSADP, provides cattle fattening loan to farmers for the purchase of draught animals.

Economic and Financial Implications of DAP System Development

Tables 2 and 3 present various requirements and costs of a draught animal power (workbull) unit and the tractor unit, respectively. Attempt was made to estimate the per ha cost of performing the various agricultural operations using both tractor and workbull in the tables. The costs per ha of the services performed by both power sources were based on the number of hours utilized to perform the various operations. The costs were derived based on the straightline depreciation method of the power source and the various implements. (3) The drivers' wages for tractor and draught animals were also taken into consideration (though drivers are employed during the planting season alone). The cost of family labour, which is usually used for draught animals, was also included.

The tables clearly show the marked differences in the costs of utilizing the two agricultural power sources. The overriding comparative cost advantage of the workbull unit over the tractor unit can also be seen. Also, as the draught animal system utilizes local resources and endowments its financial advantage over tractorization can be seen. Farmers utilize the services of these power sources comprehensively within four months of the year (May-Aug.), i.e., 960 h for tractor and 600 h for workbull. It can be inferred that more hours of idleness, i.e., 1920 h for tractor and 1200 h for workbull arise with the possession of tractor than workbull.

As inferred from the data base, yields of various crops do not depend on the agricultural power source utilized as all farmers sampled performed all the necessary land preparation operations no matter the power source possessed or utilized. The yields obtained for specific crop activities were, therefore, statistically the same. So, in as much as farmers procure other necessary agricultural inputs and sell their products at the same market, they are bound to incur

Table 2 Costs and Requirements of a Workbull or Oxen Unit

Item	Market Value 1988 (₦)	Expected Life (Years)
Pair of oxen 3-4 years old	1 600	4
20 Mandays training at ₦/day	120	
Trained oxen	1 720	4
"Used" oxen 7-8 years old	4 000	
Equipment: Ox plough	225	8
Yokes*, ropes, muzzles*, grease etc	100	2
Annual upkeep		
Annual feeding cost	1 800	
Maintenance labour 50 man-days	250	
Water	720	
Total annual upkeep cost	2 770	
Depreciation cost per year		
Plough	28.1	
Equipment	50.0	
Total	78.1	
Appreciation value of oxen = 4 000 − 1 720	= ₦2 280	
Appreciation value of oxen per year	= ₦570	
Total annual cost = ₦2 770 + ₦78.1	= ₦2 848.1	
Less appreciation value per year	= ₦2 848.1 − ₦570 = ₦2 278.1	
Number of months worked a year	= 4 months = 120 days	
Average number of hours worked a day	= 5 hours	
Daily cost of work	= ₦18.9	
Cost per hour of operation	= ₦3.8	
Number of hours used per hectare of ridging or earthening up	= 6 hours	
Cost per hectare of ridging or earthening up (workbull)	= ₦22.9	
Cost of labour during work (2 men) at ₦/man/ha.	= ₦12	
Cost of labour for an hectare for two men	= ₦12	
Full cost per hectare of ridging or earthening up	= ₦22.8 + ₦12 = ₦34.8	

* Yoke = Wooden stick (shaped piece of wood).
**Muzzle = Guard of straps or wires placed over an animal's mouth or nose.

Table 3 Costs and Requirements of a Tractor Unit (1988 price)

Item	Value (₦)	Expected Life (Years)
Tractor	150 588	10
Plough	9 900	4
Harrow	12 450	4
Ridger	9 700	4
Depreciation cost per year		
Tractor	15 058.8	
Plough	2 475.0	
Harrow	3 112.5	
Ridger	2 425.0	
Total	23 071.0	
Other costs		
Maintenance cost	805.0	
Spare parts and others	2 000.0	
Two drivers at ₦200 per driver for 6 months	2 400.0	
Fuel and oil (6 months)	522.0	
Total	5 727.0	
Total annual cost = ₦23 071 + ₦5 727 = ₦28 798		
Peak periods of operations (4 months) May, June, July, August = 120 days		
Cost per day	= ₦239.9	
Cost per hour (8 hours working day)	= ₦30	
Cost per hectare of harrowing (1 h)	= ₦30	
Cost per hectare of ploughing (2 h)	= ₦60	
Cost per hectare of ridging (1.5 h)	= ₦45	

Note: (1) Only harrowing and ridging are carried out on farm cost of using owned tractor per ha is ₦75.

the same cost and realize same revenue per ton for each crop cultivated/marketed. As workbull farmers incur lesser cost per ha of land cultivated, the gross margin of crops cultivated will be more than those of tractor farmers and would definitely make more profit.

The tables also show that the monetary value for one tractor unit can successfully acquire about 80 workbull units. Therefore, the provision of financial support for the purchase of workbulls would create a bout 80 workbull owners instead of one tractor owner and the work accomplishments of these workbull units for agricultural operations, e.g., ridging, per day (about 67 ha) would successfully override that of a tractor unit (about 5 ha). This will create more employment opportunities as more people are engaged in farming, due to reduction in drudgery which prevents most people from going into farming and the provision of more job opportunities for labourers due to the creation of other agricultural operations.

Problems and Limitations

Although the various aspects of the DAP system and the benefits derivable from the introduction and subsequent development had been highlighted, there are still some problems and limitations which should be adequately addressed if such benefits are to be realistically derivable. Some of these problems and limitations include:

(i) Lack of specialized breed of cattle for draught purposes, especially in the data base. Farmers utilize any available breed of cattle as draught animals.

(ii) Inadequacy of animals for draught purposes as the main sources of supply are the cattle Fulanis who hardly sell their cattle except during migration and due to ill health.

(iii) Lack of specialized training personnel for draught animals. The problem of having to search for training specialists often discourage some farmers from the urge to possess draught animals.

(iv) Lack of financial support to purchase the animals and accompanying implements as most of the farmers are small scale farmers with poor financial base. Also, some of these implements are 'expensive' to purchase by these farmers.

(v) Lack of adequate maintenance facilities for the various agricultural implements due to lack of and expensive spare parts and lack of motivation and adequate support for the locally trained blacksmiths to repair and even manufacture these implements.

(vi) Inadequate provision of veterinary health officers and health facilities for the treatment of animal diseases. Farmers often travel to the state capital to procure the services of health officers. This problem poses a great risk to draught animal possession due to death of animal.

(vii) Lack of adequate research in the area of power harnessing to increase the work accomplishment of the draught animals and also improve the design of the animal-drawn implements to increase efficiency.

(viii) Underutilization of the draught animals as uses are limited to the rainy season. This problem arises due to the unavailability of irrigation facilities for dry season farming and the availability of only land preparation implements which, therefore, prevents animals from performing other operations, especially weeding. This problem also results from the shortage of water during the dry season which prevents the survival of animals.

(ix) Overworking and underfeeding of animals which usually result in death of animals. The problem arises because of inadequacy of draught animals and inability of the farmers to purchase the necessary feed ingredients for adequate feeding.

(x) Low rate of tractor hire charges which discourages even large scale farmers from purchasing workbulls. Some small farmers purchase workbulls out of frustration due to inability to acquire the services of tractors at optimal time as those who acquire tractor services wield their political power.

Recommendations

Based on the present economic situation in Nigeria, the prevailing economic and financial evaluations of the DAP system and the various problems and limitations highlighted in the previous sections, the following recommendations are hereby made:

(i) The immediate awakening of government's interest in the DAP system.

(ii) The establishment of DAP system research institute to constitute researchers such as agricultural engineers, veterinary specialists, agricultural extension specialists, ágricultural economists, animal nutritionists, and crop scientists to take adequate care of areas such as training of specialized personnel for DAP training, the development of specialized breeds of cattle which can restrain all forms of diseases; health hazards; and power strains for draught purposes, the economic and financial evaluation of all the various processes and steps in DAP system development, preparation of special feeds which contain necessary ingredients for the type of work the animals perform, development of efficient power harnessing devices and animal-drawn implements with provision of locally made spare parts, development of special drugs and various forms of treatment for draught animals, and extension of various forms of institute's development to the farmers and farmers' problems to the research institute.

(iii) The provision of financial support for small and medium scale farmers for the acquisition of the various 'ingredients' of the DAP system at subsidized interest rates with imposition of favourable repayment period and sufficient moratorium.

(iv) The establishment of a special insurance programme for draught animal owners whereby at least 60% of the total cost of acquisition of draught animals are paid to farmers in circumstances of death of animal. This incentive will alleviate the problem of risk of death of animals.

