International specialized medium for agricultural mechanization in developing countries

ISSN 0084-5841

AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.19, NO.4, AUTUMN 1988

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VOL.19, NO.4, AUTUMN 1988

Edited by

YOSHISUKE KISHIDA

Published quarterly by

Farm Machinery Industrial Research Corp.

in cooperation with

The Shin-Norinsha Co., Ltd.

and

The International Farm Mechanization Research Service

TOKYO

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FARM MACHINERY INDUSTRIAL RESEARCH CORP.
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7, 2-chome, Kanda Nishikicho, Chiyoda-ku, Tokyo 101 Japan
Printed in Japan

This is the 61st issue since the issue, Spring of 1971

EDITORIAL

The Freakish Weather and Its Consequence

There is such a popular parlor, pastime game called *Truth and Consequence* which might well be equated with the freakish weather this year (truth) and the havoc (consequence) that it leaves behind. For, even before the current year is over, there have already been several discouraging accounts of the unseasonable weather in many parts of the world. The mass media, the TV, in particular, is able to relay on the screen in millions of living rooms around the world live or on-the-spot scenarios of, for example, i) famine-stricken humanity in many parts of Africa, ii) the heatwave and scorched farmlands in Mid-west USA; iii) surging flood waters that inundated about a third of the plains and residential areas in Bangladesh; iv) raging forest fires fanned by strong winds in the West Coast and many mountain states of the USA that have burned million acres of woodlands (watersheds), meadows and hundreds of homes and other farm buildings; v) a hurricane that has levelled much of Jamaica and threatens (at this writing) to devaste the Gulf Coast of the USA; and vi) in Japan, a very short rainfall in the springtime but too many rainy days with scanty sunshine in the summertime.

These are but a few of the reported aberations of the weather this year and one can only be sure that there are many, many more of such cases of vagaries of Nature that have taken or are taking place in many agricultural areas of the world that do not show on TV screens nor the printed word.

What all this amounts to, sans any statistical estimates at the moment, is a major setback in gains already made in development efforts – agricultural, industrial, residential, etc in the affected areas and countries. In consequence, it means that food derived from crops and livestock will not only be in short supply but will inevitably be accompanied by a rise in prices at the expense of consumer even as this usually brings about an economic phenomenon, i.e., a rise in prices of farm products at the Chicago Board of Trade or New York Stock Exchange triggers an increase in prices of farm products in developing countries.

From where the AMA sees the consequence, it only underscores the fact that the destruction must be restored with the least possible delay, hence the use of machineries, agricultural and otherwise, is indespensable – be it building floodways, digging irrigation canals and drainage, plowing the farmlands in fallow, providing temporary energy from standby generators or stationary engines, or otherwise keeping the machineries on the farms in order to respond quickly to recovery operations. Not that the AMA wants these catastrophies to happen now and then but there is no telling when and where the weather will misbehave again. And yet, it is clearly another argument or reason why the AMA continues to promote a wider use of various kinds of farm machineries in both developed and developing countries where their use is inevitable if high and sustained efficiency is desired by governments or private entities to hasten development and reconstruction – agricultural and otherwise.

Yoshisuke Kishida
Chief Editor

Tokyo
October, 1988

CONTENTS

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol. 19, No. 4, Autumn, 1988

Yoshisuke Kishida	7	Editorial
Sheruddin Bukhari Masood Ahmed Bhutto Jan Mohammed Baloch Allah Bachayo Bhutto Ali Nawaz Mirani	9	Performance of Selected Tillage Implements
T.C. Thakur B.P. Varshney A. Yadav P. Chand	15	Effects of Load and Speed on Performance of Clod Crushers
S.C. Pradhan S.K. Dash H. Raheman	21	Development and Testing of Bullock-drawn Land Scraper and Land Grader
J.G. Nagy H.W. Ohm L.L. Ames L.D. Schaber	25	An Animal-drawn Mechanical Ridge Tier for the Cereal Farming Systems of Burkina Faso
Mehmet Yilmaz Nuri Yilmaz	31	The Tir Seeding Method and Tir Drills: A Literature Review
H.S. Bisen N.S.L. Srivastava	34	Laboratory Studies on Spray Distribution Pattern of the Wide-swath Spray Boom
Abdul Razzaq Ch. Bashir Ahmad Ch. Bashir Ahmad Sabir	39	Comparative Use of Self-propelled and Tractor-drawn Combines
S.D. Deshpande T.P. Ojha	44	Testing and Evaluation of Improved Yaatra Ox-cart
Jatindra Nath Samajpati T.T. Pedersen	49	Modern Food Grain Silos in Bangladesh
Shingo Furuichi David K. arap Some	53	Possibilities of Mechanizing Paddy Production in Kenya
M.A. Choudhary S.W. Brown	58	Potentials for Computer-aided Farm Machinery Decisions in Pakistan
V.P. Bahl D.N. Sharma M.L. Jain	63	Cotton Cultivation in Haryana State, India
B.S. Pathak Amar Singh R.N. Verma	68	Performance of Oil Milling Technologies in India
Kamaruzaman Jusoff	73	A Wood Chip-fired Residential Boiler
Rimfiel Janius	75	Alcohol as Tractor Fuel – Is There Any Future?
Abstracts	78	
News	79	

* * *

ERRATA 67
Index to Advertisers 74
New Co-operating Editors 85
Co-operating Editors 86
Back Issues 88
A Note to AMA Contributors 90

Performance of Selected Tillage Implements

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Introduction

Agricultural engineers have been concerned with tillage implements for many years now in identifying and qualifying physical performance specifications for farm machines so that they can be selected and utilized properly for any given application.

A comparative study of selected tillage implements (moldboard plow, disk plow and cultivator) was carried out with a view to assessing their performance. The moldboard plow is one of the most widely used tillage tools. It does a good job of turning over soil and is effective in retarding weed growth. Plowing pulverizes, aerates and loosens the soil making it more friable and mellow. Moldboard plowing also offers the best means of improving the quality of poorly drained soils. The disk plow is used when conditions are adverse. It works well in wet, sticky and hardpan soils. It will ride over stones and rocks. Field cultivator is used as tillage implement in light soils.

The objective of this study was to evaluate the performance of tillage implements. The performance parameters were draft requirements, travel reduction, speed of operation, width of cut, depth of cut, field capacity, soil disturbance and soil inversion. This type of study would provide the guidelines for farmers in selecting suitable implements.

Experimental Procedures and Methods

Two sites were selected for evaluation of performance of moldboard plow, disk plow and cultivator. The first site (Malir Farm) is located about 1 km in the southwestern part and the second site (Latif Farm) 1 km in the northeastern part of the Sind Agriculture University, Tandojam.

All the variables of implement performance were measured and recorded accoring to the recommendations of RNAM test codes and procedures for farm machinery technical series No. 12, 1983.

Machines

The implements used in the research study are described in **Table 1**. All the implements were standard field machines without modification. The implements were powered by a Belarus 10M3-6AA diesel tractor with 15.5 – 38 rear tyres and 7.5 – 20 front tyres.

Table 1 Specifications of Implements

Implements	Specifications
Moldboard plow	3-furrow, mounted, general purpose moldboard with moldboard extension of 21.5 cm, width 1.2 m and vertical clearance of 68 cm.
Disk plow	3-disk, mounted, disk diameter 57 cm, dish of disk 7.2 cm, disk guage 4.5 mm, vertical clearance 64 cm, tilt angle 20° and disk angle 42°.
Cultivator	11 times, mounted, tine spacing 20 cm, width 2.2 m, vertical clearance 58 cm, tine spacing adjustable, two springs for each tine to trip any obstacle.

Table 2 Mechanical Analysis of Soil Types

Soil type	Sand 0.05 mm %	Silt 0.05–0.002 mm %	Clay 0.002 mm %
Silt loam (Malir Farm)	18.4	56	25.6
Clay loam (Latif Farm)	22.4	48	29.6

Table 3 Soil Moisture Content (Wet Weight Basis) in %

Replications	Depth of soil sample (cm)					Average
	0–5	6–10	11–15	16–20	21–25	
			SITE-I			
1	15.44	14.71	16.14	15.90	15.23	15.48
2	14.74	15.41	15.13	16.62	14.80	15.34
3	15.29	15.38	17.25	15.22	15.72	15.77
4	15.43	15.64	16.08	16.67	15.54	15.87
Average						15.62
			SITE-II			
1	15.51	16.25	16.36	15.11	14.58	15.57
2	15.34	15.19	15.54	16.48	16.41	15.79
3	15.57	16.42	16.57	16.05	15.69	16.06
4	15.82	15.72	16.29	15.00	16.66	15.91
Average						15.83

Table 4 Bulk Density of Soil (Dry Mass Basis) in g/cm³

Replications	Depth of soil sample (cm)					Average
	0–5	6–10	11–15	16–20	21–25	
			SITE-I			
1	1.099	1.254	1.439	1.384	1.469	
2	1.079	1.162	1.369	1.429	1.555	
3	1.108	1.283	1.252	1.432	1.547	
4	1.224	1.224	1.350	1.578	1.632	
Average						1.344
			SITE-II			
1	1.270	1.424	1.239	1.817	1.262	
2	1.316	1.332	1.778	1.755	1.255	
3	1.293	1.293	1.124	1.509	1.509	
4	1.270	1.424	1.839	1.516	1.424	
Average						1.432

Soil Types

Two soil types available at Sind Agriculture University Farms were selected. These soils are clay loam and silt loam. The mechanical analysis of the soils done by DRIP is given in **Table 2**.

Soil Moisture Content

Soil moisture content on wet weight basis was determined. For measurement of soil moisture content percent, the core samples of soil were taken from depths of 5, 10, 15, 20 and 25 cm at 4 different locations of test plots selected randomly. The soil moisture percent (wet weight basis) shown in **Table 3** was calculated by using the formula:

$$\text{Moisture (\%)} = \frac{W - D}{W} \times 100$$

Where

W = Weight of wet soil sample

D = Weight of oven dry sample

Bulk Density of Soil

To measure the bulk density (g/cm³) of the soil, cylindrical cores were taken from 4 locations selected randomly at depths of 5, 10, 15, 20 and 25 cm in the test plots. The diameter and length of the cylindrical soil samples were measured with vernier callipers. The bulk density of the soil shown in **Table 4** was determined (dry weight basis) by using the following formula.

$$\text{Bulk density of soil (g/cm}^3) = \frac{M}{V} = \frac{4M}{D^2 L}$$

Where

M = Mass contained in core sampler of oven dry soil (g)

V = Volume of cylindrical core sample (cm³)

D = Diameter of cylindrical core sample (cm)

L = Length of cylindrical core sample (cm)

Data Collection

Operation Speed

Outside the long boundary of the test plot, two poles 50 m apart were placed approximately in the middle of the test run. On the opposite side, two poles were also placed in a similar position (50 m apart) so that all four poles form corners of a rectangle, parallel to each other. The speed was calculated from the time required for the tractor and implement to cover the distance of 50 m between the assumed line connecting two poles on opposite sides AC and BD (**Fig. 1**). A stop-watch was used to record the time of travel of tractor and implement for two gear speeds.

Working Width

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.

Travel Reduction

Tractor drive-wheels slip in all field operations. The distance the tractor moves forward in a given number of revolutions of the drive wheel decreases when wheels slip. A simple method in determining the amount of travel reduction was used by making a mark with chalk on the drive wheel of the tractor

and the distance the tractor travelled in 10 revolutions with no load (A) and with load (B) was measured (Fig. 2). The travel reduction was calculated by using the formula.

$$T_R\ (\%) = \frac{A - B}{A} \times 100$$

Where

T_R = Travel reduction

A = Distance travelled with no load

B = Distance travelled with load

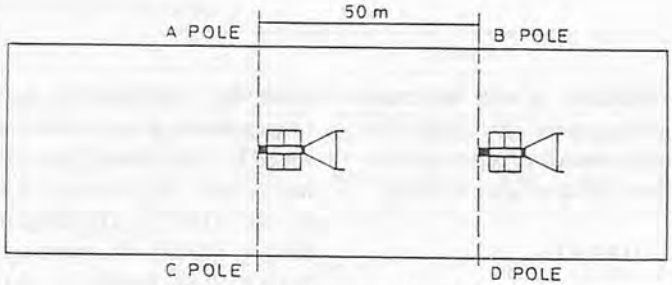

Fig. 1 Measuring operating speed.

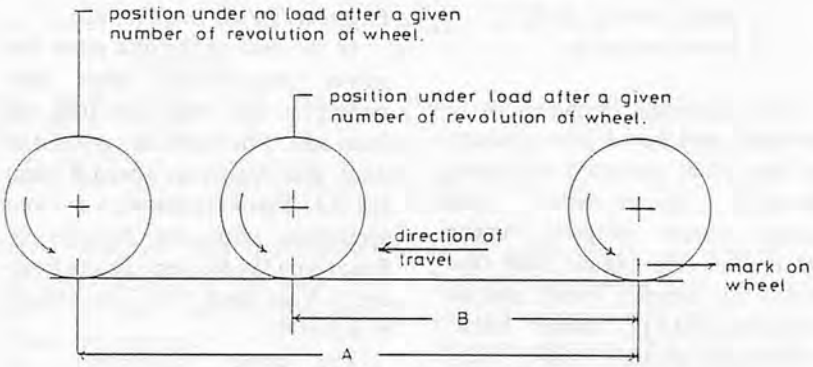

Fig. 2 Measuring wheel slip.

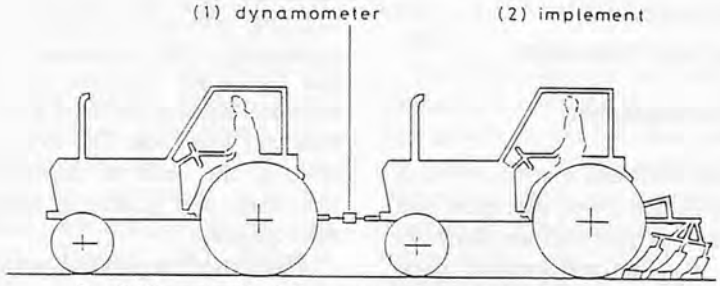

Fig. 3 Measuring draft for a tractor-mounted implement.

Draft of Implements

A hydraulic dynamometer (pull type) 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 through the dynamometer. The auxiliary tractor pulled the implement-mounted tractor being 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 out of 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 draft is shown in Fig. 3.

Soil Inversion

Soil inversion is expressed as the ratio of weeds and stubbles left on soil surface after implement operation to the total quantity of weeds and stubbles present before the operation. The soil inversion was computed by the formula:

$$F = \frac{W_P - W_E}{W_P} \times 100$$

Where

F = Soil inversion, %

W_P = Weight of weeds and stubbles before implement operation (g)

W_E = Weight of weeds and stubbles on the tilled surface after implement operation (g).

Before the operation of tillage implements, the weeds and stubbles were collected from three randomly selected places in both sites by using 0.5 m square frame. The average weight of weeds and stubbles thus collected was recorded. After the operation of each tillage implement, the same procedure was repeated for collecting the weeds and stubbles left on the tilled soil surface in both sites. Hence the soil inversion in percent was calculated.