(v) Provision of irrigation facilities for dry season farming and location of dams at specific points to solve the problem of water shortage.

(vi) The removal of tractor services subsidy and granting of loans for the possession of tractors. This action is long overdue as the primary objective of the government to establish public tractor hire scheme was to demonstrate the effectiveness of mechanization rather than provide a blanket tractor service with the hope that private contractors would be encouraged who, it was realized, would in the long run provide a more efficient service (4). However, the objective had been shattered as government continued to subsidize tractor hiring, therefore, making it impossible for private contractors to come into the scene and the inability of government to meet demand. Also, the fact that some farmers still purchased tractors in the face of subsidized government hire rates indicates that those subsidies are mistake.

Conclusion

Policy makers and agricultural professionals had misconstrued mechanization as tractorization in the past and, therefore, neglected the DAP system. However, the importance of the DAP system and the urgency for its modernization and development have become critical on account of the present economic dilemma in the country and the cry for self-sufficiency in food production and limited foreign economic reliance.

The paper had highlighted the various subsystems of the DAP system with particular emphasis on the economic and financial advantages of the system. It had also pinpointed some of the problems and limitations of the DAP system and made recommendations which if adequately implemented would contribute greatly to the urgent introduction and development of the system.

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Animal Traction and Farm Labour Use: A Case Study of Three Villages in Northern Ghana

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Abstract

This paper discusses the impact of animal traction technology on farm labour use in northern Ghana. The analysis is based on farm management data on 42 households, of which 12 mainly used hoes for cultivation and 30 used animal traction technology (ATT). The current ATT package in the area is limited to ridging. Comparison of the allocational patterns of labour use for both household groups indicates that ATT, as currently used, has no significant impact on the farm labour economy of the rural households in the region. It is recommended that ATT package suitable for performing other secondary farming operations (planting, weeding, harvesting and transportation) should be introduced and promoted in the region.

Introduction

As in many African countries, labour is an important resource for smallholder farmers in northern Ghana. Its allocation for cropping follows a distinct pattern usually based on sex and age of available labour, crops grown, and the type of farming operation (Panin, 1988). One of the main constraints on crop production in the region is seasonal labour shortages.

Animal traction farm technology was introduced in parts of northern Ghana in the early 1930s (Münzinger, 1982) as a means of overcoming the critical problem of seasonal labour shortages and also to increase crop production in the region. Survey results have shown that ATT farmers achieve higher crop yields and higher net farm incomes than their hoe counterparts (Panin and de Haen, 1989). Besides, investment in animal traction in the region is profitable, producing internal rates of return (IRR) of 46% and 54% for short- and medium-term periods, respectively, with equity financing and 79% and 90% with debt financing (Panin, 1989). These notwithstanding, the use of ATT can induce major changes in the labour use patterns of the traditional farmers. For example, it is possible that the employment of ATT for one particular operation may not only change its labour requirements but also benefit a particular category of household members at the expense of others. ATT's impact on the labour use patterns can be evaluated through its increasing or decreasing effects on total labour requirements per unit of farmed area, and on total input of individual labour types.

The impact of ATT is considered to be positive when the labour intensity is significantly reduced, and negative when it is increased. The differential impact of ATT on labour is hypothesized as a function of the level of ATT package in use. If the latter is highly developed, thus, offering the possibility for ridging/ploughing, planting, weeding, harvesting and transportation, the technology is assumed to be "complete". On the other hand, it is considered to be "partial" when it is limited to ridging or ploughing only. The labour reduction (or saving effect) of the complete package is likely to be great, and vice versa.

Clearly, a better understanding of the possible effects of ATT on farm labour use is crucial for developing any animal traction project. This issue, using farm management data collected from

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animal traction-using households (ATHs) and hoe-using households (HHs) in parts of northern Ghana, is addressed in this paper. The ATT sample farmers are currently using the "partial" technology which is the main package introduced in the area.

Table 1 Average Characteristics of Sample Households, N. Ghana, 1982/83

Characteristics	HH	ATH
Sample size	12	30
Age of household's head	49.3	59.0**
Wives per head of household	1.3	2.1**
Size of household	10.8	14.5**
Percent of which formerly educated[a]	8.5	9.2
Adult workers (16 – 55 yrs.)	3.8	6.1***
Cultivated area (ha)	3.6	5.6***
Percent of which ridged with AT	8.2	74.9
Acreage per adult worker (ha)	1.0	1.1
Number of cattle owned	1.5	17.3***
Households owning at least one cow or ox (%)	25.0	100.0

HH = hoe household; ATH = animal traction household
a). defined as having at least 6 years of primary education
** = $p < 0.05$, *** = $p < 0.01$

The Study Area and Data Collection Methods

The villages Nakpanduri, Sakogu and Gbingbalanchet in the Gambaga district of northern Ghana were selected as a study area because farmers there were among the early adopters of ATT. About 20% of the farming population in the area use ATT for tillage, and this is probably the highest in northern Ghana (Panin, 1988).

The district capital, Gambaga, is about 900 km from Accra, the capital of Ghana. Unlike much of northern Ghana, the population density in the study area is high. Even though the exact figure is not available, the estimated 40 persons per km^2 is higher than the average of 17 persons per km^2 for the whole region (Central Bureau of Statistics, 1984). The general infrastructure of the area, particularly the transportation network, is highly undeveloped.

Rainfall in the area as throughout northern Ghana is unimodal and averages 950 mm of which 75% falls in the main rainy season between July and September. The average monthly temperature is about 30°C, with a maximum of 33°C recorded in March. The vegetation is grassland savanna with scattered trees.

The economy of the area like the rest of northern Ghana is predominantly subsistence farming, only about 10% of the farm produce is sold. Households cultivate an average area of 4 ha (Panin, 1989). Except livestock, the capital stock of the farmers consists mainly of hand tools, grain stores and household seeds. Almost every household in the area keeps livestock of which sheep, goats, and fowls are the most common.

The distribution of cattle ownership in the area is skewed: only 25% of hoe using households own cattle (the average holding being 1.5 per household), while every household using ATT possesses cattle, averaging 17.3 per household. Common demographic characteristics of the area are: large household size, polygamous families, and a high level of illiteracy (**Table 1**). The average age of a head of a household is 49 and 59 years in the hoe and animal traction households, respectively.

The main crops of the area are millet (early and late), maize, sorghum, and groundnut which is the main cash crop. These crops are usually grown in mixtures of which corn/late millet/beans, and sorghum/beans are the most important in terms of respective cropped areas. Crop production in the area is dominated by smallholders who depend almost exclusively on family labour and mainly use the traditional hand-hoe technology.

Data for this analysis were collected from April 1982 to March 1983 (Panin, 1988). Fourty-two randomly selected farming households, of which 12 mainly used hoes for cultivation and 30 used ATT were surveyed. The ATT sample which was deliberately overrepresented, was divided into three groups according to their experience with the technology so as to evaluate the imapct of this experience on farmers' performance. It is clear that the sample size was not large enough thereby raising doubts about its representativeness. However, the homogeneity of the households reflected by their capital stock, farming technology, family size and composition, and the virtual lack of non-farm employment in the study area (Panin, 1988), implied that the potential variations in resource and enterprise combinations were very limited. This, therefore, simplified considerably the problem of selecting the representative households (Clayton, 1964; Doll and Orazem, 1984).

Data on various aspects of crop production were collected through direct measurement, observation, and formal and informal interviews. At the beginning of the growing season, each cultivated plot was mapped and measured. The collection of data on household labour allocation to each plot involved a number of visits. Daily labour inputs were recorded during tri-weekly visits of enumerators. Household and non-household labour, as well as specific operations performed by each labour type, were recorded separately. The labour record did not include time walking to and from the fields. All labour inputs recorded for each labour type were converted into man-working equivalent (ME)[1].

Effects of ATT on Labour Use Patterns

Labour input

The profile of annual total contributions of labour made by household and non-household members did not show any major difference between HHs and ATHs (**Table 2**). On average, household members contributed 83% and 85% of the annual labour used on the hoe and animal traction farms, respectively. The remaining 17% and 15% were provided by non-household members consisting of casual labourers and communal workers.

Casual labourers are paid in cash at a fixed wage for a day's work, but communal labour is recruited from the farming communities in the same village or neighbouring villages based on reciprocal arrangements. As shown in the table, communal labour is the most common among the non-household members. Its contribution to total farm labour is almost the same for both farming systems, 10% in the HHs and 11% in ATHs. The total labour inputs by casual labourers under each of the farming systems underline the virtual absence of a class of landless labour in the study area.