Field Capacity

The field capacity of the selected implements was calculated in ha/h by using Hunt's formula assuming 70% efficiency of the implement.

$$C = \frac{SWE}{10}$$
$$= 0.075SW$$

Where

C = Field capacity, ha/h

S = Speed of operation, km/h

W = Width of implement, m

E = Field efficiency, decimal

Soil Volume Disturbed

The soil volume disturbed in m^3/h was calculated by multiplying the field capacity with the depth of

cut and 10 000. It was assumed that the implement disturbed the soil up to its recorded depth and no undisturbed patch of land was left.

$$V = 10\,000\,CD$$

Where

V = Soil volume disturbed, m^3

C = Field capacity, ha/h

D = Depth of cut, m

The materials required were mounted moldborad plow, mounted disk plow, mounted cultivator, hydraulic dynamometer, stop watch, vernier callipers, ranging poles, steel tape (small), steel tape 50 m, soil sampler (core), sample containers, 0.5 m square frame, 0.5 m scale, physical balance, oven, polythene bags and white chalks.

Result and Discussion

Draft of Implements

Total draft and draft/m of width of moldboard plow, disk plow and cultivator at two sites are shown in **Table 5**. The performance parameters were recorded at two speeds in silt loam and clay loam soils.

In the case of moldboard plow, the power requirements were greater in clay loam soil than in silt loam soil. At speed-II the power requirements were greater than at speed-I. The results are in agreement with the findings of Kepner et al. (1972), O'Callaghan and McCoy (1965), Promersberger and Pratt (1958), Bukhari et al (1981), Singh et al. (1979) and Agricultural Engineers's Year Book (1982).

In the case of the disk plow, the power requirements were also greater in clay loam soil than silt loam soil. For both soil types, the draft was higher at speed-II than speed-I. These results were in close agreement with the findings of Feuerlein (1968), Agricultural Engineer's Year Book (1982) and Singh et al (1979).

The power requirements of cultivator were also higher in clay loam soil than silt loam soil. The soil type affected the draft of the implements. The implement draft was less in silt loam soil than clay loam soil because silt loam is lighter than clay loam soil. The speed also affected the draft of implements. The draft was greater at speed-II than speed-I.

From the comparative performance of the moldboard plow, disk plow and cultivator it is concluded that the average width of strip covered by a cultivator in single pass was 48.5% more as compared to moldboard plow and 59.1% more as compared to disk plow. The total draft of all the three implements were very close to each other. However, the draft/m of width varied greatly because of variation in the width of implements. The lowest draft/m of width was recorded for cultivator whereas the highest draft/m of width was recorded for disk plow which was in agreement with the findings of Kepner et al. (1972).

Travel Reduction and Soil Inversion

The travel reduction or wheel slip affects the traction efficiency of the pulling machine. The complete soil inversion is preferred where the clean and neat cultivation is needed. The partial soil inversion is required in areas of soil erosion problems. The data regarding the travel reduction and soil inversion of moldboard plow, disk plow and cultivator is shown in **Table 6**.

The travel reduction while plowing in silt loam soil with the moldboard plow was greater at speed-I than speed-II which was due to deeper penetration of the moldboard plow at lower speeds. However, in the case of clay loam soil the travel reduction was greater at

Table 5 Power Requirements of Selected Tillage Implements

Replications	SITE-I						SITE-II					
	Moldboard plow		Disk plow		Cultivator		Moldboard plow		Disk plow		Cultivator	
	Total draft kN	Draft per meter of width kN/m	Total draft kN	Draft per meter of width kN/m	Total draft kN	Draft per meter of width kN/m	Total draft kN	Draft per meter of width kN/m	Total draft kN	Draft per meter of width kN/m	Total draft kN	Draft per meter of width kN/m
						SPEED-I						
1	7.562	7.27	8.007	9.53	9.341	4.03	8.674	7.45	8.674	7.88	8.229	3.62
2	8.007	7.55	8.452	9.99	8.452	3.61	8.896	7.60	9.564	8.64	8.007	3.54
3	7.117	6.59	8.896	10.50	8.896	3.86	9.341	7.93	9.230	8.35	9.564	4.19
Average	7.562	7.14	8.45	10.01	8.896	3.83	8.970	7.66	9.15	8.29	8.600	3.78
						SPEED-II						
1	8.229	6.33	9.786	12.08	8.007	3.49	11.121	9.18	9.564	9.73	8.452	3.64
2	8.452	6.66	9.564	11.73	8.452	3.71	10.008	8.23	9.786	9.84	8.229	3.59
3	7.784	6.18	10.008	12.20	8.229	3.60	10.898	8.93	9.897	9.93	9.119	3.99
Average	8.155	6.39	9.786	12.00	8.229	3.60	10.676	8.78	9.749	9.83	8.600	3.74

Table 6 Travel Reduction and Soil Inversion by Selected Tillage Implements

Replications	SITE-I						SITE-II					
	Moldboard plow		Disk plow		Cultivator		Moldboard plow		Disk plow		Cultivator	
	Travel reduction %	Soil inversion %	Travel reduction %	Soil inversion %	Travel reduction %	Soil inversion %	Travel reduction %	Soil inversion %	Travel reduction %	Soil inversion %	Travel reduction %	Soil inversion %
					SPEED-I							
1	16.39	95.00	17.29	51.11	12.26	7.26	12.32	93.20	16.47	38.25	12.08	4.76
2	17.16	94.40	16.94	42.22	11.65	5.45	13.56	96.10	16.06	45.35	10.90	7.94
3	18.69	96.30	16.86	45.32	10.94	6.25	15.22	95.30	16.48	51.75	11.39	2.81
Average	17.41	95.20	17.03	46.22	11.62	6.32	13.70	94.87	16.34	45.17	11.46	5.17
					SPEED-II							
1	16.05	94.00	18.31	50.40	14.53	5.51	16.68	94.00	18.77	50.43	15.25	3.25
2	17.41	95.00	18.59	51.30	13.82	4.16	16.12	94.00	17.94	49.63	13.11	5.14
3	14.65	97.00	17.63	52.60	15.17	6.25	15.34	95.00	18.36	52.25	14.10	4.35
Average	16.04	96.00	18.18	51.43	14.51	5.31	16.05	94.00	18.36	50.77	14.15	4.25

speed-II than speed-I. At speed-I, the travel reduction was greater in slit loam soil than clay loam soil. The increase in travel reduction in clay loam soil was 21.31%. However, the speed-II, the travel reduction was nearly the same in both the soil types.

In the case of the disk plow, the travel reduction for both soil types increased as the tractor speed was shifted to the next higher transmission gear of the tractor. In silt loam soil increasing the speed 13.96% the travel reduction was increased by 6.33%. But in the case of clay loam soil, the travel reduction increased by 11% at 13.96% increase in speed. At speed-I the wheel slippage was 4.05% greater in silt loam soil than clay loam soil. However, at speed-II the wheel slippage was nearly the same for both soil types.

The travel reduction of the cultivator in both soil types is greater at speed-II than speed-I. In the case of silt loam soil, the increase in travel reduction due to increase in speed was 19.92% and in clay loam soil the increase was 19%. At speeds-I and II, the travel reduction was greater in silt loam soil than clay loam soil.

The comparative evaluation of travel reduction is that at speeds-I and II, the highest wheel slip occurred while plowing with the disk plow and lowest by the cultivator. The soil type also affected the travel reduction. The travel reduction was greater in silt loam soil than clay loam soil for the three tillage implements.

On the average, the soil inversion by the moldboard plow at both speeds and both sites was nearly the same which was 95%. A very small quantity of crop residue was left on the surface of plowed piece of land. The moldboard plow almost completely inverted the soil. The findings are in agreement with the findings of Frank (1979), Hawkins (1964), Bowers and Bateman (1960).

The disk plow at both sites and speeds inverted the soil by about 50%. It is evident from the data that the soil inversion by the cultivator is so small that it could be considered negligible. The inversion is between 4 and 6%.

The comparative performance of moldboard plow, disk plow and cultivator regarding the soil inversion indicates that the moldboard plow rates the best implement for clean seedbed. The cultivator inverted the soil too small which is negligible.

Field Capacity and Soil Disturbance

Field capacity and soil disturbance are two major factors in determining the performance of tillage implements. The field capacity of the machine is the function of its width, speed and efficiency. The soil disturbance is the function of field capacity and depth of implement operation. The data regarding field capacity and soil volume disturbed by moldboard plow, disk plow and cultivator is presented in **Table 7**.

The field capacity and soil disturbed by moldboard plow at site-I was greater at speed-II than speed-I by 41.12 and 25.91%, respectively, whereas at site-II and speed-II the increase in field capacity and soil disturbance was 23.85% and 26.58%, respectively.

In the case of the disk plow, the field capacity and soil volume disturbed at site-I was higher at speed-II than speed-I. The increase in field capacity and soil disturbance was 11.08% and 10.84%, respectively. At site-II, the field capacity and soil disturbance was slightly increased at speed-II by 4.44% and 4.29%, respectively.

At site-I the field capacity and soil disturbance by field cultivator were lower at speed-II than speed-I. The decrease in field capacity was 18.20% and soil disturbance was 31.74%. At site-II the field capacity and soil disturbance decreased at higher speed. The decrease was 17.82% and 21.45%, respectively.

The soil type affected the field capacity as well as soil disturbance. The field capacity and soil disturbance were greater for the silt loam

Table 7 Field Capacity and Soil Volume Disturbed by Selected Tillage Implements

Replications	SITE-I						SITE-II					
	Moldboard plow		Disk plow		Cultivator		Moldboard plow		Disk plow		Cultivator	
	Field capacity ha/h	Soil volume disturbed m^3	Field capacity ha/h	Soil volume disturbed m^3	Field capacity ha/h	Soil volume disturbed m^3	Field capacity ha/h	Soil volume disturbed m^3	Field capacity ha/h	Soil volume disturbed m^3	Field capacity ha/h	Soil volume disturbed m^3
						SPEED-I						
1	0.298	655.60	0.253	506.00	0.779	888.06	0.391	801.55	0.339	698.34	0.780	811.20
2	0.259	543.90	0.266	555.94	0.803	1019.81	0.376	767.04	0.349	704.98	0.807	863.49
3	0.295	737.50	0.279	585.90	0.823	1111.05	0.288	717.40	0.356	719.12	0.798	845.88
Average	0.284	643.83	0.266	548.76	0.802	1004.91	0.352	727.58	0.348	832.85	0.795	840.32
						SPEED-II						
1	0.528	1003.20	0.289	640.70	0.657	689.85	0.492	1062.72	0.359	721.59	0.617	654.02
2	0.436	741.20	0.308	609.84	0.686	734.02	0.434	941.78	0.376	763.28	0.706	720.12
3	0.485	873.00	0.298	613.88	0.623	635.46	0.462	965.58	0.356	733.36	0.641	608.95
Average	0.483	869.40	0.298	614.77	0.656	686.83	0.462	988.68	0.363	737.98	0.654	660.54

than clay loam soil. The speed also affected the field capacity and soil disturbance. The field capacity and soil disturbance increased at higher speeds.

The comparative performance of all three tillage implements in terms of field capacity and soil disturbance indicates that the cultivator gave the highest field capacity. The lowest field capacity was obtained by plowing with disk plow. At speed-I the soil disturbance by the cultivator in both sites was more than that of the moldboard plow and disk plow whereas in both sites and speed-II the soil disturbed by the disk plow and cultivator was nearly the same. However, the soil disturbance by moldboard plow was about 29% more than disk plow and cultivator.

Conclusions and Recommendations

The total draft of all three tillage implements employed was nearly the same. However, the draft/meter of width varied greatly. The lowest draft/meter of width was recorded for the cultivator whereas the highest draft/meter of width was recorded for the disk plow. The draft was lower for the silt loam than the clay loam soil. At speed-II the draft was greater than at speed-I. The strip plowed by the cultivator in single pass was 48.5% greater as compared to moldboard plow and 59.10% greater than the disk plow. At speeds-I and II, the travel reduction was highest for the disk plow and lowest for the cultivator. The travel reduction was greater in the silty loam soil than in the clay loam soil. The cultivator plowed greater area than moldboard plow and disk plow. The disk plow covered the least area among the tillage implements used in the study. The soil volume disturbed by the moldboard plow was about 29% greater than the disk plow and cultivator. The moldboard plow inverted the soil completely which amounted to 95%. Soil inversion by the use of disk plow averaged 50%; and the cultivator inverted the soil to 5%.

The findings of the present study suggest that the cultivator should be used in light soils. Where soil erosion is not a problem and clean cultivation is desired, the moldboard plow should be used. The use of moldboard plow is also recommended in weed-infested lands because it completely inverts and buries the weeds in the soil. The disk plow is recommended for problem soils where other tillage implements cannot operate satisfactorily.

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Effects of Load and Speed on Performance of Clod Crushers

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Abstract

The performance of corrugated clod crushers viz. Cambridge roller and angle iron bar crushers with 70 and 140 mm spacing between bars were evaluated under field soil bin conditions in a silty-clay-loam soil at 14% (d. b.) moisture content. The speed and load were varied from 1.2 to 6.5 km/h and 214 to 428 kg/m width of crushers, respectively. The change in clod mean-weight-diameter, bulk density and draft were measured. The maximum reduction in clod mean-weight-diameter was obtained at a forward speed of approximately 3.5 km/h for all the crushers. The angle iron bar crusher with 70 mm spacing gave the best performance. The bulk density of soil increased linearly with the load but had an inverse relationship with speed. The second subsequent operation of crushers on test plots showed minor effect on the performance parameters considered.

Introduction

Preparation of soil for sowing seeds may consist of loosening of upper soil layers, breaking of clods and consolidating the pulverized soil. After opening the soil with primary tillage tools, a greater degree of pulverization at shallow depth is obtained through the use of secondary tillage implements. In India, the most common tool used for breaking clods and consolidating the pulverized soil is a flat wooden planker. This tool, however, is not very effective in breaking hard clods as they are forced into the soil and reappear during the sowing operation. Clods are not desirable in the seedbed and if present, may cause obstructions to the furrow openers of the seeding machines. Moreover, large clods result in poor contact between seed and soil, thus hampering the germination as well as emergence of seeds.

Clods are generally formed in clay soils when ploughed at dry or wet conditions. Possibilities of breaking clods depend upon applying a downward force to cause brittle failure with the help of a heavy roller. Under high moisture conditions of the soil, breaking of clods is possible by cutting either with disk or rotary tools. The consolidating effect of rollers on the soil is governed by four factors viz. weight, diameter, type and conditions of soil and speed of operation. The first two factors can be considered while selecting the roller and the last two when using it.

In some parts of India, plain rollers made of wood or concrete are used for breaking clods. These rollers are better than the flat wooden planker but not very effective because they also press clods in the soil without proper disintegration. For effective breaking of clods, corrugated clod crushers can be considered as an appropriate choice. This paper, therefore, describes the performance of corrugated clod crushers under field conditions.

Literature Review

Apparently little research information has been reported on the performance of different types of clod crushers. However, their use and importance have been quoted in various technical literature and text books.

Diokoto et al (1971) conducted studies on flat wooden disks and conventional soil packers to determine the effect on bulk density. They found that an increase of 41% in packer weight (141.4 to 199.1 kg/m width) resulted in less than 1% increase in soil bulk density. The variation in diameter (192 to 610 mm), wheel width (13 to 38 mm) and spacing (25 to 127 mm) gave no significant difference in the bulk densities.

Bernacki et al (1972) derived a relationship for the draft of a plain packer as given below:

$$P = \frac{Gl}{r} \qquad (1)$$

where,

P = draft
G = weight on the roller
r = roller radius, and
l = length of the arm between the vertical central axis of the roller and the point of action of resultant soil reaction.

The above equation indicates that the larger the diameter of the roller, the lower the draft because of less bulldozing action. The arm "*l*" depends on the penetration depth of the roller into the soil and elevation of soil in front of the roller. Therefore, the resistance of the packer is comparatively high in light unpacked soil. Under normal conditions if sinkage does not exceed 20 mm, the ratio *l*:r ranges from 0.15 to 0.30 depending upon the type and state of soil pulverization.