Labour input of household members by sex-age group

As reflected in the data presented in **Table 3**, ATT effected no major change on the patterns of farm labour inputs of individual household members grouped according to their gender and ages. In both hoe and traction farming systems, two-thirds of the labour input were from adults; children from 10-15 years contributed 17%. Labour from smaller children (6-9 years) was very low, adding as little as 5% and 3% to the input of the HHs and ATHs, respectively.

With respect to labour contributions made by men and women, ATT slightly increased those of males (69% in ATHs compared to 66% in the HHs), but reduced those of women by 4%. The mean difference was not statistically significant. However, this information indicates that mechanical innovations are capable of reducing womens' workload.

Contribution of labour by sex and farming operations

Except harvesting labour, ATT did not influence the criteria used by the traditionalist to allocate specific farm operation labour among males and females in a household. As clearly shown in **Table 4**, the more difficult farming operations such as land-clearing, ridging, mounding and weeding are exclusively male domain. More than 90% of the labour requirements for each of the aforementioned operations were contributed by males in either household.

Women, on the other hand, dominated in the share of total labour requirements for planting, contributing 65% and 70% in the HHs and ATHs, respectively. As regards harvesting labour, ATT reduced it for women from 58% to 48%, making men the major contributor in the animal-traction farming system. This change in role by men in the latter farming

Table 2 Distribution of Total Annual Farm Labour Input Among Household and Non-household Members, N. Ghana, 1982/83

Item	ATH	HH
Household members	84.9%	83.4%
Non-household members:		
communal	10.8	10.2
casual	4.3	6.4

ATH = animal traction household;
HH = hoe household

Table 3 Distribution of Total Hours Worked by Household Members according to Sex-age Group (%), N. Ghana, 1982/83

Item	HH	ATH
Age group (years):		
6-9	4.8	2.5
10-15	17.2	17.3
16-55	66.2	66.8
>55	11.8	13.5
Sex-age group		
male (years):		
6-9	3.8	2.3
10-15	13.3	14.5
16-55	38.8	43.4
>55	9.7	9.0
all male	65.5	69.2
female (years):		
6-9	1.0	0.1
10-15	3.9	2.8
16-55	27.4	23.4
>55	2.1	4.5
all female	34.5	30.8

HH = hoe household;
ATH = animal traction household

Table 4 Distribution of Labour among Household Members by Sex and by Farming Operation (%), N. Ghana, 1982/83

Farm operation	HH		ATH	
	male	female	male	female
Lnad clearing	100.0	0.0	98.6	1.4
Ridging with:				
hoe	98.5	1.5	93.9	6.1
ATT	N.A.	N.A.	100.0	0.0
Mounding	100.0	0.0	100.0	0.0
Planting	35.4	64.6	30.0	70.0
Weeding	92.5	7.6	98.2	1.8
Application of fertilizer	68.0	32.0	76.2	23.8
Harvesting	42.4	57.6	52.2	47.8

HH = hoe household; ATH = animal traction household;
N.A. = not applicable

1. The following aggregated weighting coefficients derived through observation of specific tasks performed by individual group of persons in the farming communities were used for the computation of the man-working equivalents.

Sex	Age group (years)			
	6-9	10-15	16-55	over 55
Male	0.25	0.85	1.00	0.61
Female	0.25	0.69	0.85	0.52

Table 5 Average Labour Use on Different Cropping Patterns by Technology (h/ha)

Crop mixture	HHT	ATT
Corn/late millet/beans	833.0	715.0
Groundnut/grains	751.0	903.0
Sorghum/late millet/beans	575.0	537.0
Late millet/beans	423.0	563.0
Sorghum/beans	249.0	679.0

HHT = hand hoe technology;
ATT = animal traction technology.

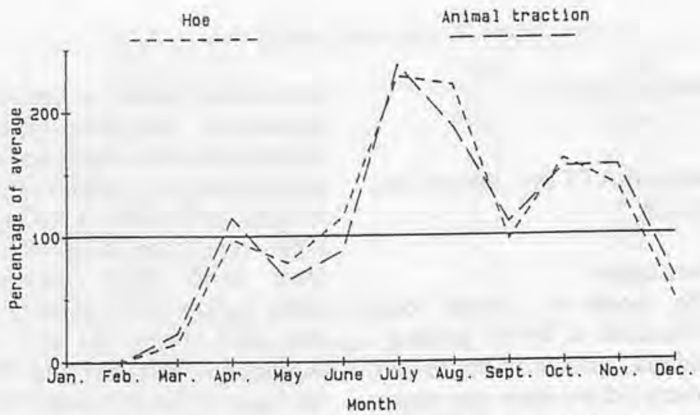

Fig. 1 Seasonal index of farm labour used per month for hoe and animal traction households.

Table 6 Average Labour Use per Farm and per Major Farming Operation, N. Ghana, 1982/83

Farming operation	HH (h/ha)	CV (%)	ATH (h/ha)	CV (%)
Clearing	39.9	80	48.4	55
Ridging	42.0	78	28.1**	40
Planting	77.6	45	69.9	43
Weeding	208.9	50	229.7	73
Harvesting	192.5	43	233.2	37
Mounding	0.3	268	3.1	175
Applying fertilizer[1)]	6.7	178	12.4	279
Total	567.9	19	624.8	38

HH = hoe household; ATH = animal traction household; h/ha = hour/hectare; CV = coefficient of variation; ** = $P < 0.05$

1) Mounding and application of fertilizer are not major farming operations in the study area. Mounding is done for yam cultivation which unlike in other areas in northern Ghana, is rare in the study area.

system might result from the overall increased yield among the animal traction farmers (Panin and de Haen, 1989).

Labour requirements of major crop mixtures

As indicated earlier on, growing crops in association is an important characteristics of the existing farming systems in the study area. The main crop mixtures and their respective labour requirements per hectare are compared for the hoe and the animal traction farming systems. Comparison of the data **(Table 5)** does not reveal a discernible trend for labour effect of ATT on the various crop enterprises. Whereas it raised the labour intensity for some crop mixtures (e.g., groundnut/grains, late millet/beans, and sorghum/beans), it reduced it for others (e.g. corn/late millet/beans and sorghum/late millet/beans).

The potential labour impact of ATT on various crops cannot be fully portrayed by just comparing their respective labour requirements on farm basis. This is due to the fact that some hoe farmers may hire ATT for ploughing some of their plots or plant them directly without ploughing. Also, it could be attributed to the possible failure of animal traction-farmers to plough all their plots with ATT, especially when the conditions of the plots do not permit the use of the technology.

Seasonality in farm labour use

As demonstrated in **Fig. 1** which presents the distribution of total labour inputs over the farming year, there is a high seasonality in labour use in the area's farming systems. Labour becomes a critical factor of production in the area, particularly during the peak periods of weeding and harvesting. Weeding is principally done in the months of July and August, and harvesting in October. In contrast, labour is underutilized during the period between January and March. From December until March there is little agricultural work in the area. Farming operations normally begin with land clearing in March, followed by planting in April.

Both ATHs and HHs experience great variations in their monthly labour inputs. The coefficient of variation in annual labour input was, respectively, 78% and 75% in the hoe and animal traction farms. This implies that ATT's contribution towards solving the problem of seasonal labour constraints in the area is insignificant.

Allocation of household labour to major farming operations

The average labour input per hectare for all major farming operations together increased with the introduction of animal traction **(Table 6)**. On average, ATHs spent 57 me-hours more than their hoe counterparts, but the mean difference was not statistically significant ($P > 0.05$). The result, which contrasts those of similar studies (e.g. Barret et al, 1982; Lassiter, 1982), tends to suggest that the adoption of the partial technology may lead to increased labour use per unit of land.

Annual labour input of each household member

The use of ATT changed the levels of labour contributions made by individual groups of household members. Nevertheless, none of the changes were statistically significant (**Table 7**). On average, men in the ATHs worked more hours than their counterparts in the HHs. The greatest increase was among elderly men (over 55 years), who worked 63% more hours. This is because of the increased demand for harvesting labour among the traction farming system. The annual labour input from boys (10-15 years) in the ATHs was 59% more than those in the HHs. This increase, which has also been identified in the studies of Norman et al (1981), is attributed to the fact that with the introduction of ATT, only the boys are used to lead the draught animals during ridging. The 16-55 year old group in the ATHs worked slightly more hours (16%) than the same age group in the HHs.

In contrast to boys and active male workers in the ATHs, girls (10-15 years) and active women (16-55 years) worked fewer hours than their counterparts in the HHs. Like elderly men, elderly women in the ATHs spent more hours working on the household farm than the elderly women in the HHs (**Table 7**). The increase is again associated with the overall increase of labour requirements for harvesting among the ATHs.

The average annual labour supplied by the heads of households was higher among the HHs than the ATHs. The variation in labour contribution of this group of workers is a function of differences in age, in consumer: worker ratio, as well as in the number of adults per household (Panin, 1988).

Table 7 Annual Farm Labour Input per Household Member by Sex-age Category, N. Ghana, 1982/83

Item	HH (h/yr)	CV (%)	ATH (h/yr)	CV (%)
Male:				
10-15 yr	142.5	158	227.0	80
16-55 yr	426.1	60	494.1	54
>55 yr	126.7	158	206.2	102
Female:				
10-15 yr	53.0	74	43.0	146
16-55 yr	229.1	69	201.6	59
>55 yr	41.1	292	75.7	146
Head of household	401.6	42	382.7	72

HH = hoe household; ATH = animal traction household;
CV = coefficient of variation; h/yr = hour/year.

Conclusions

The study of the impact of ATT on labour use patterns for cropping shows that the shift from hand-hoe technology to ATT had no significant impact on the household's farm labour economy in the study area. Whether this can be attributed to the current level of the technological package in use ("the partial technology") or not, would require further comparative studies of traction farming systems based on the two levels of ATT technological packages.

However, based on the experience in many parts of the world where highly developed ATT has been practised, it is believed that the improvement of the technological package would effect positive changes in the labour use patterns in the area. It is, therefore, recommended that the use of ATT package suitable for performing other secondary farming operations (planting, weeding, harvesting and transportation) should be introduced and promoted in a wide scale in the region. Also, institutional support systems, including credit for financing the increased capital investment costs, and training of farmers on how to use the complete technology should be emphasised in any future-animal-traction programme.

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A Mathematical Model for Repair and Maintenance Cost of Agricultural Machinery

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Abstract

A mathematical model for repair and maintenance costs of agricultural machinery is proposed. Model parameters for tractors, threshers, trailers and cultivators were found. The model estimates repair and maintenance costs, proportional to the initial cost of the machine. The model can be adopted for other machines as well as for other locations if data is available.

It is important to note that the model calculates the expected repair costs for a given machine. However, large variations can occur from one farm to another due to differences in operating practices, management of machinery, maintenance routine and machine operation.

Introduction

Repair costs contribute a major share in the operating cost of a machine. These costs are generally 10-15% of the total cost of machine operation but tend to increase with machine age (Rotz, 1985). In the first year, repair costs are almost zero as most repairs would be covered by a warranty. However, they increase as the machine becomes older. Ultimately, they attain a constant value near the end of machine life. Therefore, they are considered a main factor which influences the optimal time for machinery replacement. Its accurate knowledge is very important for calculating the ownership cost of a machine.

Repair costs include maintenance cost as well as the cost of spare parts and labour charges which are fairly low when the machine is new then continue to increase as the machine gets older. These are difficult to estimate because accurate records of repair costs over the life time of a machine are not readly available and the wide differences in repair costs exist due to variation in operating conditions, management of machinery, maintenance programme, and labour charges (Kepner et al, 1987).

A number of repair cost models already published have been discussed by Rotz (1985). He also proposed a standard model for repair costs of agricultural machinery but all these models were based on the data for machinery used in the U.S.A. Although, in general, the repair pattern of a machine with respect to its use should be similar the repair costs are very much location-specific. Labour charges as well as spare parts costs vary from place to place. Therefore, this study has been conducted with the aim of developing a mathematical model for the estimation of repair costs of agricultural machinery in Pakistan. However, this model will serve equally good for the developing countries with conditions similar to Pakistan's. Due to the limitation of data availability, only four machines, i.e., tractor, thresher, cultivator and trailer were considered for the study.

Methodology

A survey was conducted to collect the data for repair and maintenance of agricultural machinery in the study area comprising of 24 villages. The area was selected representing four major crop rotations, i.e., wheat/cotton, rice/wheat, sugarcane/wheat and wheat/sugarcane/maize. Six villages from each crop rotation were selected and five farmers among each village with different farm sizes were interviewed.

The information was gathered for accumulated use of farm machines and their respective repair costs on annual basis. In most cases, particularly for older machines, data for accumulated hours of use was not available. Therefore, the following technique used by Ward (1985) was adopted.

Each machine was grouped by age and the mean annual use for each age group together with the mean annual repair cost for that group was calculated. The annual repair costs were expressed as a percentage of the initial capital cost of the machine. The total accumulated use (TAUH) was calculated for each year group by summation of mean annual use for all years up to and including that year. The same technique was used to obtain the total accumulated repair (TAR) for each group. An appropriate equation was evolved for each machine to determine the relationship between the accumulated repair costs and the accumulated use of machine in hours by using the regression analysis.

Results and Discussion

A total of 120 farmers were interviewed of which only 84 could furnish the required information. The data was recorded for 93 tractors (some of the farmers had more than one tractor), 57 cultivators, 39 threshers and 28 trailers.

Model Development

A precise model for repair and maintenance cost is impossible to create since these costs are stochastic in nature. Standard deviations in repair cost data often exceed the mean annual values (Hunt, 1974). Rotz (1985) proposed that the typical trend in repair and maintenance costs can be best described by the following relationship:

$$TAR = A(TAUH)^B$$

Where,

TAR = Total accumulated repairs, % of the list price.

TAUH = Total accumulated use in hours, % of wear out life.

A,B = Model parameters.

Parameter B describes the distribution of repair and maintenance costs throughout the machine life while A describes the magnitude of the costs. Rotz advocate that the increase in complexity of the model is unjustified since the standard deviation of the repair cost data is often greater than the mean.

This first order exponential model predicts very low repair costs in the initial stage of machine life with a moderate increase in later life. This model also predicts a nearly constant rate of increase in the accumulated repair costs toward the end of the machine's life. Therefore, this model represents more real situation and can provide reliable estimates of the repair costs. The same model was adopted by Ward (1985).

Wear rate which varies from machine to machine can easily be accommodated in the model by varying the parameter B. As the value of B approaches 1, the annual rate of repair approaches a constant value. As its value is incrased, the repair costs are pushed more towards the later life the machine (Rotz, 1985).

By regression analysis of the data, this proposed equation was found best fit, having coefficient of determination (R) equals to

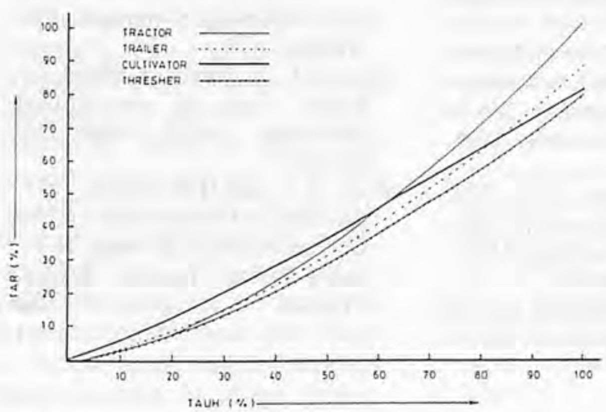

Fig. 1 Proposed model curves for tractor, trailer, cultivator and thresher.

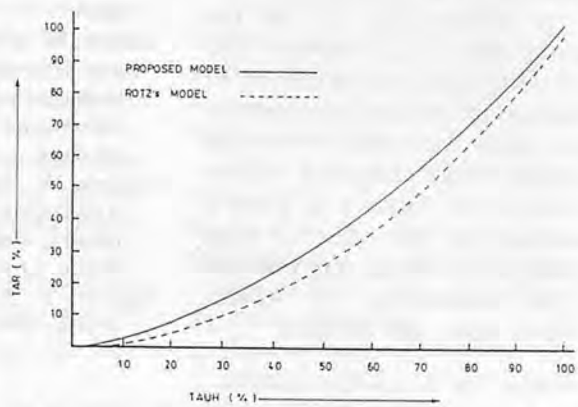

Fig. 2 Comparison of tractor repair and maintenance costs predicted by the proposed model to that predicted by Rotz (1985).