Goryachkin (1974) used the following equation for the draft of a smooth land roller.

$$P^3 = \frac{KG^4}{BD^2} \qquad (2)$$

where,

G = weight on the roller, kg
B = width of the roller, m
D = diameter of the roller, m
P = draft, kg
K = 0.8×10^{-5} for harrowed soil and 0.1×10^{-5} for stubble fields.

It is evident from equation (2) that the draft is most greatly affected by the roller weight (G), then by the diameter (D) and least by the width (B).

Wolf and Luth (1979) designed and tested a soil combine for breaking hard clods into desired seedbed aggregates in a single pass. The resulting performance of the machine was 80% higher with greater soil pulverization, 30% more than that of an offset disk harrow. However, high draft requirement and formation of shatter resistant clods made seedbed preparation a slow and expensive process.

Kumar et al (1985) conducted feasibility trials on a pulverization roller-cum-puddler in black cotton and sandy-loam soils. It produced less finer modules compared to the cultivator operation in the sandy-loam soil . However, its effect was insignificant in black cotton soil where maximum pulverization was obtained with the cultivator at 5.73 km/h speed of operation.

Materials and Methods

The experimental test rig consisted of a rectangular angle iron frame with provision for mounting different crushers, a box for adding ballast and a drawbar dynamometer as shown in **Fig. 1**. Three types of crushers, namely; Cambridge roller, angle iron bar types with 70 and 140 mm spacing were used in the investigations. Seven V-shaped cast iron wheels each with a working width, diameter and weight of approximately 100 mm, 460 mm and 27 kg, respectively, were arranged

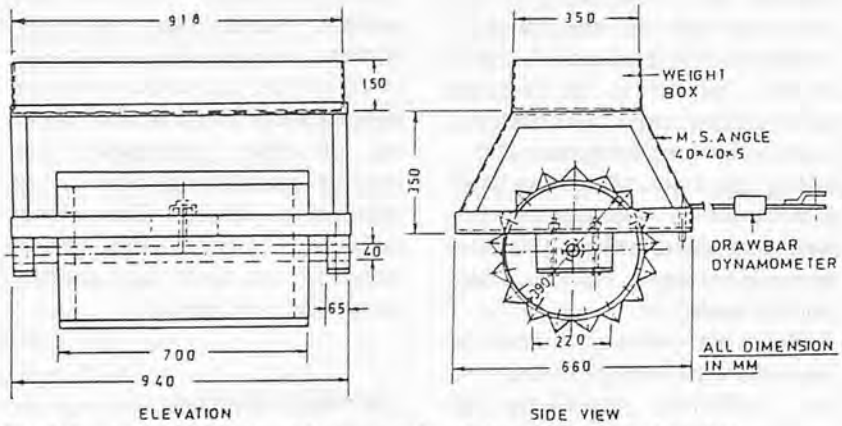

Fig. 1 Experimental test-rig with corrugated angle iron bar type clod crusher.

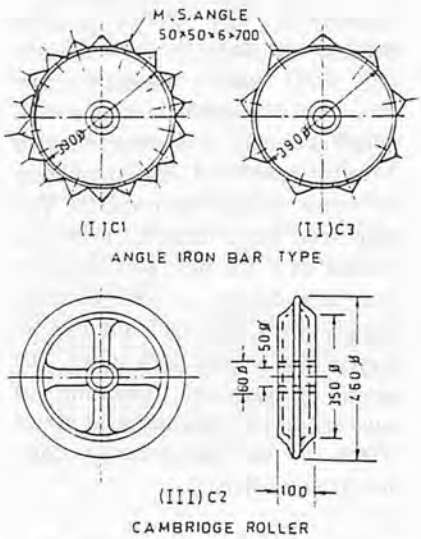

Fig. 2 Crushers used in the experimental study.

successively on the axle of the crusher to make a Cambridge roller of approximately 700 mm effective width.

The second type of crusher was designed from 17 mild steel angle iron bars (50 x 50 x 6 mm) mounted longitudinally on two circular plates with nuts and bolts. The size of the angle iron bars was selected such that the corrugations were approximately similar to that of Cambridge roller. The effective diameter of this crusher was kept close to the Cambridge roller at 460 mm and spacing between bars was as approximately 70 mm.

The third type of crusher was made from the second crusher by removing the alternate angle bars to obtain 140 mm spacing. All other dimensions were kept similar. The experimental rollers are shown in Fig. 2.

The experiments were conducted in outdoor bins with silty-clay-loam soil (61.4% silt, 29.7% clay and 8.8% sand) at different forward speeds of 1.2, 2.5, 4.8, and 6.5 km/h. There were 20 soil bins of 60 m length and 2 m width. Each bin was divided into two halves which was further sub-divided into four parts of 5, 5, 10 and 10 m. In each half of the bin, one set of experiment was conducted keeping the weight of the crusher as constant and varying the forward speed. The experiments were conducted in fresh soil using completely randomized design with three replications. The total weight of the crushers varied from 214 to 428 kg/m in steps of 71.5 kg/m width. However, in the case of the Cambridge roller only two loads of 321 and 428 kg/m were chosen as lower loads were not possible in the present design. The effectiveness of clod crushers was observed for two subsequent operations on respective test plots.

Clods were formed by ploughing the bins with the mould board plough up to a depth of 160 mm. The bins were left for two days to dry and, subsequently, tilled twice with a tractor-operated trailed disk harrow followed by two passes of a cultivator to expose most of the clods on the surface. The experimental test rig was attached to a Ford 3600 tractor and the experiments were conducted at different speeds and loads. In order to define the initial soil conditions, samples were collected from each bin (total 20 samples) separately to determine the average bulk density and clod mean-weight-diameter which were recorded 1.38 g/cc and 40.40 mm, respectively. The soil and clod moisture contents were also determined from these samples. After each test run, samples were collected for first and second operations separately to define the final soil conditions on the basis of change in initial parameters. All the experiments were completed within 3 days to minimize the effects of variations in moisture content of the soil.

The moisture content of soil and clods were determined by the oven dry method and recorded to be 14 and 2% on dry weight basis, respectively. The bulk density samples were collected from depths up to 120 mm using a bulk density kit and inserting a known volume of cylinder into the soil. The bulk density was thus determined on wet basis by weighing known volume of soil samples. The draft of different clod crushers was determined directly with drawbar dynamometer. For determining the clod mean-weight-diameter an area of 50 x 50 cm^2 was marked using a frame. The clods as well as the pulverized soil were collected from top surface and mixed. From this, a composite sample was taken, air dried in the laboratory and a sieve analysis was performed using 40, 20, 10, 5.6, 2.4 and 1 mm size of sieves. Each sample was agitated for 5 min on the sieve analysis apparatus. The weight of soil retained on each sieve was recorded to determine the clod Mean-Weight Diameter (MWD) of soil aggregates, using the following relationship proposed by Van Bavel (1949).

$$MWD = \frac{\sum_{i=1}^{n} W_i d_i}{W} \qquad (3)$$

where,

MWD = mean-weight-diameter of soil aggregates,

W_i = weight of soil samples retained over the ith sieve, g

d_i = class of mean size for ith sieve, and

W = total weight of soil sample, g.

Results and Discussion

The experimental data was analyzed to determine the clod MWD, bulk density and draft per unit width of crushers. The relationships with respect to different forward speeds and loads were established.

Effect on Clod MWD

The variations in clod MWD with respect to different speeds and loads of crushers are shown in Figs. 3 and 4. The maximum reduction in the clod size was obtained for speed range of 2.5 to 4.8 km/h with an average value of approximately 3.5 km/h. At the minimum speed of 1.2 km/h and maximum of 6.5 km/h, the breaking of clods was poor which gave higher values of clod MWD. The reasons for this variation in clod MWD may be due to the fact that at minimum speed the breaking of clods is only due to downward pressure of the crushers. With an increase in speed a greater degree of shearing and shattering of clods was obtained due to larger impact force. However, at maximum speed of 6.5 km/h, the crushers were virtually bouncing

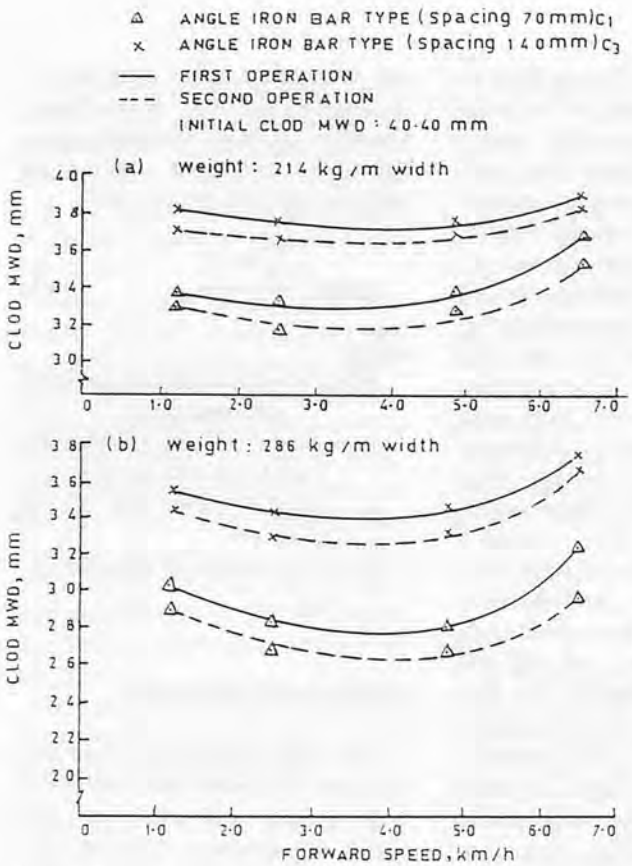

Fig. 3 Effect of forward speed of crushers on the clod MWD for 214 and 286 kg/m loads.

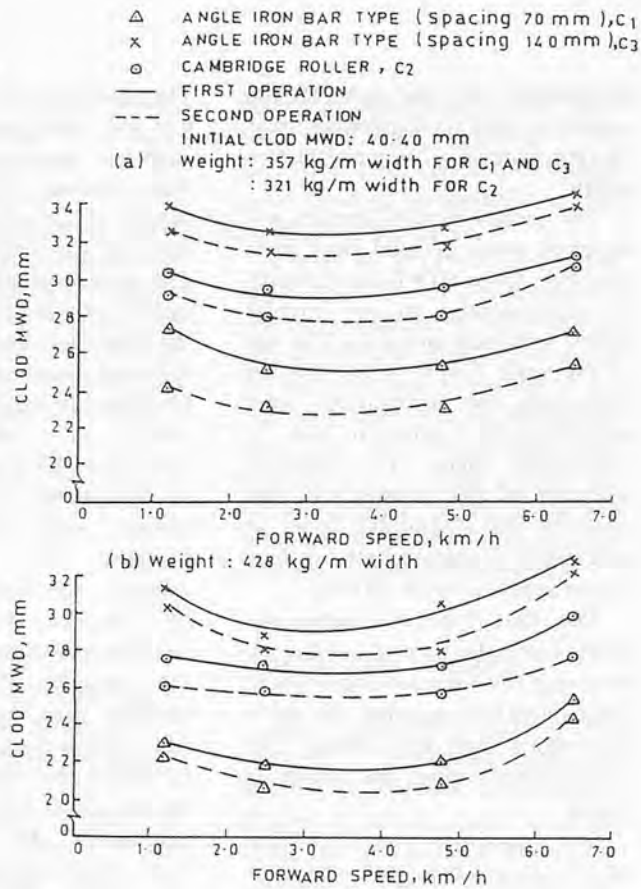

Fig. 4 Effect of forward speed of crushers on the clod MWD for 357 and 428 kg/m loads.

over the soil surface which resulted in poor contact between clod and crushers, thus giving higher values of clod MWD.

At the maximum weight of 428 kg/m width (**Fig. 4b**), where all the clod crushers are compared, it is observed that for the speed of 3.5 km/h, the clod MWD decreased from its initial value of 40.4 to 21.8 mm, 25.0 and 28.8 mm in case of angle iron bar type (C_1, 70 mm spacing), Cambridge roller (C_2) and angle iron bar type (C_3, 140 mm spacing), respectively. This has revealed that the reduction in clod MWD for crushers (C_1), (C_2) and (C_3) was in the order of 46, 38 and 29%, respectively. The reduction in clod MWD from first to second operation was approximately 5% for all three crushers. The reasons for small reduction in clod MWD for the second subsequent operation of crushers may be associated with the fact that most of the clods were either broken or pressed into the soil during the first operation itself, hence left only a limited number of clods on the surface.

The increase in load reduced the clod MWD for all the crushers at various speeds. The crusher (C_1) gave maximum reduction in clod size followed by (C_2) and (C_3). For the speed of 3.5 km/h doubling the weight of crushers from 214 to 428 kg/m width reduced the clod MWD from 32.5 to 21.5 mm in case of (C_1) crusher. A similar increase in weight for (C_3) crusher gave clod MWD of 37 to 29 mm. However, for the Cambridge roller (C_2), an increase of load by 33.3% from 321 kg/m initial load, reduced the clod MWD from 29 to 27 mm from initial clod MWD of 40.4 mm.

Effect on Bulk Density of Soil

Bulk density is one of the important parameters used for the evaluation and comparison of clod crushers. The compaction of seedbed in terms of increased bulk density is desirable for conserving soil moisture and ascertaining intimate seed to soil contact for better germination which is automatically obtained while breaking the clods.

The relationships between the bulk density and load at different speeds of operation is illustrated in **Figs. 5** and **6** showing a linear increase in bulk density with the load for all speeds. The crusher (C_1) gave maximum increase in bulk density and C_3 the minimum. For the crusher (C_1) at minimum speed of 1.2 km/h and 214 kg/m load, the bulk density increased to 1.44 g/cc (**Fig. 5a**) from the initial value of 1.38 g/cc. At double the load from 214 kg/m, the bulk density was recorded at 1.57 g/cc, giving an increase of approximately 9%. For the second operation only a slight increase in bulk density (approximately 1%) has been

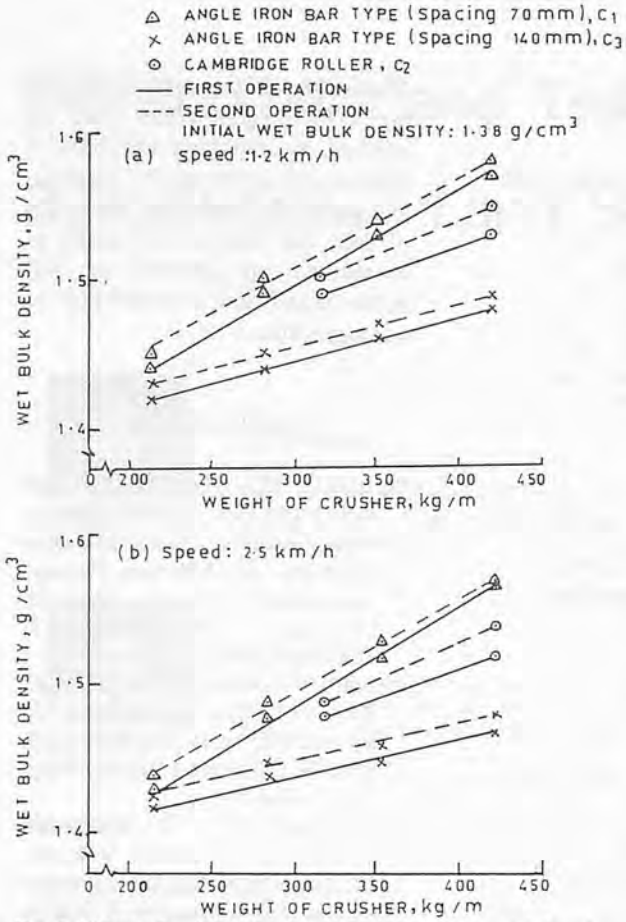

Fig. 5 Effect of weight of crushers on bulk density at 1.2 and 2.5 km/h forward speed.

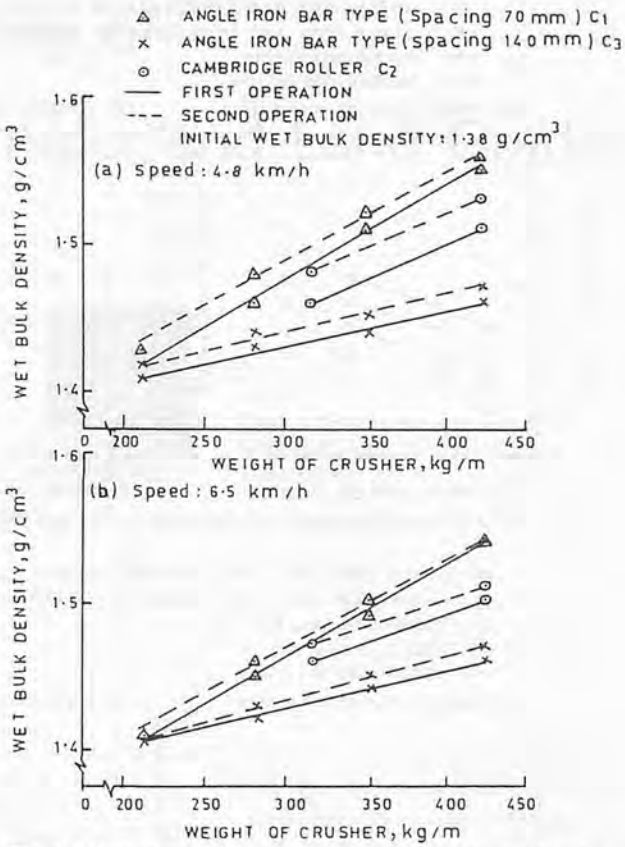

Fig. 6 Effect of weight of crushers on bulk density at 4.8 and 6.5 km/h forward speed.

observed which is in agreement with many investigators who reported approximately 80% compaction of soil in the first pass under loose soil conditions (Jones, 1973 and Soane, 1983). A similar trend was observed at other speeds as shown in **Figs. 5b** and **6**.

The variation in bulk density with speed shows an opposite trend to that of the effect observed with the load. The decrease in bulk density with speeds may be accounted for the bouncing effect of crushers at higher speeds which resulted in poor disintegration of clods and re-arrangement of soil aggregates.

Effect of Load and Speed on Draft

The relationshps between speed and draft per meter width at different loads for all the crushers are shown in **Figs. 7** and **8**. In general, for all the clod crushers, it is observed that with the increase in speed from 1.2 to 2.5 km/h, 2.5 to 4.8 km/h and 4.8 to 6.5 km/h, the draft is increased by 8 to 14%, 10 to 16% and 14 to 22%, respectively.

From **Fig. 7a**, it is evident that at the minimum load of 214 kg/m and speed of 1.2 km/h, the crusher (C_1) gave 0.50 KN/m draft and crusher (C_3) a value of 0.64 KN/m. Similarly, at maximum speed of 6.5 km/h, the draft was 0.78 KN/m and 0.93 KN/m for crushers (C_1) and (C_3), respectively. For the load of 428 kg/m where all the crushers are compared, the crushers (C_1), (C_2) and (C_3) gave 0.78, 0.71 and 1.00 KN/m of draft, respectively, at minimum speed of 1.2 km/h, whereas the draft values of 1.14, 1.03 and 1.50 KN/m were noted at maximum speed of 6.5 km/h. The reason for the minimum draft for the Cambridge roller (C_2) may be due to comparatively lower rolling resistance. However, in crusher (C_1) the horizontal bars strike the clods with greater impact force which resulted in better clod breaking and pulverization, thereby, required higher draft. In the case of crusher (C_3), the maximum values of draft were obtained due to higher rolling resistance and difficulty in smooth rolling of the crusher. It is also observed from the relationship that the second operation required about 0.05 to 0.15 KN/m width lower draft in comparison to the first operation.

Conclusions

1. The minimum value of clod MWD was obtained at a speed of 3.5 km/h for all the crushers. The angle iron bar type crusher

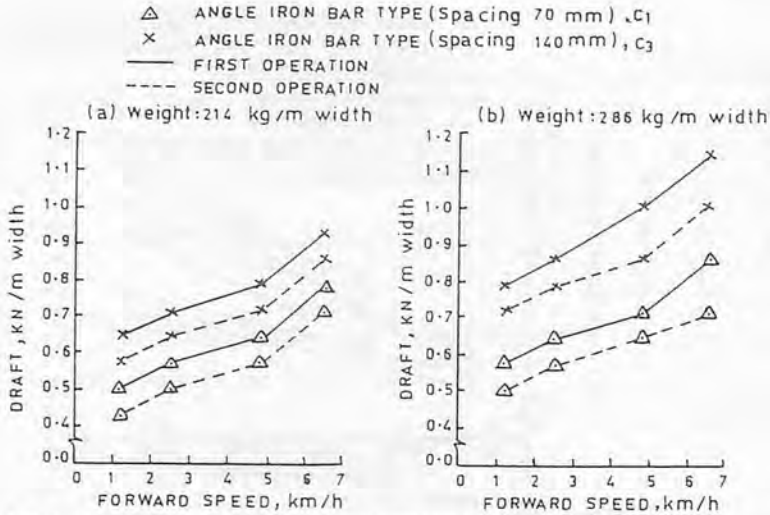

Fig. 7 Effect of speed on draft of clod crushers for 214 and 286 kg/m loads.

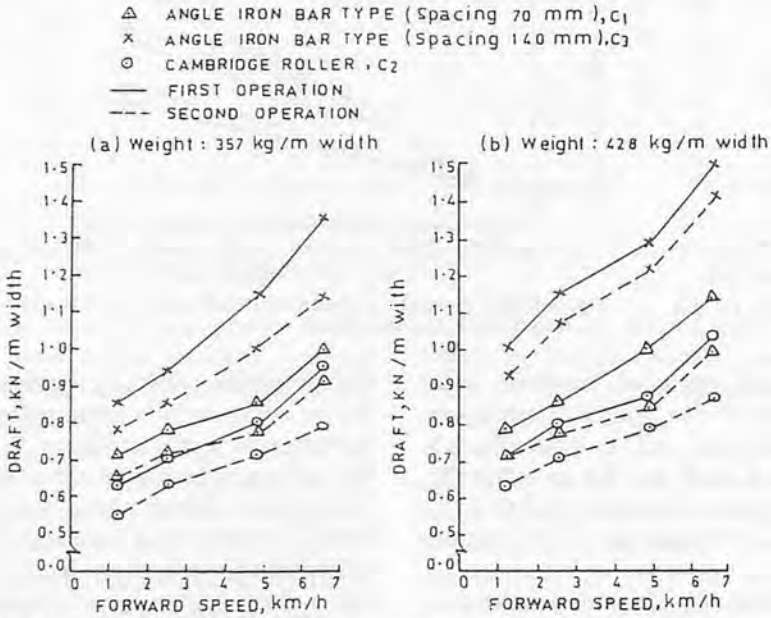

Fig. 8 Effect of speed on draft of clod crushers for 357 and 428 kg/m loads.

with 70 mm spacing gave maximum reduction in clod size.

2. The bulk density decreased with an increase in speed but increased with the load of crushers. For angle iron bar crusher (70 mm spacing) at a load of 357 kg/m width and operational speed of 3.5 km/h, the bulk density increased to approximately 1.52 g/cm^3 from the initial value of 1.38 g/cm^3 giving about 10% increase.
3. The draft of crushers inceased with the increase in load and speed. The angle iron bar crusher (70 mm spacing) at a load and speed of 357 kg/m width and 3.5 km/h, respectively, gave a draft of 0.82 KN/m width. However, in the case of the Cambridge roller the draft was the lowest at 0.75 KN/m width.

In general, the angle iron bar crusher with 70 mm spacing gave the best performance. According to the power source available, the speed of crushers may be kept 2.5 km/h for animal and 3.5 to 4 km/h for tractor-drawn models. The width of the crusher and load up to 350 kg/m width may be selected by matching the draft of crusher and power source. Depending upon the type and condition of soil, the load can be varied to obtain varying degrees of soil pulverization and consolidation of soil aggregates.

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Development and Testing of Bullock-drawn Land Scraper and Land Grader

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Abstract

The topography of land in Orissa State varies from district to district. Substantial portion comprizes of upland and hilly areas where slope varies from 2 to 10%. Increased irrigation potential and consolidation of land have compelled the farmers to reshape their fields. A suitable bullock-drawn scraper and a land grader were developed and tested to meet the requirement of the farmers. A saving of Rs.0.83 per m^3 of soil was recorded when the field was levelled by the scraper and grader in comparison to manual method.

Introduction

Land grading is reshaping of the field surface to a planned grade. Usually the agricultural field is not graded to a truely leveled surface, but a gentle uniform slope is maintained to meet the requirements of irrigation and drainage. Therefore, land grading smoothes the field to eliminate uneven surface, permits uniform distribution of water and facilitates construction of channels to handle excess flow.

The irrigation potential of the State in the last decade has been increased(4) due to the expansion of gravity irrigation and tapping ground water. Judicious use of this water needs agricultural fields to be perfectly graded without which there is uneven crop, low yield and loss of irrigation water and fertilizer.

Land grading is equally beneficial in un-irrigated areas to conserve moisture, reduce soil erosion and facilitate surface drainage(5). The uncultivable and fallow lands can be converted to pastures or planted to crops if proper land grading and surface drainage measures are undertaken. The emphasis has been given for land consolidation. After the consolidation farmers layout their land afresh for increasing the cropped area, better cultural operations and facilitation of the use of agricultural implements.

Usually the land levelling work after ploughing operation in the State is done by manual operation which is time consuming, labourious and not scientific. The costly human energy is under-utilized. The bullock-drawn land levelling devices are available viz. "ladder", "korada" and "rampa" (1), but these are less efficient because of improper design. Power-operated land levelling devices such as push type scrapers (bulldozers), drag type scrapers, wheel type carrying scrapers and tractor-mounted land smoothers are available but their hire charge is prohibitive for small and marginal farmers.

Keeping in view the present immediate need of the large section of the farmers of the State a set of scraper and land grader was designed, developed and tested.

Land Scraper

The various components of this implement are cutting blade, end bits, wooden body, drag links and handle **(Fig. 1)**. Detail specifications are given in **Table 1**. This implement is operated by a pair of bullocks. The operator holds the

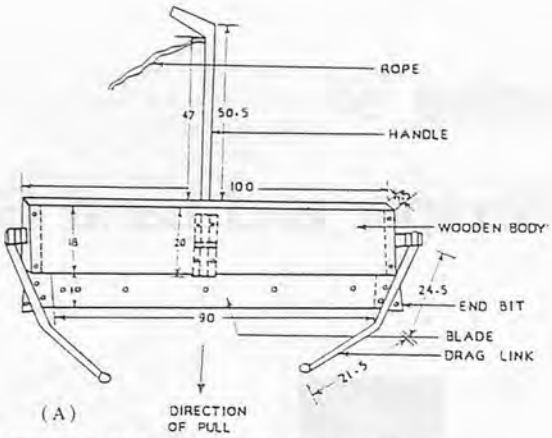

Fig. 1 (A, B) Bullock-drawn scraper, unit: cm.

Table 1 Specifications of Bullock-drawn Scraper

Name	Material	Dimension
Blade	Heat treated M.steel	90 cm × 10 cm × 6 mm
End bits	Heat treated M.steel	10.6 cm × 7.8 cm × 12 cm × 8.5 cm × 6 mm
Wooden bottom	Wood	1 m × 25.5 cm × 1.25 cm
Side pin	M.S.Rod	2.5 cm dia, 7 cm length
Drag link	M.S.Rod	1.8 cm dia, 66 cm length
Handle	M.S.Flat	73 cm length, 5 cm flat
Rope	Plastic	14 mm dia, 6 m length

handle and at higher spots in the field the implement is inclined at such an angle that the soil is cut and dragged to the lower spots easily. At lower spots the soil is released slowly by reducing the pressure on the handle.

Land Grader

This is also a bullock-drawn implement. The various components of this grader are cutting blade, front and rear wooden plank, shoes and triangular frames and foot board (**Fig. 2**). Details of specifications are given in **Table 2**.

Cutting blade – This is a long, narrow strip of mild steel which is bolted along the length of the front plank of the grader. The blade protrudes by 2 cm from the lower edge of the plank. It cuts higher spots of the field surface and moves the soil to the lower spots.

Front and rear wooden plank – A front wooden plank imparts strength to the cutting blade so that it does not bend. This plank can be bolted with the triangular frame at angles 45° and 67.5° as to provide same cutting angles to the blade. The depth of cut can be adjusted by changing this angle of cut of the front blade. A rear wooden plank runs parallel to the front wooden plank at a distance of 25 cm. The edge of this plank just touches the ground to smooth the field.

Shoes and triangular frames – The shoes provide a base line for smoothening the surface and give support to the wooden planks. The frames are mounted on the sides to provide 45° and 67.5° angles of inclination of the front wooden plank. This arrangement facilitates the selection of suitable cutting angle and depth of cut.

Foot board – Two wooden foot boards are provided so that the operator can stand on the grader at high spot.

Hitch – Hitching is done by plastic rope with two eye bolts in the front.

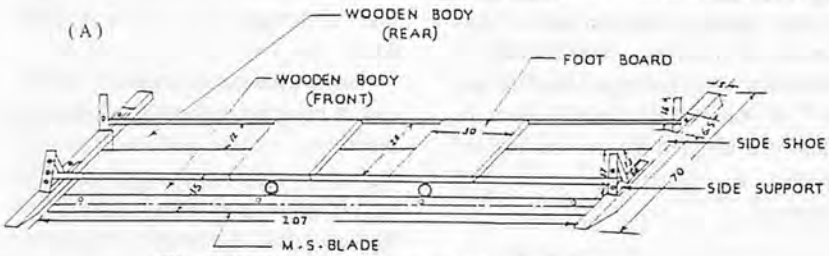

Fig. 2 (A, B) Bullock-drawn land grader, unit: cm.