0.996 for tractors, 0.998 for threshers, 0.99 for trailers and 0.998 for cultivators.

The values of model parameters were estimated for each machine and the following equations were developed which are presented in **Fig. 1**:

for tractor

$$TAR = 0.0669 (TAUH)^{1.592}$$

for thresher

$$TAR = 0.0936 (TAUH)^{1.465}$$

for trailer

$$TAR = 0.0927 (TAUH)^{1.488}$$

for cultivator

$$TAR = 0.3840 (TAUH)^{1.164}$$

Model Verification

In order to verify the results obtained with the proposed model, a comparison was made between this model and the model developed by Rotz (1985) for tractors. The proposed model reflected similar trend as that the Rotz's (**Fig. 2**). After comparison, it is concluded that the repair and maintenance costs for tractors are slightly higher in Pakistan as compared to those in the USA. As depicted in the figure the total accumulated repair and maintenance costs at 60% usage life are 9.3% higher compared with the cost calculated by Rotz. This may be attributed to poor management, inadequate repair facilities, and unavailability of spare parts, particularly in remote areas.

A comparison of all the parameters, i.e., wear-out life, total life repair cost in percent of initial price, A and B calculated in this study were made with other studies already conducted which is shown in the **Tables 1**, **2**, **3** and **4**, respectively. The values of these parameters compare very well with those determined by ASAE, Ward, Rotz, and Bowers.

Table 1 Estimated Hours of Wear-out Lift

Machine	Value assigned in this study	Ward et al 1985	Rotz 1985	ASAE 1985	ASAE 1974	ASAE 1966	Kepner et al 1978	Bowers & Hunt 1970
Tractor (2WD)	12000	12000	10000	10000	12000	12000	10000	12000
Cultivator	3000	—	2000	2000	2500	2400	2500	—
Thresher	6000	—	—	—	—	—	—	—
Trailer	3000	—	—	3000	2500	—	5000	—

Table 2 Total Life Repair Cost Expressed in Percent of the Machine's Initial Cost

Machine	Value in this study	Rotz 1985	ASAE 1985	ASAE et al 1974	Kepner & Hunt 1987	Bowers 1970
Tractor (2WD)	100	100	120	120	100	120
Cultivator	80	80	80	120	120	—
Thresher	80	—	—	—	—	—
Trailer	88	80	80	100	90	—

Table 3 Value Determined for the Model Parameter 'A'

Machine	Value assigned in this study	Ward et al 1985	Rotz 1985	ASAE 1985	ASAE 1983
Tractor (2WD)	0.0669	0.042	0.01	0.012	0.029
Cultivator	0.3840	—	0.30	0.300	0.360
Thresher	0.0936	—	—	—	—
Trailer	0.0927	—	0.19	0.190	—

Table 4 Values Determined for the Exponent of a Power Model (B) Describing Repair and Maintenance Cost of Agricultural Machinery as a Function of Machine Use

Machine	Value assigned in this study	Ward et al 1985	Rotz 1985	ASAE 1985	ASAE 1983	Farrow 1980	Hunt 1974	Bowers & Hunt 1970
Tractor (2WD)	1.592	1.895	2.0	2.0	1.5	1.49	2.03	1.6
Cultivator	1.164	—	1.4	1.4	1.3	1.74	1.40	—
Thresher	1.465	—	—	—	—	—	—	—
Trailer	1.488	—	1.3	1.3	—	—	—	—

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Towards Self-sufficiency in Agricultural Machinery Production in Iran

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Abstract

An impact study on the self-reliance policies adapted by the Government of Iran in relation to the indigenization of agricultural machinery production was conducted. The data were collected from a number of types of new machineries brought to the Agricultural Engineering Research Testing and Training Center (AERTTC) at Karaj for tests and issue of approval certificates between 1967 and 1989.

During an eight-year period (1980-87), Phase II, a yearly increase of ten-fold was recorded as compared to the first 13 years (1967-79), Phase I. Since the introduction of incentive scheme in 1987 for industry, Phase III, the number of new designs tested doubled in a two-year period (1988-89) compared to Phase II or a twenty-fold increase over Phase I. Furthermore, major increases were recorded in tillage (20%); crop protection (19%); post-harvest (8%); and irrigation equipment (8%) designs.

Introduction

Agricultural mechanization is not only agricultural technology but is usually the most visible and easily recognized form of technological change in the rural areas of developing countries. Therefore, the amount, type and level of mechanization must reflect the need for more than an increase in the agricultural productivity on the farm (FAO, 1984).

Research and development of agricultural machinery and the resultant agricultural mechanization activities must be oriented towards the following objectives as earlier stated by Choudhary (1989):

1) To better utilize soil and water resources in order to achieve optimum plant population and crop yields.
2) To increase productivity through cost-effective use of seed, fertilizer, pesticides and labour.
3) To reduce on-farm drudgery.
4) To minimize post-harvest losses.
5) To assist in indigenisation of machinery manufacture.
6) To assist in standardization of machinery.

Undoubtedly, the overall purpose of the above mentioned activities is to help improve the cash flow of the farmers which will have flow-on effect on other sectors of human endeavour.

The Agricultural Engineering Research, Testing and Training Centre in Iran was established in 1961 as a regional centre to provide facilities in the field of agricultural engineering to post-graduate students from Iran, Turkey and Pakistan.

The centre was expanded in 1969 to undertake other activities such as research and development on agricultural machinery and modern irrigation techniques.

Over recent years the training component of the centre has been administratively separated from the research and testing activities.

The AERTTC has the following main objectives:

1. Testing and evaluation of different kinds of tractors and implements.
2. Design and building prototype equipment.

3. Comparative tests of different kinds of machinery.
4. Experiment on dryland machinery.
5. Study, modifications and adoption of imported and locally-manufactured machinery.

Objectives of Machinery Testing

Agro-climatic conditions vary from country to country and within a country. The level of awareness among farmers about technology is very much dependent on their level of technical education, economic conditions and social structure. Hence, it is important that both locally-manufactured and imported equipment must be tested for their conformity to local agro-ecological conditions, technical standards, durability and local safety regulations and laws in a country.

Testing and evaluation under standard codes allow easy interchangeability of parts among machines and help in economy of scale for mass production. Furthermore, it allows countries to protect themselves from becoming dumping ground for unsuitable and unwanted imported implements.

Test Procedure and Codes

In order to compile laboratory and field test observations in a meaningful and comparative manner, and to upgrade the test methods, standard codes are necessary.

At the AERTTC a combination of Nebraska, Silsoe, RNAM and Iranian National Standard Codes are followed. Testing and evaluation encompassing laboratory and rigorous field testing are followed in a procedure shown in the **Fig. 1**.

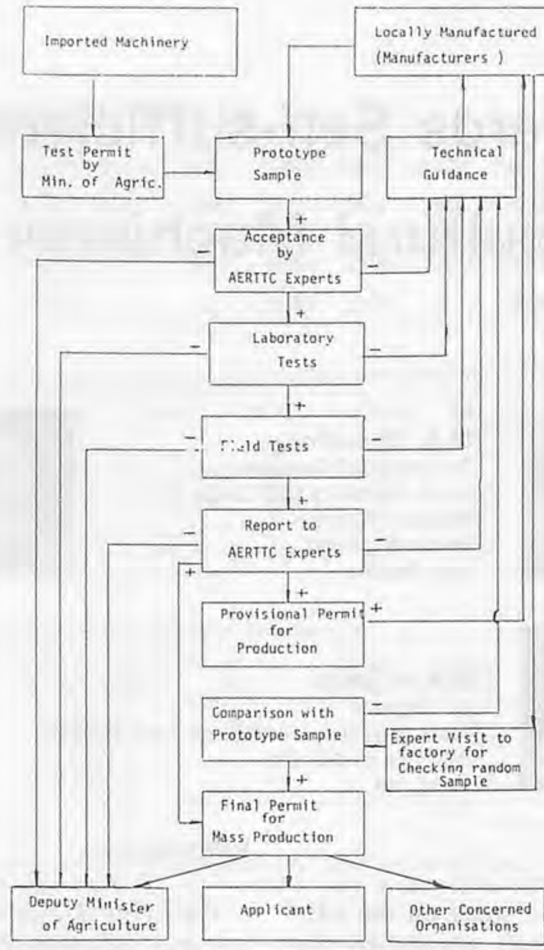

Fig. 1 Schematic procedure chart for testing of agricultural machinery at AERTTC.

Categories of Machinery Tested at AERTTC

Table 1 shows 15 broad categories of machineries and implements which have been tested and evaluated at the AERTTC between 1967 and 1989. Within each category the list of implements tested gives only a general guide and it is by no means an exhaustive list or description of the type of equipment. The development of agricultural machinery by the private manufacturers which reflect a general trend towards mechanization in Iran can be distinctly

Table 1 Categories of Agricultural Machinery Tested at AERTTC

Sector	Equipment/Implement
Tillage	Mouldboard, disc. chisel plough, cultivators, rotavator, harrows
Seeding and planting	Seed drills, planters, transplanters
Plant protection	Booom sprayers, knapsacks, orchard sprayers, sprayer pumps
Fertilizer spreaders	Tractor-mounted broadcasters
Grain harvesting	Windrowers, binders, combines
Land development	Ridgers, ditchers, levellers, stone pickers, loaders
Fodder harvesting and conservation	Mowers, choppers, hayrake, balers
Animal production	Milking machines, chillers, poultry feeding
Transportation	Trailers, wagons
Water pumps and Irrigation	Pumps, sprinklers, drip, trickle
Root and tuber harvesting	Potato diggers, beetroot lifters
Tractor and prime movers	Double and single axle tractors
Post-harvesting	Cleaners, graders, threshers
Hand tools	Sickles, pruning scissors
Others	Twines, chain saw, tea leaf picker, power prunners

Table 2 Categories and Numbers of Agricultural Machinery and Implements Tested at AERTTC during 1967-1989

Sector	Phase I													Phase II								Phase III		Total	Percent
Year	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89		
1. Tillage				3	3	1			1		2	1	5	4	12	4	9	13	28	12	5	14	25	142	20
2. Seeding and planting				2	2	3	3		1	1		1					1	2	4	3	3	7	8	41	6
3. Plant protection				2	1	3									9	8	27	11	8	11	11	13	31	135	19
4. Fertilizer spreader				1			1							1	3	3		1	4	5	5	1	6	30	4
5. Grain harvesting		1			1		1		1			1		2	1	1	2	1		1		2	3	20	3
6. Land development					1				1						8	2		4	4	4		4	2	30	4
7. Fodder harvesting and conservation				1											2	3	3	1	5	5	4	7	7	38	5
8. Animal production														1					5	7	1	3	3	20	3
9. Transportation															1			2	4	13	4	5	13	42	6
10. Root harvesting							1		2		1			1			3	3	4		5	4	2	26	4
11. Water pumps and irrigation equipment															1	1	2	2	3	8	6	16	16	55	8
12. Tractors	3	1	2	3		1	3					1	1		4	4	2							25	4
13. Post harvest machinery														8		6	8	4	7	4	5	4	11	57	8
14. Hand tools								1							1			1	3	3	6	4	4	23	3
15. Others						1		3		1	1				7		2	1	2	2	2	3	5	30	4
Total	3	2	2	12	8	9	9	4	5	5	4	4	6	17	49	31	59	46	81	78	57	87	136	714	100
	Total (1967-79) = 73													Total (1980-87) = 418								Total (1988-89) = 223			

defined in three phases **(Table 2)**. Phase I: Pre-revolution (1967-79), Phase II: Policy of self sufficiency (1980-87), and Phase III: Financial incentives scheme for quality and certified machinery (1988-to date).

Phase I: Pre-revolution (1967-79)

During this period of the AERTTC, majority of the machinery and implements brought forward for testing and evaluation at the centre were imported. Only a few were locally manufactured. The total number of machines tested during 13 years were 73, a meagre 5.6 machines/year **(Table 2)**.

Furthermore the types of equipment were limited to tractors and some tillage, seeding and grain harvesting (reapers, binders) machinery. However, the change of Government in Iran in 1979 and the outbreak of war in 1980 changed all this.

Phase II: Policy of Self-sufficiency (1980-87)

The austerity measures and declaration by the Government of the policy of self-reliance acted as a blessing in disguise for the local agricultural machinery manufacturing industry. This had a tremendous positive impact on the indigenization of the industry despite many forthcoming difficulties due to the shortage of appropriate raw materials, foreign exchange availability and overseas trade restrictions.

During Phase II, a ten-fold increase was registered in the development of new and locally adopted versions of the imported machinery which were referred to the AERTTC for testing and certification **(Table 3)**. By far the biggest numbers of implement designs were recorded in the tillage and plant protection technologies **(Table 2)**. Most tillage equipment were related to primary operation such as mouldboard and disc ploughs. This apparently suggested increased awareness among manufactures and users about the need for good seedbed preparation in association with crop intensification in the irrigated areas. This was also reflected in significant advancement in the irrigation equipment manufactured in the country during the same period.

Similarly, the numbers of locally produced units for crop protection, e.g., sprayers and post-harvest machinery (threshers-cum-cleaners) significantly increased **(Table 2)**. Modest increase in the development of fodder harvesting and conservation equipment such as mowers, rakes and balers were registered. This was associated with the Government's policy of encouraging animal production.

Machine milking also attracted the manufacturer's attention. The above analyses clearly suggests

Table 3 Towards Self-Reliance in Agricultural Machinery Production in Iran: New Machines Tested at AERTTC

	Phase I (1967-79)	Phase II (1980-87)	Phase III (1988-89)*
No. of years	13	8	2
Total No. machines	73	418	223
No./year	5.6	52.2	111.5
Locally manufactured (%)	4.1	87.8	93.7
Approved for certification (%)	94.5	40.2	33.2

* No. of machines tested in 1990 and beyond are expected to significantly increase further.

that, overall, in the second phase (1980-87), significant indigenization of machinery manufacture within the country occurred in the general area of crop production, i.e., tillage, crop protection, irrigation and in the post-harvest technologies.

Phase III: (1988 to date)

In 1988 the Government of Iran, in its efforts to further advance self-reliance programmes, introduced an incentives scheme for local production of quality equipment. Under the new scheme, regulations were introduced which authorized the AERTTC to test and certify new machinery. Upon approval of particular designs, the manufacturers could:

1. Have preferential access to subsidized import of raw material. This gave significant advantage to the participating manufac-

turers as the prices of implements manufactured with raw material bought in the open market made purchasing price prohibitive for the farmers.

2. Sell more easily through Government Rural Bank and "BONGAH" system.
3. Encourage standardization for interchangeability of parts and for mass production of machinery with large economy of scale.

This incentives scheme had such a tremendous positive impact that it attracted potential investors to the agricultural industry. In two years (1988-89), the number of new designs brought for testing per year doubled compared with the numbers during Phase II (**Table 3**). The indications for the year 1990 suggest further improvement in this trend. All in all, during the first 13 years (Phase I) of operation of AERTTC, an average of 5.6 machines/year were tested. This increased by nearly ten times to 52 machines/year during the next eight years (1980-87).

Over the last two years (1988-89), 111.5 machines/year were tested: an increase of more than 100% over Phase II and 20-fold increase over Phase I.

Another aspect of the mechanization trend clearly suggests that major emphasis has been on the crop production technologies such as tillage (20%); crop protection (19%); irrigation equipment (8%); and post-harvest machinery for grain production (8%). This was not unexpected given the fact that major cereal crops (wheat and barley) cover 83% of the total cropped areas of Iran (Choudhary, 1990). The government also places a high priority on self-sufficiency in these strategic crops.

The machinery development in other categories of mechanization has also made steady progress and constituted an average of about 4% each of the total number of machines tested at AERTTC. It is noted that the importance of fodder harvesting and conservation and transportation have also attracted priority by the industry and a number of new designs have been released in the market in recent years. A significant aspect of agricultural mechanization in Iran has been the virtual elimination of animal-drawn implements. Since the center's testing operation began, no animal-drawn implements have been brought forward for tests although a number of hands tools, e.g., pruners, sickles etc. have been tested.

During Phase I, locally manufactured machinery was almost negligible at 4.1% as most machinery was imported (**Table 3**). This trend was reversed during Phase II when 87.8% of machines were locally developed or copied. This trend continued during Phase III as more machines were designed locally.

Table 3 also gives the percentage of machines which received approval certificate from the AERTTC. Not unexpectedly, during Phase I, most machines (94.5%) received certification for local release as almost all of these were of foreign origin and were already commercial. As the number of locally designed machines increased during Phases II and III the percentage of certification decreased markedly to 40.2% in Phase II and 33.2% in Phase III. This probably reflects an enthusiasm for local design and development on the one hand, and lack of design expertise, experience and technical assistance, on the other. The AERTTC can perhaps play a greater role in helping the potential designers in this respect.