Table 2 Specifications of Bullock-drawn Grader

Name	Material	Dimension
Blade	Heat treated M.steel	207 cm × 6.5 cm × 6 m
Wooden body (Front)	Wood	207 cm × 12 cm × 2.5 cm
Wooden body (Rear)	Wood	207 cm × 12 cm × 2.5 cm
Side support	M.S.Flat	45 cm × 2.5 cm
Wooden foot boards (2 nos.)	Wood	30 cm × 25 cm × 2.5 cm
Nuts and bolts	M.S.	3.75 cm length
Rope	Plastic	14 mm dia, 6 m length

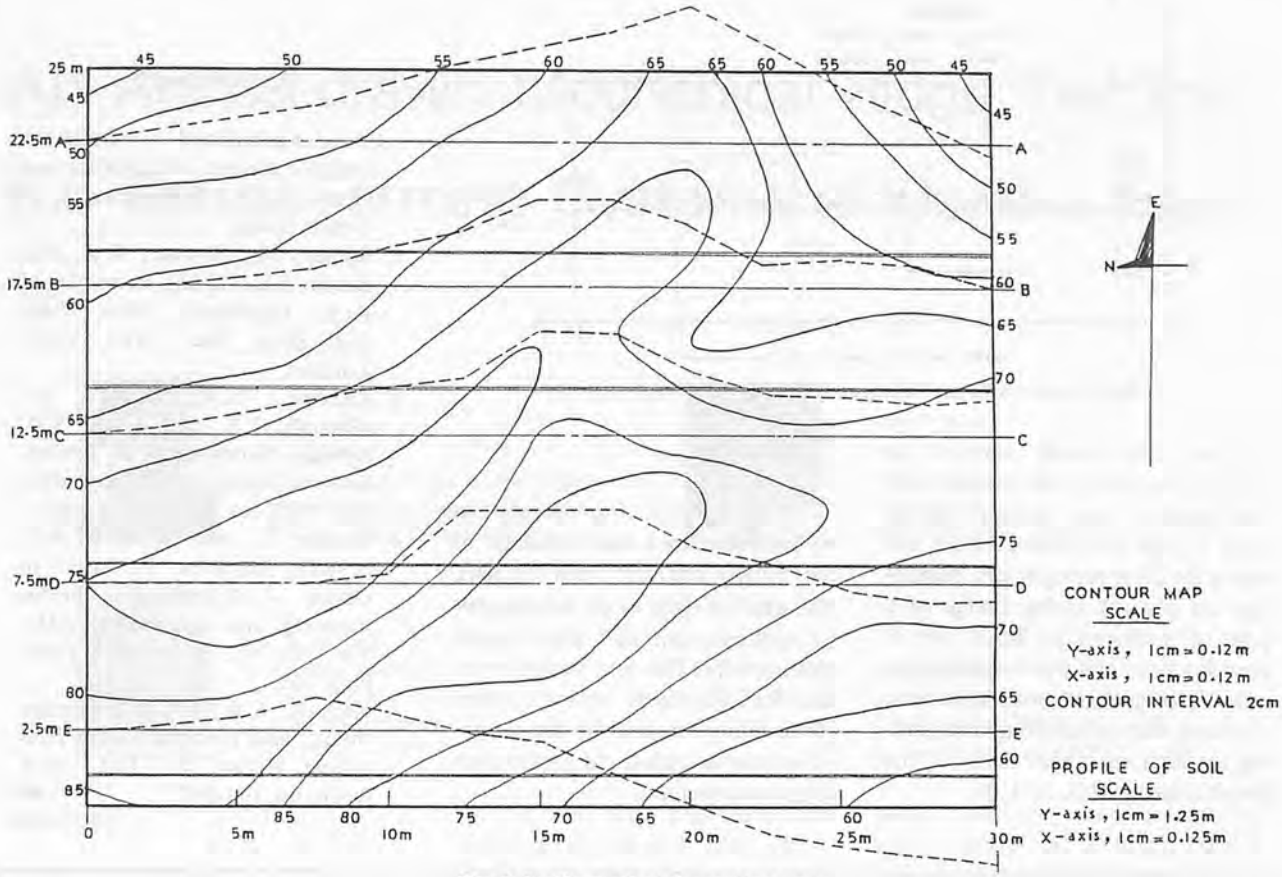

Fig. 3 Profile method for grading land.

Test Procedure

An undulating plot of 30 m x 25 m was selected in the Central Farm of the Orissa University of Agriculture and Technology. In order to carry out the operation the contour map **(Fig. 3)** with an interval of 2 cm was plotted to record the roughness of the field. Then the volume of the soil was calculated to make the field nearly level taking cut fill ratio 1.15:1 using the profile method. An average pair of bullock was engaged with a plough man. The draft was measured using the spring type dynamometer. Effective time of operation of the implements was taken into account. The soil moisture content was determined by oven drying method.

Results and Discussion

After preparing the contour map, the plot was divided into five strips of 5 m x 30 m. To level each strip in north-south direction the cutting and filling areas were marked. The scraper was used after ploughing the field with mouldboard plough. The soil carrying capacity of the scraper was 0.025 m^3 with hauling distance of 10 to 15 m and the draft was 60 kg. Alternative ploughing and scraping were done twice to achieve a level surface in each strip. The earth work of cutting 7.85 m^3, 5.45 m^3, 4.71 m^3, 6.23 m^3 and 11.42 m^3 soil was done in strip A, B, C, D and E, respectively, during 15 working hours. The total volume of 35.66 m^3 of soil was cut to level each strip. Then the field had a soil profile as shown in **Fig. 4**. Similarly, the mean level point was calculated and the field was levelled by alternative ploughing and scraping in east-west direction for three times during 30 working hours. The total earth work for levelling the field was 72.3 m^3. After the field was completely levelled the land grader was used thrice in north-south direction to have a desired grade of 0.5%. The earth work involved in this case was 14.06 m^3 during 8 working hours. The draft of land grader was 31.5 kg/m.

Table 3 Test Report of Bullock-drawn Scraper and Grader

Observation	Scraper	Grader
Weight, kg	13	22
Soil type	Sandy loam	Sandy loam
Soil moisture, %	9	9
Average pull, kg	65	45
Angle of pull, degree	22	21
Average draft	60 kg	31.5 kg/m
Width of cut, m	1	2.0%
Soil carrying capacity, m^3	0.025	0.015
Hauling distance, m	10 to 15	12 to 20

In order to level and grade the field the total volume of soil handled was 122.02 m^3. If the above volume of soil was carried manual-

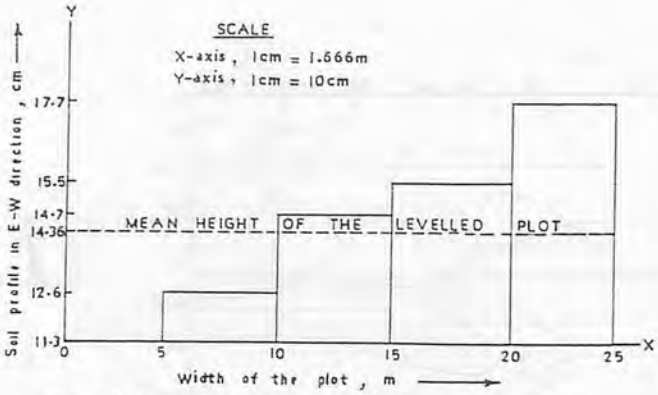

Fig. 4 Soil profile in E-W direction after levelling strip-wise.

ly, the cost would amount to Rs.366.06. Using the scraper and land grader, one operator along with a pair of bullocks were engaged for 53 working hours. Assuming the present hiring charge of a pair of bullocks at Rs.30 for 8 working hour and the wage of operator Rs.10 per 8 at working hours, the total cost of levelling and grading the field amounted Rs.265. This shows a saving of Rs.101.06.

Conclusion

These low cost implements can be manufactured and repaired at the village level by local artisans. The draft is light as an average pair of bullocks can pull these implements easily. The test results reveal that Rs.0.83 per m^3 of soil is saved for levelling the land by the designed scraper and grader in comparison to manual method.

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An Animal-drawn Mechanical Ridge Tier for the Cereal Farming Systems of Burkina Faso

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Abstract

An animal-drawn, mechanical ridge tier was tested under on-farm, farmer-managed conditions to evaluate its technical viability in the field, profitability and farmer acceptance in the cereal farming systems on the Mossi Plateau of Burkina Faso, West Africa. Previous field research had shown that the water retention technique of tied ridge construction in combination with fertilizer use was technically viable in the field and profitable. Manual tied ridge construction, however, requires a large amount of labor which precludes its use in the present cereal farming systems of the Mossi Plateau. The mechanical ridge tier proved to be technically viable in the field, profitable and substantially reduced the labor requirements and, in general, was acceptable to farmers.

Acknowledgements: The authors would like to acknowledge the assistance of Mr. Sibiri Sawadogo, IBRAZ Farming Systems Coordinator, Mr. Jeff Wright (PCV) and Dr. Mario Rodriguez IITA/SAFGRAD. Research was conducted by the Purdue University Farming Systems Unit (FSU), Contract AFR-C-1472 with the Agency for International Development under the Semi-Arid Food Grain Research and Development Project (SAFGRAD), P.O.Box 1783, Quagadougou, Burkina Faso.

Introduction

The Purdue University farming systems unit (FSU) under the Semi-Arid Food Grain Research and Development Project (SAFGRAD), conducted a farming systems research on the Mossi Plateau of Burkina Faso in West Africa. The project focused a major part of its research effort on the description and understanding of the constraints to cereal production and on the agronomic and economic evaluation of technological interventions designed to alleviate these constraints. Two of the major constraints are low soil fertility and poor soil water retention. The soils are alfisols which are shallow, poorly structured, and deficient in phosphorus, nitrogen and organic matter. The soils contain only weak aggregates and after a rain the soil surface dries and forms a crust which restricts water infiltration and aeration and increases rainfall runoff (Kowal and Kassam, 1978). Thus two technological interventions that FSU experimented with were fertilizer use and the water retention technique of tied ridging.

Tied ridges are small depressions made between the crop rows either by hand tillage or with a combination of animal traction and hand tillage. If constructed solely by hand, depressions 32cm long by 24cm wide and 16cm deep are made between the rows spaced 1.5 m apart. If constructed in combination with animal traction, the cultivator (Houe Manga) is equipped with a middle sweep to create a furrow which is then followed by hand tillage to make a 16-cm high ridge perpendicular to the furrow every one to two meters. The depressions catch and hold water after a rain and increase soil water infiltration and retention. Both methods are very labor-intensive.

Neither tied ridging nor fertilizer application are traditionally practiced by cereal farmers on the

Mossi Plateau. Most farmers, including those with animal traction, plant on unprepared land with a small hoe "daba" within 1-3 days after a major rain. A first weeding is undertaken 3-4 weeks after planting and in most years a second weeding at 6-8 weeks after planting. Farmers who utilize animal traction use a cultivator at both first and second weeding but use a large middle sweep on the cultivator at second weeding to make ridges that deposit soil at the base of the plant for support.

FSU on-farm, farmer-managed trials in 1983 and 1984 indicated that the technology interventions of tied ridging alone or tied ridging and fertilizer use in combination were technically viable in the field under on-farm conditions and economically profitable (Lang et al., 1984: Ohm et al., 1984a and 1984b). When using tied ridges alone, yields are constrained by soil fertility. The technology intervention of fertilizer alone is, however, financially very risky and must be combined with a water retention technique such as tied ridges before the levels of the risk of losing a fertilizer cash outlay are low enough to be acceptable to farmers. Despite being technically viable in the field and economically profitable, farmer interviews and labor data analysis indicate that the combination of the labor-intensive technology interventions of fertilization and tied ridging did not fit the farming systems because of a labor shortage in the critical planting – weeding period; the same period in which fertilizer use and tied ridging must take place.

Labor data collected by the field staff from FSU 1983 and 1984 trials indicate that it requires up to 100 man-hours/ha above normal weeding practices for the average household to construct tied ridges by hand and up to 75 man-hours/ha above normal weeding practices when animal traction-made ridges are ties by hand (Ohm et al., 1984a and 1984b). An FSU adoption of technology survey in 1984 indicates that the average hectarage of manual construction of tied ridges above that constructed for FSU experiments was only 0.32 at Nedogo (Ohm et al., 1984b). Farmers further indicated that hiring from an outside labor pool was limited because all the active labor force of the households were fully occupied with work on their own fields during this period.

The information on the labor shortage was communicated to other researchers within SAFGRAD after the 1983 field campaign and in late 1983, a USA Peace Corps Volunteer with the IITA/SAFGRAD maize agronomy program at Ouagadougou started work on a prototype mechanical device (**Fig. 1**) to tie the ridges (Wright and Rodriguez, 1985) which was, subsequently, field tested by FSU in 1985 and is the subject of this paper.

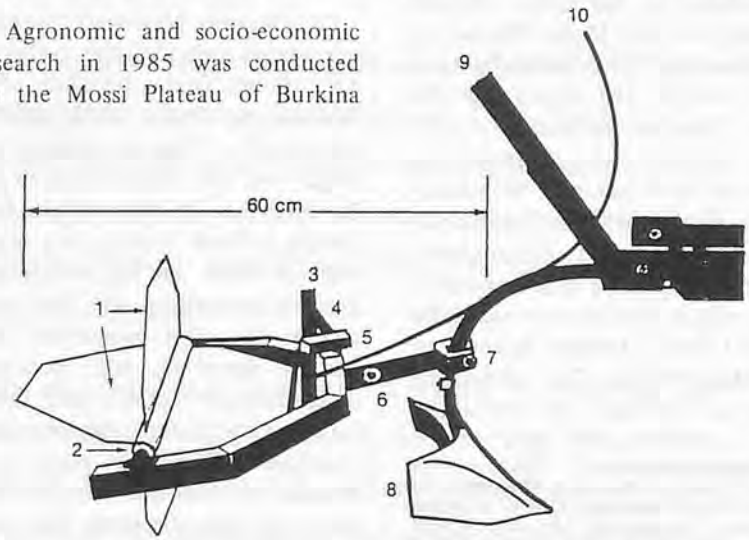
Materials and Methods

Agronomic and socio-economic research in 1985 was conducted on the Mossi Plateau of Burkina Faso in the villages of Nedogo, 30km northwest of Ouagadougou, and Poedogo, 130km south of Ouagadougou. The villages are at the 200-300m elevation above sea level and 11-13 degrees N Latitude. Sand, silt and clay content on the Mossi Plateau ranges from 60-70%, 20-30% and 5-10%, respectively, (Vierich and Stoop, 1984).

The 1985 Mechanical Ridge Tier Experiments

Experiments were conducted with donkey-traction and ox-traction farmers. All treatments received 100kg/ha 14-23-15 fertilizer applied in a band 10-15cm from the crop rows 2 weeks after planting plus 50kg/ha urea applied in a band 10-15cm from the crop rows 6-8 weeks after planting.

The experiment included the mechanical ridge tier (MRT) which is a device (**Fig. 1**) attached to an animal-drawn cultivator with one large middle sweep. The ridging and tying of the ridge can be done simultaneously in one pass through each crop row or the operation can



1. Shovels
2. Axel bearing (pipe)
3. Latch lever
4. Rubber band (inner tube strip)
5. Latch adjuster (for correct angle and to compensate for wear in bearings, shovels and latch)
6. Shovel angle adjusting bolt
7. Coupler
8. 30 cm ridger that allows soil to flow over the top
9. Handles of "houe Manga" (FAO donkey weeder)
10. Bicycle cable to brake lever

Fig. 1 The IITA/SAFGRAD mechanical ridge tier (donkey version).

be done in two passes. When using the two-pass method, the rows are first ridged in the normal way and then in a second pass the ridges are tied by the MRT which is attached to the cultivator. The device is essentially a paddle wheel (45cm in diameter) with four paddles, one scraping the ground, building up earth until it is tripped by the operator every 1.5-2m to create the tie in the ridge. The treatments for the experiment were as follows:

1) Traditional animal-traction practices, including flat cultivation and no fertilizer, the control (C);
2) Tying of the animal traction-made ridges every 1-1.5m by hand at second weeding, (TR-Manual);
3) Tying the ridges mechanically with the MRT at second weeding, (MRT-1); and
4) Tying the ridges mechanically with the MRT at first weeding and again at second weeding, (MRT-2).

Treatment 4) allowed an assessment of tying the ridges at an earlier stage of plant growth when the ties should be more beneficial and also assesses whether the farmers had problems in constructing ties at second weeding because of the presence of the ties made at first weeding.

The experimental design for the Nedogo on-farm, farmer-managed experiments was a split-plot with whole-plots (types of traction) arranged in a completely random design and treatments were the subplots. At Poedogo, the experimental design was a randomized complete block with farmer's fields as the replications. Each treatment was randomly assigned to a parcel of the farmer's field. The one parcel of each treatment in each farmer's field was considered as an observation.