Summary and Recommendations

The Islamic Republic of Iran is making major strides towards self-reliance in agricultural machinery production which in turn is expected to have far-reaching effect on crop productivity, cash flow of farmers, and rural industrial development and employment. To attain these goals, the Government has taken steps at introducing and enforcing incentive schemes for the machinery manufacturers who allow their designs to be tested, and get a certificate of approval from the Ministry of Agriculture and Natural Resources.

AERTTC is playing a key role in testing and evaluation of locally manufactured and imported agricultural equipment for their suitability to local conditions, and providing technical assistance for design selection and local manufacture.

This report recommends that upon achieving a pre-determined numerical threshhold of machinery production and availability in Iran, the Government should introduce regulations to make it mandatory for all locally-produced and imported machinery to obtain certificates to facilitate high quality and standardized machinery availability to help protect farmers as well as increase agricultural productivity.

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DLG-FoodTec '92
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November 3-7, 1992, Frankfurt am Main, Exhibition Grounds

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  - process automation
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- ☐ Sales equipment and facilities
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International Conference for Agricultural Machinery & Process Engineering

October 19-22, 1993, Korea Exhibition Center, Seoul, Korea

Agricultural engineering will emerge as one of the promising areas in the 21st century. Being on the leading edge of a fresh engineering concept and orientation for the future agricultural research is a challenge. This conference is to provide a forum for agricultural engineers who are responding to worldwide competition and challenge to explore the state-of-the-art research and future directions in the agricultural machinery and process engineering.

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- Post-Harvest Technology
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- Drying and Storage of Agricultural Products
- Off-Highway Vehicle Dynamics and Terramechanics
- Farm Mechanization & Management

Call for Papers

All participants who wish to present papers are requested to submit an abstract in English by **December 31, 1992.**

The abstract should be less than 400 words, single spaced, and include a title of the paper, full names and addresses of all authors, objectives, methods and significance of the reported results.

The Organizing Committee will review abstracts and the selected papers will be announced to the authors by **February 28, 1993.** Instructions for preparing manuscript will be sent to the authors of the selected papers.

For further information, please write to or call:

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Do Sup Chung Receives 1992 Kishida International Award

The 1992 ASAE Kishida International Award is presented to **Do Sup Chung** in honor of his outstanding contributions to the improvement of food production systems and education for the international community. Since 1965, Chung has been involved in teaching, research, and international programs for grain postharvest technology at Kansas State University. He has been a project member of The Food and Feed Grain Institute at Kansas State University and has had a continuing agreement since 1967 with the Bureau of Science and Technology of the Agency for International Development (AID) to provide technical assistance to developing countries concerning postharvest grain systems. Chung has provided technical assistance and training programs to government agencies, universities and research institutes in numerous developing countries. His efforts have been recognized by the governments of Costa Rica, Indonesia, and Korea.

Chung has published 115 technical papers and has given technical presentations at many national and international meetings on grain postharvest technology.

Chung received an ASAE Paper Award in 1973, and the Young Engineer of the Year Award in 1975. He has served as vice chair and chair of the Kansas Section and as a member of several committees. He is currently a member of the Presidents Club of the ASAE Foundation.

Douglas L. Bosworth Elected President of ASAE

Charlotte, North Carolina - Douglas L. Bosworth, P.E., manager of engineering testing and reliability at John Deere Harvester Works in East Moline, Illinois, has been installed as president of the American Society of Agricultural Engineers (ASAE).

He assumed this position in the Society at its International Summer Meeting, June 21-24, at the Charlotte Convention Center, Charlotte, North Carolina. As president of the society, he is primary spokesperson for over 10,000 members in 50 states, 10 provinces, and 110 countries. He will hold the position of president for one year, then serve on the Executive Committee for one year in the position of Past President.

Bosworth has been involved in a number of ASAE committees during his 30 years of membership. He chaired the former Illinois-Wisconsin Region, then served as vice president of the Membership Council. He has chaired the Finance Committee and the Constitution and Bylaws Committee. Bosworth has been a member of the Executive Vice President Search Committee, the Committee on University, Industry, and Government Cooperation, and served a five-year term on the Engineering Accreditation Commission.

In addition, Bosworth has served on the Board of Directors for the Quad-City Human Services, Inc., the Visiting Nurses and Homemakers Association of Rock Island County, the Associated Employers, the Moline Rotary, the United Medical Center, the United Way of the Quad-Cities, the American Cancer Society of Rock Island County, and the Quad-City Engineering and Science Council.

Bosworth has received peer recognition in the form of the 1973 ASAE FMC Corporation Young Designer Award, and the 1981 Iowa State University Alumni Achievement Award.

Richard J. Godwin Elected Director ASAE International Department

Charlotte, North Carolina - Richard J. Godwin, P.E., dean of faculty of agricultural engineering, food production, and rural land use at Silsoe College, Silsoe, Bedford, England, has been elected Director of the International Department of the American Society of Agricultural Engineers (ASAE).

He was installed during the Society's International Summer Meeting, June 21-24, at the Charlotte Convention Center, Charlotte, North Carolina. His term will run for two years.

As International Director, Godwin will represent ASAE members in over 110 countries. The Board of Directors develops policy for the nonprofit, technical, scientific, and educational society.

In addition to his position as dean of Silsoe College, Godwin is professor of Agricultural Machine Technology, head of the Department of Engineering for Agriculture, and head of Strategic Research.

An ASAE member for 22 years, he has served on the Society's International Committee and on the task force to rewrite soil dynamics in tillage and traction. He is also an active member of the Institute of Agricultural Engineering, and is on the editorial board of the *Journal of Agricultural Engineering Research*. ■■

Locally made Equipment for Teaching and Research in Agricultural Engineering and Development Technology

(Australia)

Series Editor: Ross H. Macmillan

A series of designs under this title has been developed by the University of Melbourne. This equipment is intended for manufacture by Universities, Colleges and Research Institutes in developing countries for their own use. The designs are, as far as possible, based on the use of industrial components and allow the use of a range of transducers to be provided locally.

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One set of these is available free of charge to each institution in developing countries and at a cost of A$5 for each manual (includes packing and postage) to others. Copies of the manuals & further information is available from:
Ross H. Macmillan
Senior Lecturer in Agricultural Engineering, Department of Civil & Agricultural Engineering, University of Melbourne, Parkville, Victoria, 3052, Australia.

A Primer on Organic-Based Farming

(Philippines)

by R.K. Pandey

Fertilizer is a major input in rice production. As the use of chemical fertilizers has grown, traditionally organic materials such as farmyard manure and green manure crops have been increasingly neglected.

The harmful environment effects of heavy and improper chemical use are becoming more evident. Furthermore, the fossil fuels used to produce nitrogen fertilizers are becoming scarcer.

Thus, interest is growing in sustainable farming, using renewable resources that are easily and cheaply available on the farm. Such a system maintains soil fertility as far as possible by the traditional biological means — rotating cereal crops with legumes, recycling manure and other organic wastes, using green manures and combining them with moderate amounts of chemical fertilizers. Research has shown such combinations to be more effective than any single nutrient source in improving soil quality and nutrient use efficiency, and thus, yields.

Such a system is also more environmentally sound than one that relies solely on chemical fertilizers.

About 50 legumes suited to a wide range of rice-growing environments are described so that farmers may choose best suited for their own needs. Most are multipurpose crops that not only will replenish soil nutrients but will also provide food, fodder, fuel, and extra income for the rice farmer.

Size: 23 × 15 cm, pp. 201, paperback. Price: HDC US$13.75, LDC US$2.75 plus airmail (US$5.00) or surface mail (US$2.00) postage.

Order to: Division PR, Information Center, IRRI, P.O. Box 933, 1099 Manila, Philippines.

Rice Production in Uttar Pradesh — Progress and Suggestions for Improvement

(Philippines)

by M.D. Pathak

Uttar Pradesh state in India is one of the largest and most diverse rice-growing regions in the world, with about 5.4 million hectares planted to rice — more than the total rice areas of many countries. U.P. also has low and stagnant average yields — also typical of many rainfed rice areas.

Dr. M.D. Pathak's holistic analysis of U.P. rice production provides a case study of a predominantly rainfed rice region. He has examined the range of factors that contribute to rice productivity — research, extension, infrastructure, and organization — to analyze the causes of low yields and to recommend an integrated approach to improving different rice cultures.