Farmers managed and carried out the experiments and were responsible for all labor inputs. Fertilizer was supplied to the farmers. Local sorghum varieties were used and planted at traditional densities of 60 000 plants/ha. Seventy-five cm row spacings were traced out prior to planting. FSU field staff delineated each parcel with colored stakes and measured the areas of all parcels prior to planting. Parcel size ranged from 0.05 to 0.12 ha depending on the size of the farmers' field. Field plots were chosen using the following criteria: at least a 1% slope (most plots were 2-3%), no previous mineral fertilizer and homogeneity in soil texture and type. FSU field staff frequently visited the farmers to ensure that seeding, fertilizer application, tied ridge construction and other tasks were done correctly and on time. Prior to harvest, all parcels were evaluated for general conditions of the crop. Farmers harvested all parcels by hand and the field staff weighed the harvest.

Eight farmers with donkey-traction and 7 farmers with ox-traction were selected at Nedogo and 15 farmers with donkey-traction were selected at Poedogo. They were selected at random from a group of farmers experienced with animal-traction and would be classified as good to very good farmers.

At Nedogo, the total rainfall received in 1985 was 572mm as compared to the long term (1952-1975) average of 809mm (latest available data from the weather station at the nearby village of Pabre) but above that of the 452mm received in the drought year of 1984. At Poedogo, the total rainfall received in 1985 of 805mm was below the long term average of 905mm (Manga weather station) but higher than the 1984 rainfall of 633mm. The months of July and August at Poedogo were very wet, 222.5mm and 242.0mm, respectively The distribution of rainfall and its timeliness for plant growth was very good at both sites in 1985. Crop establishment was excellent with minor plant stress throughout the growing season.

Socio-economic and Labor Data Survey

Labor data surveys were conducted to obtain the hours of labor required to construct tied ridges by hand, in combination with animal-traction, and with the MRT. Labor inputs were obtained by field staff of a farmer recall basis within 1 week of the operation. Because men, women and children are engaged in farming activities, a composite labor hour figure in terms of man-hours/ha was calculated using the following weights: one male hour ($\geqslant$ 15 yrs) = 1, one female hour ($\geqslant$ 15 yrs) = 0.75, and one child hour ($\geqslant$ 15 yrs) = 0.5.

The price of sorghum and the costs of fertilizer and the MRT were required for the economic budget analysis. The sorghum prices used in the economic analysis represent three month average post harvest farm gate prices. Fertilizer prices used were the official government subsidized prices at planting time. The total cost of a MRT is estimated at US$ 31.60. To obtain the capital cost of the MRT for 1 year, the US$ 31.60 is annualized over 5 years at 15% interest rate assuming the MRT is used on 3 ha/year which is equal to US$ 3.10/year. For reference, US$ 1.00 = 475 FCFA (West African Monetary Union) in the second quarter of 1985.

A farmer survey of those involved with the MRT trial was conducted just prior to harvest to obtain farmers' opinions, problems and suggestions about the MRT.

Results and Discussion

The results of the agronomic and economic analysis for the on-farm trials are reported for the village site of Nedogo only while

the labor data analysis and farmer interviews are reported for both Nedogo and Poedogo. Fourteen (7 donkey and 7 ox) of the 15 farmers at Nedogo and 7 of the 15 farmers at Poedogo completed the trials satisfactorily.

The Labor Data Survey

The average number of labor hours required for tying the ridges by hand after the ridges had been constructed by animal traction in treatment TR-Manual was 38.6 man-hours/ha in Nedogo and 45.6 man-hours in Poedogo. (These figures are for above-average farmers and, therefore, less than the 75 man-hours/ha overall average figure previously quoted). Farmers used the MRT in one pass (simultaneous ridging and tying) in Nedogo. Farmers with donkey traction required only 1.0 actual hour/ha above normal weeding practices or 2.0 man-hours/ha assuming 2 men worked with the donkey-traction team. Ox-traction farmers at Nedogo only required an additional 0.42 actual hours/ha more than the traditional weeding practices or 0.82 man-hours/ha. This represents a substantial labor saving compared to the manual ridge tying method.

In Poedogo, farmers constructed ridges with the MRT using the one-pass method at first weeding but used the two-pass method at second weeding (ridging first, then tying with the MRT). The two-pass method was used at second weeding because the soil is heavier than at Nedogo and the heavy rainfall received at Poedogo when the MRT operations were to be done made it difficult for farmers to work in the field. Also, farmers at Poedogo use a larger middle sweep at second weeding than at first weeding which adds to the draft. At first weeding, farmers required an additional 3.34 actual hours/ha to construct the ties with the MRT above that of traditionally constructing ridges alone. At second weeding, 13.7 actual hours/ha were required to construct tied ridges. Discussions with the field staff indicated that the 13.7 h/ha figure was high and that farmers could easily decrease the figure by at least a third.

The 1985 Nedogo MRT Field Campaign

All three treatments consisting of tied ridging resulted in significant yield increases over the control (**Table 1**). Given the distribution and timeliness of the rains in 1985, the yields of the tied ridging experiments were not dramatically higher than the yields of the control. The three ridging treatments did not significantly differ. The yield, however, tended to be higher when the ridges were tied manually (TR-Manual) as compared to those tied with the MRT. The lower yields observed in the two treatments using the MRT may be the result of root pruning or the damage caused to the young plants by the MRT. To overcome this problem, the width of the MRT should be made shorter or the rows wider by about 5 cm keeping in mind that the operation must also deposit enough soil at the base of the plants at second weeding to keep them from lodging. Also, the manually-constructed tied ridges were higher (16 cm) than the ties of the MRT (13 cm) which may have allowed more water to accumulate during a rain thus creating a larger moisture reserve. In the future, it may be expected that the yields obtained from the MRT treatments will be similar to that obtained in treatment TR-Manual once the equipment is improved and the farmers gain experience and adapt the MRT technology.

Yields in treatment MRT-2 where the MRT was used at both first and second weeding was not significantly different from yields obtained in treatment MRT-1 where the MRT was used at second weeding only. The timely and adequate rains (228.3 mm in July alone) made the yield difference minimal between the two treatments.

Table 1 Means for Effects of Animal Traction and for Three Methods of Tied Ridging at Nedogo, 1985

Treatments[1]	Mean grain yield (kg/ha)
Traction – MRT[2]	
Donkey	920.5
Ox	882.6
SE[3]	71.6
Tied ridging methods[4]	
Control (Treatment 1)[5]	740.0
TR-Manual (Treatment 2)[6]	954.4
MRT-1 (Treatment 3)[7]	875.6
MRT-2 (Treatment 4)[8]	927.5
SE[3]	62.8
CV%	19.0
N[9]	14

Source: Nagy et al., 1986.
Notes: [1]. Local varieties of sorghum were used; [2]. Comparing the mechanical tying of ridges by donkey-traction with the mechanical tying of ridges with ox-traction; [3]. Standard Error of the difference between two treatment means; [4]. Fertilizer application of 100 kg/ha 14-23-15 in a band 10 to 15 cm from the rows of sorghum 2 to 3 weeks after planting and 50 kg/ha urea applied in a band 10 to 15 cm from the rows of sorghum 6 to 8 weeks after planting was applied to all treatments; [5]. Flat cultivation without tied ridges; [6]. Manually tying the ridges made by animal-traction 6 to 8 weeks after planting; [7]. Mechanically tying the ridges 6 to 8 weeks after planting; [8]. Mechanically tying the ridges 2 to 3 weeks after planting and again at 6 to 8 weeks after planting; [9]. The number of farmers' fields (replications) on which the experiment was grown – 7 farmers with donkey and 7 farmers with ox-traction.

No difference in sorghum yields between mechanically tying the ridges with donkey-traction and mechanically tying the ridges with ox-traction were observed (**Table 1**).

The gross and net revenue figures on a per ha basis are presented in the partial budget analysis in **Table 2**. The net revenue figures account for the cost/ha of fertilizer and the annual cost of the MRT. The net revenue/ha figures for all three tied ridging treatments are above the net revenue/ha figure of

the Control (C), and the difference is expressed in **Table 2** as the net revenue gain/ha. The net revenue gain/ha of the three tied ridging treatments represent the net revenue gained solely because of the increased yield from tied ridging. The net revenue gain/ha of using the MRT (treatments MRT-1 and MRT-2) are below the net revenue gain/ha of tying the ridges by hand (treatment TR-Manual). The cost of the MRT and the lower yields observed in treatments MRT-1 and MRT-2 contributed to the lower net revenue gain/ha.

The important fact, however, is that there is a labor constraint which precludes the tying of ridges manually on a significantly large hectarage per household. Results from a linear programming model of a Nedogo donkey-traction representative farm using labor data from the MRT trial indicate that family labor availability constrained the manual tying of ridges to 0.9 ha, whereas, when given the option to use the MRT, family labor and donkey-traction resources existed to profitably tie ridges on about 3.0 ha (Nagy et al., 1986). Thus when the net revenue gain above the control is calculated using 0.9 ha as the maximum area that can be tied manually (MRT-manual) and 3.0 ha as the maximum area that can be tied under MRT-1 or MRT-2, the MRT treatments show net revenue gains above the control that are larger than the net revenue gain under TR-Manual (**Table 2**).

A good rainfall year such as 1985, however, is not the norm and farmers say that a bad (drought) year such as 1984 occurs as often as a good year—about 3 years out of 10. In a poor rainfall year, research indicates that the yield difference between the control and TR-Manual treatments is much greater (Ohm et al, 1984a). Using 1984 prices and the drought year yields for the control and TR-Manual treatments and a hypothetical yield for the MRT-1 treatment (a yield similar to the relationship between TR-manual and MRT-1 in **Table 1**), an economic analysis indicates that the net revenues above the control per area tied ridged for TR-Manual and MRT-1 were US$ 71.28 and US$ 215.26, respectively, (see Nagy et al., 1986 for the calculations).

Table 2 Economic Analysis of Farmer-managed Sorghum Trials with Fertilizer, Manual Ridge Tying and Mechanical Ridge Tying, Nedogo, 1985

Item	Treatments[1]			
	C	TR-Manual	MRT-1	MRT-2
Mean grain yield, kg/ha	740	954	875	927
Yield gain above control, kg/ha	–	214	135	187
Gross revenue, US$/ha[2]	77.70	100.17	91.85	97.34
Net revenue, US$/ha[3]	50.60	73.07	61.65	67.14
Net revenue gain above control, US$/ha	–	24.47	11.05	16.54
Net revenue gain above control, US$/ area tied ridged[4]	–	20.22	33.15	49.62

[1]. C = Control (traditional flat animal traction cultivation); TR-Manual = manual tying of ridges that were made by animal traction at second weeding; MRT-1 = tying the ridges with the MRT at second weeding; MRT-2 = tying the ridges with the MRT at both first and second weeding. All treatments received 100 kg/ha of 14-23-15 applied at first weeding in a band 10-15 cm from crop rows and 50 kg/ha urea applied similarly at second weeding.

[2]. Post harvest sorghum farm price of US$0.105/kg x yield.

[3]. Gross revenue minus fertilizer cost (US$0.189/kg for 14-23-15 and US$0.164/kg for urea including 6 months interest charge of 15%) and minus yearly MRT cost of US$3.10/ha for treatments MRT-1 and MRT-2 (US$31.60 total cost annualized over 5 years at 15% interest rate assuming the MRT is used on 3 ha/year).

[4]. Based on the assumption that labor availability constrains manual tied ridging construction (TR-Manual) to 0.9 ha whereas labor and animal traction resources exist to construct 3.0 ha of tied ridging with the MRT in Treatments MRT-1 and MRT-2. Hectarage estimates are derived from a linear programming model (Table 6, Nagy et al., 1986).

The use of the MRT, therefore, increases the number of hectares that can be profitably tied ridged given the labor resources of the farm and substantially increases the net revenue of the farm under various rainfall and price scenarios. The increases in net revenues over the control as shown in **Table 2** and above are not large in absolute terms. To put these amounts in perspective, however, the average daily wage for a laborer is between US$ 0.85 and US$ 1.00. A return of up to US$ 215.26 from the use of the MRT only requiring an additional 2.0 man-hours/ha is, therefore, substantial.

Farmers' Experience with the MRT

Farmers were interviewed and questioned about their experience with the MRT. One of the problems was the weight of the MRT. Forty percent of the farmers in Nedogo with donkey-traction and 65% of the farmers in Poedogo thought that the MRT was heavy to pull and hard on the donkeys. However, all the farmers with donkey-traction in Nedogo used the one-pass method for both first and second weeding as did all the farmers at Poedogo for first weeding because of the time it saved. Those with ox-traction at Nedogo did not have a problem with the weight of the MRT.

When asked how long their animals could work when using them with the MRT, farmers at Nedogo said that they could work donkeys for an average of 2.3 h per day using the one-pass method while farmers with ox-traction can work an average of 4.7 h per day. At Poedogo, farmers indicated that they could work donkeys an average of 3.4 h per day using the two-pass method.

In general, farmers did not have problems with the MRT breaking down. Only 16% of farmers reported minor problems with the brake cable and its cover, and with the

rubber spring on the paddle release. The farmers stated that the MRT was easy to learn to use, most farmers taking less than 15 min to become familiar with it.

One problem discussed with the farmers was the size of plants at first weeding. Two-thirds of the farmers at Nedogo thought that the plants were too small to do tying at first weeding because they get covered with soil and could easily be broken or dislodged. The farmers at Poedogo did not see this as a problem.

The farmers were asked about the quality of the MRT ties. One-third of all farmers surveyed thought that the ties made by hand were better than those made by machine. There was a consensus that the MRT ties eroded more easily after a rain than did hand-made ties. The farmers, however, qualified their answer with a concern over the amount of time required to make ties by hand, concluding that the quality loss was more than offset by the gain in time.

Along with farmers' experiences, the field staff observed that the older farmers found it more difficult to trip the paddle and lock it back in time to make a proper tie. Farmers also found it difficult to turn around at the end of the rows because of awkward weight displacement of the MRT.

The field staff observed that farmers did not have any problems making ties with the MRT at second weeding in treatment MRT-2 where the ties that were made at first weeding had to be broken and gone over. The field staff also noted that ties made in very sandy soil did not hold up after a rainfall and had to be re-made, whereas tied ridges made in very low lying areas with poor drainage suppressed plant growth because of water logging.

Farmers were also asked if they would continue to use the machine next year and whether they would buy the MRT if it cost US$ 31.60. All 15 farmers in Nedogo and 6 of 7 farmers in Poedogo said that they would like to buy the MRT and use it the following year but many indicated that they would have to borrow the money from the formal credit market and that there may be a problem in obtaining such credit (See IPIA, 1986 for a further discussion on the fit of the MRT in the farming systems with respect to the sequential adoption of the MRT and other technologies that may be appropriate for the Mossi Plateau).

Conclusion

The MRT is technically viable in the field although improvements need to be made. Future work on mechanical devices to tie ridges such as the MRT must consider reducing the weight and awkwardness of the machine without reducing its effectiveness while striving for a machine that ridges and simultaneously ties the ridges in one pass. Minor engineering adjustments must also be made to the MRT.

Further information is required to assess whether the MRT is feasible to use at first weeding when the plants are small and more prone to damage. With more farmer experience and with improvements of the MRT, use of the MRT at first weeding may be acceptable to farmers. The 1985 trials were associated with a good weather year and indicated that the extra income from tying at both first and second weeding as opposed to only tying at second weeding with the MRT is fairly small. Trials under limited and erratic rainfall are required for further assessment.

The MRT was profitable for farmers to use under various good and poor weather and product price scenarios. The resulting increase in yield more than paid for the cost of the MRT. The labor savings from the use of the MRT over that of tying the ridges by hand are substantial. The MRT enables farmers to tie ridges on a larger proportion of their land, thereby substantially increasing cereal production and net revenue.

Most farmers expressed interest in continuing the use of the MRT and buying it at the US$31.60 price given that credit was available.

It is estimated that at least 40% of the present cultivated area of Burkina Faso is suitable for the introduction of tied ridging. With further development and proper demonstration, extension and credit facilities, a mechanical device like the MRT to construct tied ridges could become a significant technological innovation in the farming systems of the Mossi Plateau.

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(Continued on page 33)

The Tir Seeding Method and Tir Drills: A Literature Review

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Abstract

The tir seeding method, a method of dryland wheat culture, has been applied only in and around Van. It has no modern developments in spite of the fact that it has been known for 5000 years. It assures higher yields than other seeding methods in the districts which have insufficient rain and have moisture in the deep part of the soil. In the tir seeding method, the tir drills have been used and the seed is sown deeply (approximately 20-25 cm). The structure of the tir drills is different from that of other drills. The tir seeding method has been applied only in wheat culture at present. It can be applied successfully in dryland areas by using appropriate wheat variety and the developed tir drills.

Introduction

The tir seeding method that is used in wheat culture differs from other seeding methods. Also, the drill developed for this method and used in and around Van differs from other drills. Especially, the structure of the sower-feet of the tir drills are different from that of other drills.

It has been understood from archaeological excavates in Anatolia that the seeding method used in about 3000 years B.C. is the same as the tir seeding method (Akyürek, 1969). Samarian estimates that this was in use about 1700 years B.C. (Ross, 1970). Also, it is understood from **Fig. 1** that the cylinder seal belong to Samarian and that the tir plow has been in use by them.

As shown in **Fig. 1**, the contraption is a seed-pipe like funnel in addition to the tir plow which seems to have more developed structure than other plows used in Anatolia over the centuries.

The Tir Seeding Method

In the tir seeding method, the seed is sown 20-25 cm deep and is not repressed. In comparison, the seed is sown 5-6 cm deep and is repressed slightly after seeding in other seeding methods. The seed is sown deep in the tir seeding method because the soil surface is devoid of moisture during seeding. The volcanic structure of the soil accounts for this method in and around Van. But this explanation has not been corroborated by researchers. Therefore, it can be suggested that using this method bears the effects of traditions, too. It is a fact that the soil in and around Van is volcanic in character and is devoid of moisture on surface area. Moreover, the amount of rain annually is less than 400 mm in and around Van.

A lot of wheat varieties are not grown when sown 20-25 cm deep. Coleoptile length is 5-6 cm; for this reason it does not reach up to surface of the soil. But the length of coleoptile of *Triticum aestium* ssp. Vavilov (2n:42) known as "tir

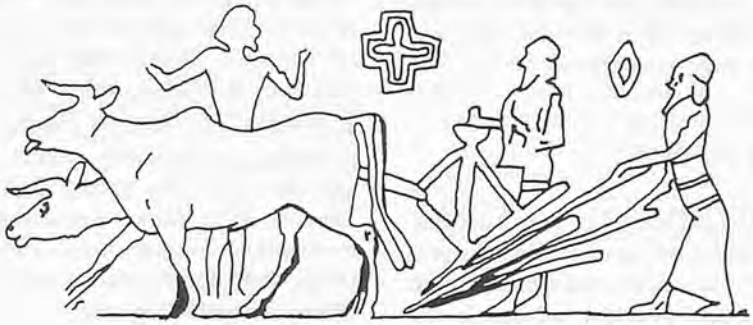

Fig. 1 The "tir" plow in use during Samarian (Ross, 1970).

Note: It is possible that the word "tir" comes from the word "ter" which means "wet" in Parsian and it means "sharp arrow" or "outumn" in Turkish. In that case the "tir seeding" might have been used in the same meaning as "seeding in a wet place" (Bal, 1978).

wheat" can be 20-25 cm. For that reason this wheat variety is used in the tir seeding method.

In South Dakota, USA, a method similar to the tir seeding method is currently used. It has been applied since 1945 and is known as the "deep furrow seeding method." In this method the seed, just as in the tir seeding method, is sown in deep part of soil with moisture (Akyürek and Ross, 1968).

Deep seeding assures the following advantages in the tir seeding method:

1. Seed germinates easily because of the fact that it is in the part of the soil with moisture;
2. Since the seeding takes place in autumn, the seed remains under the soil through the winter, and thus is protected from cold and wind and from being carried by water;
3. After seeding with this method, (with rows of seeds like furrows) rain and snow water accumulates in these furrows and keep the soil wet for a long time.

What yield in the tir seeding method is higher than in other methods in and around Van. Farmers claim that the yield of the tir is 15/1; whereas, other seeding methods are 1/3. According to the research made in the district, there is a difference between yield of the tir and of other seeding methods but, this is not important statistically.

The distance between rows in the tir seeding method is wider by three times the rows of other seeding methods. But optimum length of this distance has not been explored by researches.

The Tir Drills

The drills used in the tir seeding method have an undeveloped structure. They have been manufactured by a few primitive artisans in the district. In respect of the structure of their sower-feet, they differ from that of other drills but other parts remain similar to those of other drills (**Fig. 2**).

Some features of tir drills are:

Type : Combination (seed and manure)
Volume of seed depot : 0.4 ± 0.1 cm^3
Type of sowing pipe : telescope
Number of sower feet : 3-5
Distance between rows : 0.3 ± 0.05 m
Seeding depth : 0.2 ± 0.05 m
Source of action : drill wheels

In the old types of the tir drills, there are no seed chamber, sower gear, adjusting mechanism and seed repressing system except a hand-controlled lid between seed depot and seed pipe. The lid is closed when the drill is not in operation. During the operation, the lid is opened by hand and the seed falls down through the seed pipe. In this type of drills, the number of seeds sown is undetermined.

The tir drills are attached to a 3-point system and is in a hung-up position during take away. The structure of sower-feet of tir drills are similar to those of row plough (**Fig. 3**).

In the relatively improved tir drills, the seed and manure are used at the same time. The rod upon which the sower gears are based and the rod which operates the manure spreading mechanism is driven by the drill wheels separately.

The tir drills, at first glance, look like the drills used in the seeding of industrial crops. The distance between the sower feet is not adjustable. The feet are fixed and attached to the body and they sink in soil by the weight of drill. The tir drills have no repressing mechanism because the farmers think that the repressing of seed effects the yield adversely.

The most serious difficulty met during the operation of drills is the need for extreme pulling force. A drill which has five sower-foot needs a tractor with 70 BG to pull. This drill and its feet, in particular, need to be improved.

Fig. 2 The tir drills still in use.

Fig. 3 Sower feet of tir drills.

Results and Discussion

The following results have been obtained regarding the tir seeding method and the tir drills.

1. The tir seeding method and the tir drill is commonly used in and around Van. Also, in South Dakota, USA, seeding is done in deep furrows similar to the tir seeding method.
2. The history of the tir seeding method and the tir drills dates back to civilizations of B.C. Whereas the deep furrow seeding in South Dakota is only 40 years old.
3. The purpose of the tir seeding

method and the deep furrow seeding is to place the seed in moist soil. In and around Van, the soil is volcanic and scanty rainfall, hence seeding is done deeply.

4. In Turkey, apart from Van, there are places where the rain is insufficient and the moisture is deep in the soil. But in these places the tir seeding method is absolutely not used and moreover is not known. It might be said that the traditions are effective in using the tir seeding method and the tir drills in and around Van.
5. When seeding is done deeply the wheat seed germinates with difficulty. But *Triticum aestium* ssp. Vavilov (2n:42) known as "tir wheat" is ideal for this seeding because of its long coleoptile.
6. In seeding with the tir drills, the seeding norm, the distance between rows and seeding-depth have not been determined by reliable researches.
7. The tir drills are primitive and need to be improved, especially their sower feet.
8. With some development in the tir drills, the pulling force may be decreased and the number of the feet may be increased.
9. The tir seeding method can be applied in districts with insufficient rain and with volcanic soil by using the appropriate wheat variety and developed drills. Thus new areas can be gained and an increase in yield in present areas can be realized.

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(Continued from page 30)

An Animal-drawn Mechanical Ridge Tier for the Cereal Farming System of Burkina Faso

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Laboratory Studies on Spray Distribution Pattern of the Wide-swath Spray Boom

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Abstract

The spray uniformity pattern of the tall crop spraying system using IISR wide-swath spray boom was measured on the test set-up by operating the system at 3.5 kg/cm^2. The angle of rear and front nozzles of the spray boom were varied at 15, 20, 22, 25, 30° and 30, 35, 38, 40, 45°, respectively. The nozzle tip opening was also adjusted at fully tight, one-round and two-round open settings. It was found that a maximum uniform spray distribution is achieved at 22° rear nozzle angle with nozzle tip fully-tight and 38° front nozzle angle with one-round open tip adjustment. These optimum nozzle positions at their respective tip settings gave a uniform swath of 8.5 m with a total coverage of 10.5 m width.

Introduction

The application of pesticides for tall row crops, orchards and trees is a difficult problem when carried out by conventional manually/ engine operated spraying equipment. Hand application of pesticides in suitable form is a common practice in most of the plant protection measures for trees and orchards in developing countries. This method is an inefficient way of pesticide application besides high labour requirement per unit area covered. Self-propelled machines of liquid pressure system are in use for trees and orchards spraying in many developed countries. But for spraying tall rows such as sugarcane crop, alternatives are either to use the conventional spraying equipment or orchards/ tree-spraying machines. In both cases, the operation of spraying machines in field conditions of tall-row crop poses many problems and difficulties regarding their movement and uniform application of chemicals. Keeping this problem in view, a wide-swath spraying boom was developed at IISR, Lucknow for spraying on sugarcane crop. The spray boom consists of two adjustable cone mist nozzles fitted and T-shaped aluminum frame which in combination with 2-foot sprayers give a swath of 9 m (1). This spray boom was tested in laboratory conditions to determine the effect of nozzle angle positions and their tip adjustment settings, i.e., whirl chamber length, on the spray distribution pattern and swath width covered.

The spray distribution pattern of the wide-swath spray boom will depend on the nozzle angle positions, their tip adjustment settings and the liquid pressure buildup in the discharge line connecting the boom nozzles. The energy for both atomization and propulsion of droplets from sprayer nozzle to tall crop rows is obtained from the hydraulic pressure on the liquid. A high pressure is required if enough coverage on the tops of targeted plants in the tall crop rows is to be obtained. Further, in order to propel liquid droplets without much drift for a swath of 10 m through the air, it is necessary to use medium to coarse spray consisting of optimum size of spray droplets in order to obtain a thorough coverage. Liquid pressure buildup by 2-foot pumps in the operation of the wide-swath spray boom is 3.5 kg/cm^2. Secondary atomization of droplets is achieved when the spray droplets from the boom-nozzles are delivered in the air to reach the targeted plants.

Materials and Methods

The wide-swath spray boom developed at IISR, Lucknow consists of two 25-mm aluminum square sections of 1.8 m and 2.7 m length, fastened together at an angle of 20° inclined with respect to horizontal plane as shown in **Fig. 1**. Two adjustable cone mist spray nozzles are fixed at both ends of the inclined aluminium top section of the spray boom and were having 0.67-m distance between them in vertical plane. Both nozzles of the spray boom can be adjusted at any angle

position between 0 and 90° with the help of a single swivel nozzle adapter. For measuring the angle position of the nozzles, the protector with pointer are fixed by the side of each nozzle as shown in **Fig. 2**. Mark lines were drawn in the mating body and cap of the nozzle in order to adjust them precisely at different nozzle tip adjustment settings. The nozzle adjustment settings are the nozzle tip at fully tight, one-round open and two-round open settings. The length of whirl chamber or the gap between swirl plate and nozzle tip is 0.5, 1.25, and 2.0 mm when the nozzle tip adjustments are done at fully tight, one-round open and two-round open adjustment settings, respectively.

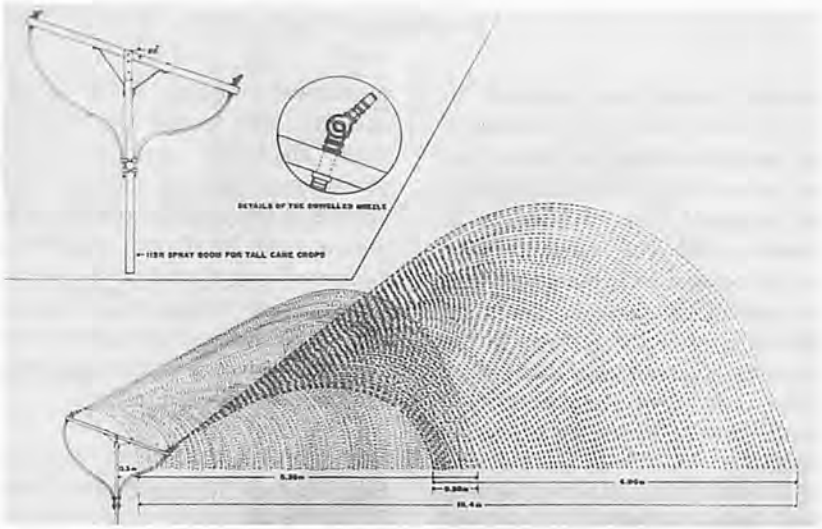

Fig. 1 IISR wide-swath spray boom and spray pattern from front and rear nozzles.

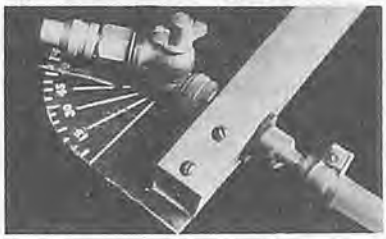

Fig. 2 Spray nozzle fitted with protector and pointer for making angle adjustment of the IISR wide-swath spray boom.

Fig. 3 Testing of IISR spray boom in combination with 2-ft sprayers on spray distribution test set-up.

Spray Distribution Test Set-up

The spray pattern measured on the spray distribution test set-up consisted of 15 galvanized corrugated sheets of (92 x 325) cm size kept in 20° inclined plane. The corrugated sheets were placed over an angle iron frame continuously side by side mating the lengths of sheets with each other as shown in **Fig. 3**. The total length of the test set-up was 12.6 m having 166 corrugations. The liquid that was sprayed in this test set-up was collected at the lower end of the corrugated sheets in plastic beakers. The plastic beakers were arranged side by side covering the total width of each individual corrugation of 8 cm. To minimize error in the liquid collection from the corrugated channels, the galvanized iron sheets were placed by mating the end corrugation completely throughout the length so that the shedding of corrugated channels is avoided. Each corrugated channel is exposed to an equal surface area for collecting spray droplets.

A boom stand was fabricated to hold the wide-swath spray boom exactly in the center of the width of spray distribution test set-up and in perfect vertical position. The spray boom is fixed to the boom stand by clamping it at two arms of the boom stand as shown in **Fig. 3**. The height of the top member of the spray boom (i.e., inclined aluminum section) can be varied with the help of arm positions in the spray boom stand and clamping arrangement.

Spray Distribution Test Measurement

The test observation on spray distribution were made during the morning and noon hours of the day, preferably at standstill air to minimize the effect of spray drift. The spray boom stand was checked and kept properly in the center of the test set-up width. The lower member of the spray boom was placed in the two arms of the boom stand in vertical position and clamped with the treaded bolts. The height of the front nozzle of the spray boom was kept 1 m above from the center of the inclined plane of corrugated sheets. The plastic beakers were arranged below the lower end of the corrugated channels of inclined galvanized iron sheets in order to collect the spray liquid from each channel of spray distribution test set-up.