Dr. Pathak served as Head of the Entomology Department and as Director, Research and Training during a 26-year career with IRRI. He is now Director General of the U.P. Council of Agricultural Research. This book was published by Wiley Eastern Limited in New Delhi and is being made available outside India through IRRI.

Size: 23 × 15 cm, 253 pages.

Price: HDC US$22.75, LDC US$6.00 plus airmail (US$7.00) or surface mail (US$1.50) postage.

Order from: Division PR, Information Center IRRI, P.O. Box 933, 1099 Manila, Philippines.

BOOK REVIEW

Agricultural Engineering Journal Volume 1, No. 1, 1992 (Quarterly)

(Thailand)

The main purpose of the journal will, of course, be the publication of scholarly articles pertinent to the development of agricultural engineering. Technical reports will also be encouraged. The focus will be primarily on developments in Asia but we hope many papers will be of interest to agricultural engineers worldwide.

Contents:

Review Paper

Enhanced Utilization of Forage Plants Through Fractionation: State of the Art - W.K. Bilanski

Research Papers

A New Type of Regulator for On-farm Irrigation Outlets - P.K. Mishra and P. Larsen

Management of Shallow Groundwater Systems for Agriculture on Coastal Sandy Soil Areas of Malaysia - Mohammud C.H., Shahrin M.Y. and Aminuddin Y.

Apple Bruise Prediction Models Using Dimensional Analysis - A.K. Srivastava, S.C. Mandhar and M.D. Singh

Technical Note

Accessing Technical Information for Agricultural Engineers - W.J. Chancellor

Published by the Asian Association for Agricultural Engineering c/o Division of Agricultural and Food Engineering, Asian Institute of Technology, GPO Box No. 2754 Bangkok, Thailand 10501.

Progress in Agricultural Physics and Engineering

(U.K.)

Edited by John Matthews, former Director, Silsoe Res. Inst., UK

The physical sciences and engineering play an important part in the advance and activities of agriculture and related industries and in the preservation and improvement of rural and amenity environments. This book provides an authoritative account of new developments in these disciplines as applied to such industries. Chapters have been commissioned on topics perceived to have made important recent advances and these are reviewed by authors of international repute.

The book will therefore have immediate value for research workers, lecturers and professionals in agricultural engineering and applied aspects of soil science, horticulture, food science and other disciplines.

Contents include:

- An analysis of research priorities in agricultural physics and engineering *J Matthews*
- The mechanics of soil machine interaction *R D Wismer (Deere & Co., Illinois)* and *D R. Freitag (Tenessee, USA)*
- Tractor ride dynamics *H Gohlich (Berlin, Germany)*
- Stability of agricultural machines on slopes *A Hunter (Edinburgh, UK)*
- The pricniples of robotics in agriculture and horticulture *F Sevila* and *P Baylou (France)*
- Image analysis in biological systems *J Marchant (Silsoe, UK)*
- Climate modelling and control in greenhouses *B Bailey (Silsoe, UK)*
- Heat and mass transfer in the drying and cooling of crops *J L Woods (University of Newcastle upon Tyne, UK)*
- Damage mechanisms in the handling of fruit *M Ruiz Altisent (Universidad Politecnica Madrid, Spain)*
- The physics and engineering of the extraction of protein from green crops *R Reznicek (Czechoslovakia)*
- Principles of abattoir design to improve animal welfare *T Grandin (Colorado, USA)*
- Biological waste treatment *W Baader (FRG)*

Size: 24 × 16 cm, pp 350, hardback. Price incl. postage: £ 49.95 (US$95.00 Americas only).

Published by C.A.B. International, Wallingford, Oxon OX10 8DE, U.K. Tel: Wallingford (0491) 32111.

Agriculture's Contract with Society

(U.S.A.)

The concerns of society for the food supply and the needs of agriculture to make it available to consumers are explored in this book recently released by the American Society of Agricultural Engineers (ASAE). The idea of a contract between society and agriculture was explored in a yearlong ASAE Roundtable Series. The discussions are summarized in a proceedings that provides insight into the contract and many economic, regulatory, and global trade issues.

The book reports the thought provoking insight of highly qualified leaders and condensed discussions of the issues presented by over 100 specialists in food and agricultural professions. It also presents an ASAE consensus view of the important issues and how the contract should address those issues. Particular attention is given to a view of responsibility for the biosphere and the issues of environmental risks entrusted to agriculture.

Copies of the book "Agriculture's Contract with Society" are available from ASAE Order Dept., 2950 Niles Road, St. Joseph, MI 49085. Price is $45.00 for the 200 page proceedings.

INSTRUCTIONS TO AMA CONTRIBUTORS

The Editorial Staff of the AMA requests contributors of articles for publication to observe the following editorial policy and guidelines in order to improve communication and to facilitate the editorial process :

Criteria for Article Selection

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

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

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a. As a rule, articles that are not chosen for AMA publication are not returned unless the writer(s) asks for their return and are covered with adequate postage stamps. At the earliest time possible, the writer(s) is advised whether the article is rejected or accepted.
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a. Whether the article is a technical or popular contribution, lecture, research result, thesis or special report, the format must contain the following features :
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   iii) an abstract following ii) above ;
   iv) body proper (text/discussion) ;
   v) conclusion/recommendation ; and a
   vi) bibliography
b. The pages must be numbered (Arabic numeral) successively at the top center. Tables, graphs and diagrams must likewise be numbered. Table numbers must precede table titles, e.g., "Table 1. Rate of Seeding per Hectare". Such table number and title must be typed at the top center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e.g., "Figure 1. View of the Farm Buildings".
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d. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
e. Express measurements in the metric system and crop yields in metric tons per hectare (t/ha) and smaller units in kilogram or gram (kg/plot or g/row).
f. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
g. Convert national currencies in US dollars and use the later consistently.
h. Round off numbers, if possible, to one or two decimal units, e.g., 45.5kg/ha instead of 45.4762kg/ha.
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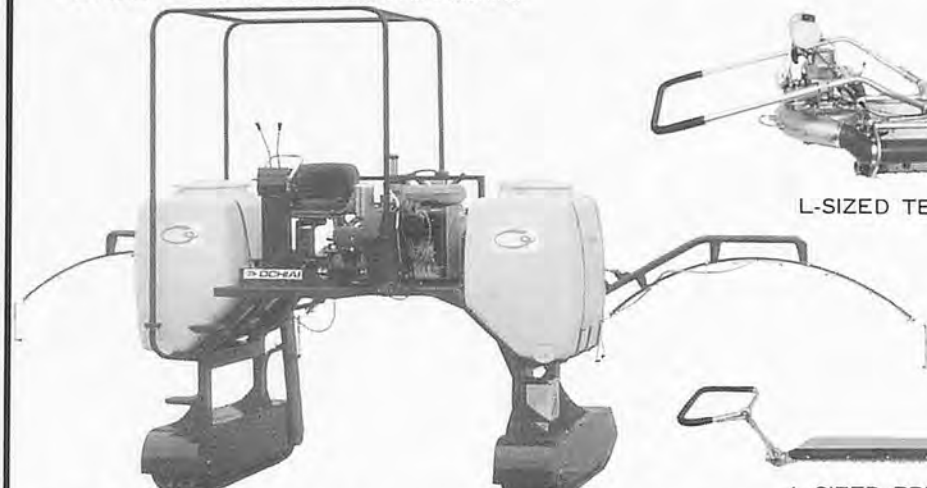

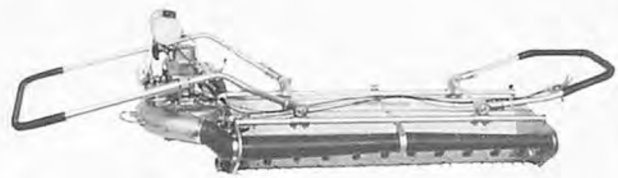

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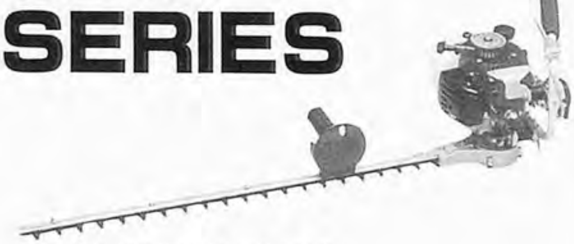

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