The spraying system was operated and checked for proper functioning of its different components like pumps, suction and discharge connections, nozzle for clogging and full development of spray cone, leakage from any components of the spraying system, obstructions/blockage of discharge and/or suction lines, etc. Before starting the spraying for spray distribution test, all the beakers were checked and emptied. All the beakers were placed properly so that the liquid from the corrugated channel of the spray distribution test set-up comes directly in the beakers without any spill of spray liquid on the ground. The nozzle angle positions and their tip settings were adjusted. The

spraying system was operated for 2 min. The liquid was allowed to fall on the corrugated sheets of the test set-up and finally collected in the arranged row of beakers for measurement. The liquid collected in the beakers were measured with the help of a graduated cylinder immediately after the test run of the spraying system was completed. The swath width of spray covered in the row of beakers was also recorded.

The spray distribution pattern of the spraying system was determined at operating pressure of 3.5 kg/cm^2 which was measured by the pressure gauge at the discharge line of the foot sprayers. The angle of the front nozzle was varied at 30, 35, 38, 40 and 45° with nozzle tip in fully tight, one-round and two-round open adjusted settings. Similarly, the angle of the rear nozzle was varied at 15, 20, 22, 25 and 30° with nozzle tip in fully tight, one-round open and two-round open adjusted settings. The volume of spray liquid collected per minute from 1 120 cm^2 were then calculated and plotted on the graph sheets which represents the spray distribution pattern throughout the swath at different nozzle positions and their tip adjusted settings.

Results and Discussions

The curves representing the spray distribution pattern of rear and front nozzles at five different angle positions and three nozzle tip adjustment settings are shown in **Figs. 4** and **5**, respectively. The spray liquid was distributed in the case of the rear nozzle from 0.8 to 9 m, 1.5 to 9 m, and 2 to 9 m corresponding to nozzle tip fully tight, one-round open and two-round open adjustment settings, respectively. Similarly, the spray liquid was distributed in the case of the front nozzle from 1.5 to 9 m, 3.5 to 11 m and 3 to 12 m corresponding to nozzle tip fully tight, one-round open and two-round open adjustment settings, respectively. It is evident from the spray distribution curves shown in **Figs. 4** and **5** that the spray swath of front nozzle at its tip in fully tight setting with different angle positions coincided with the swath covered by the rear nozzle in all the three nozzle tip adjustment settings and angle positions. A major fraction of the liquid sprayed was received between 4 to 7.5 m of swath-width when front nozzle tip is at fully tight adjustment setting with rear nozzle in any of its adjustment

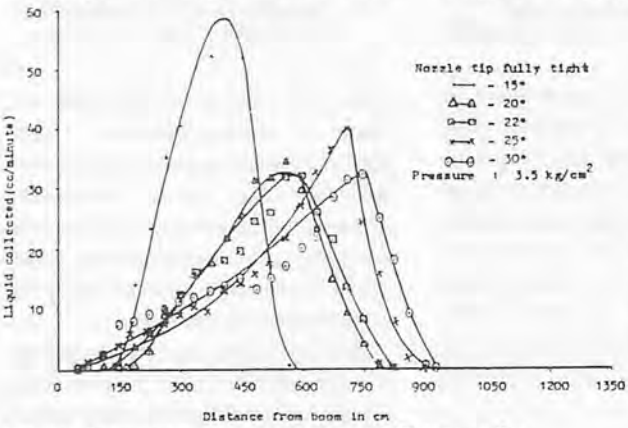

Fig. 4a Spray pattern of rear nozzle at different angles (nozzle tip fully tight).

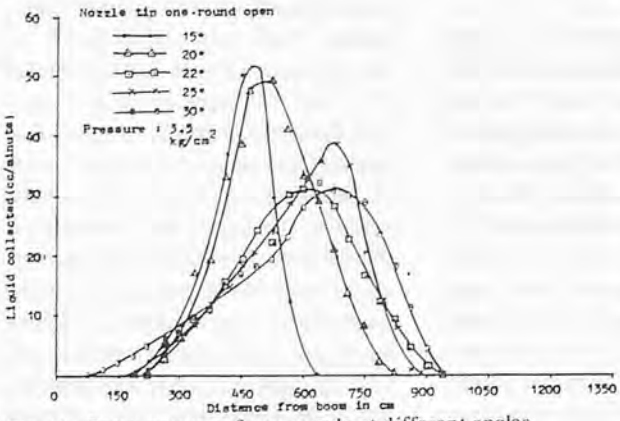

Fig. 4b Spray pattern of rear nozzle at different angles (nozzle tip 1-round open).

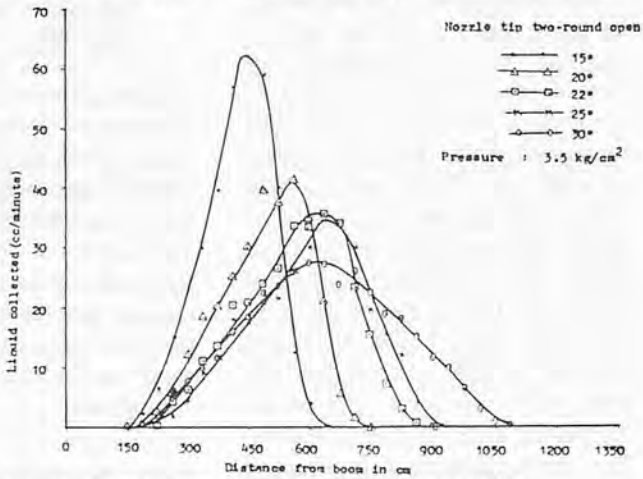

Fig. 4c Spray pattern of rear nozzle at different angles (nozzle tip 2-round open).

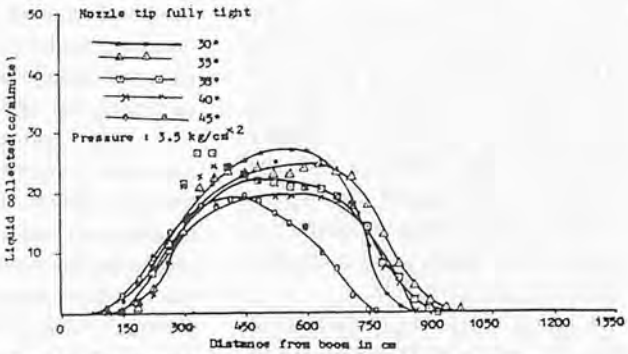

Fig. 5a Spray pattern of front nozzle at different angles (nozzle tip fully tight).

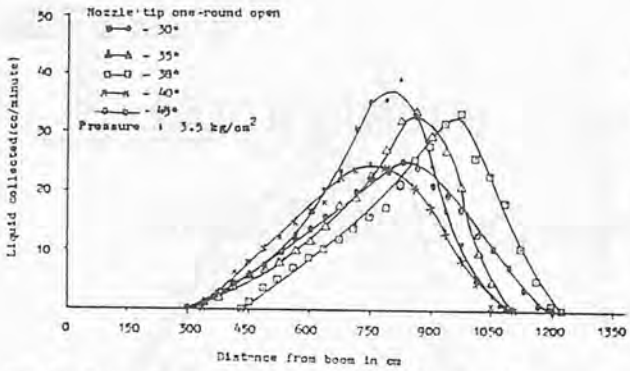

Fig. 5b Spray pattern of front nozzle at different angles (nozzle tip 1-round open).

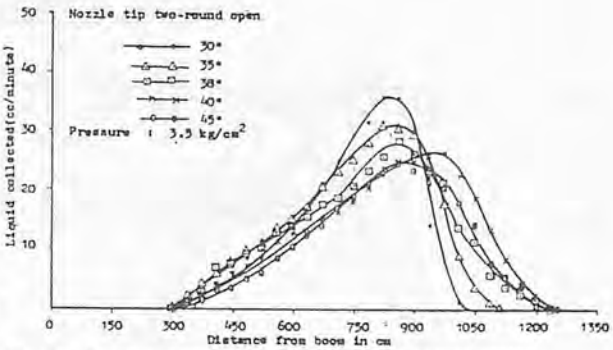

Fig. 5c Spray pattern of front nozzle at different angles (nozzle tip 2-round open).

setting. The characteristics of the spray distribution pattern in the above-mentioned combination of nozzle tip adjustment settings are the minimum swath-width covered with maximum variation in the collected volume of spray liquid.

The spray distribution pattern of front nozzle at five angle positions with one-round open setting and two-round open setting in combination with rear nozzle at five angle positions with its full tight tip adjustment setting are shown in **Figs. 6** and **7**, respectively. **Figs. 8** and **9** represent the spray distribution pattern of the front nozzle at five angle positions with tip adjustment of one-round open and two-round open settings in combination with rear nozzle at five angle positions with one-round open tip adjustment, respectively. Similarly, the spray distribution pattern is shown in **Figs. 10** and **11** for the front nozzle at five angle positions with tip adjustment of one-round open and two-round open settings in combination with rear nozzle at five angle positions with two-round open tip adjustment, respectively. In these combinations of nozzle positions and their tip settings, the swath-width covered remain more or less constant but the uniformity of spray distribution varied throughout the swath-width. It is evident from the values of swath covered in different nozzle settings and angle positions that a maximum swath-width of 10.5 m is obtained with rear nozzle at fully tight tip adjusted setting and front nozzle at one-round open tip adjustment setting.

The rear nozzle gave a better spray distribution pattern for the angle position of 22° as compared with nozzle positions of 15, 20, 25, and 30° in all the three nozzle tip adjusted settings. Similarly, in the case of the front nozzle, the spray distribution pattern of 38° was found more suitable to complement the spray pattern of rear nozzle at 22° as compared to other angle positions of 30, 35, 40, and 45°.

The spray distribution pattern of optimum angle positions of 22° for rear nozzle at fully tight tip setting and 38° for front nozzle at one-round open adjustment setting is shown in **Fig. 12**. A total swath of 10.5 m was covered at the optimum angle positions and their tip settings. The maximum value of liquid collected in the optimum angle positions and their tip settings was 32.5 cc/m. Of the 10.5 m swath covered, a fairly uniform spray pattern is obtained in swath-width of 8.5 m as shown in **Fig. 12** by the dotted line, at the optimum angle positions and their tip settings.

The curve representing the spray distribution of front nozzle at 38° angle position with nozzle tip one-round open setting had its peak

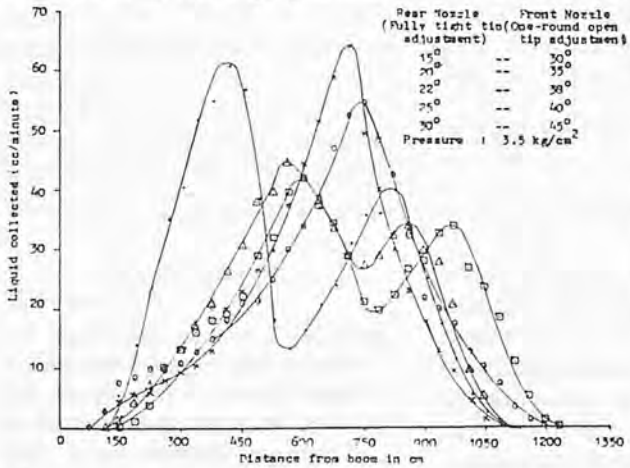

Fig. 6 Spray distribution pattern of the IISR wide-swath spray boom.

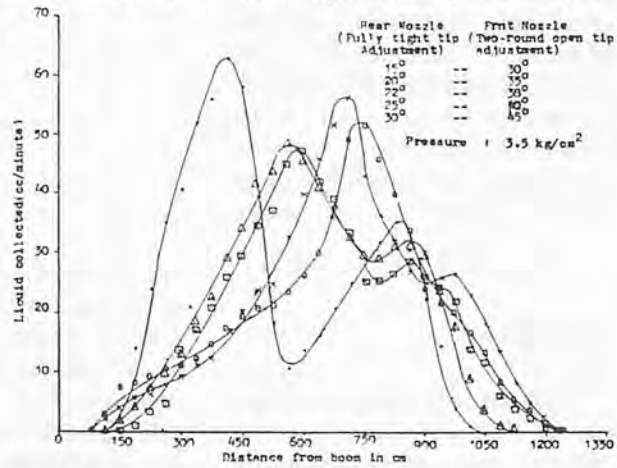

Fig. 7 Spray distribution pattern of the IISR wide-swath spray boom.

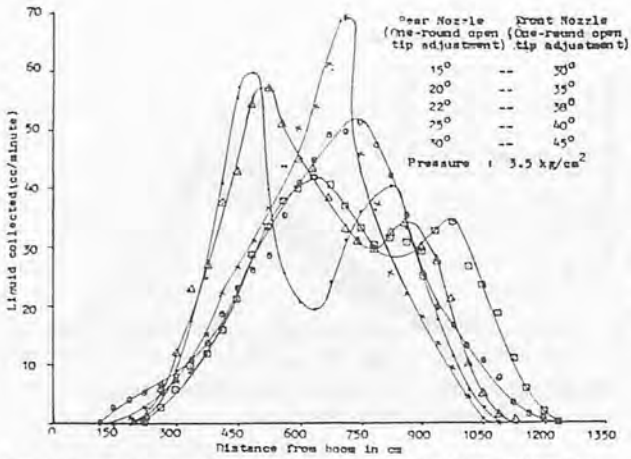

Fig. 8 Spray distribution pattern of the IISR wide-swath spray boom.

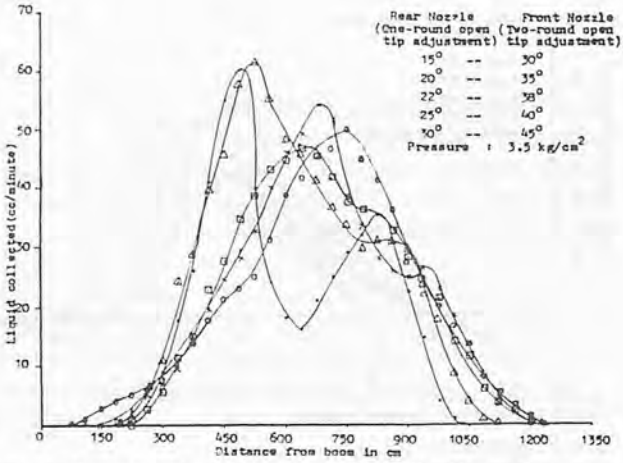

Fig. 9 Spray distribution pattern of the IISR wide-swath spray boom.

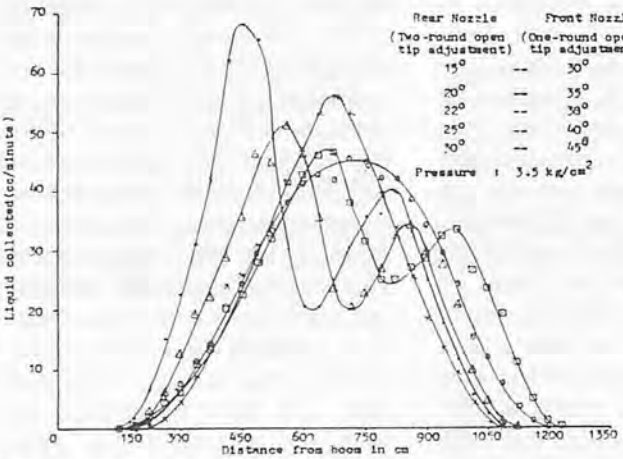

Fig. 10 Spray distribution pattern of the IISR wide-swath spray boom.

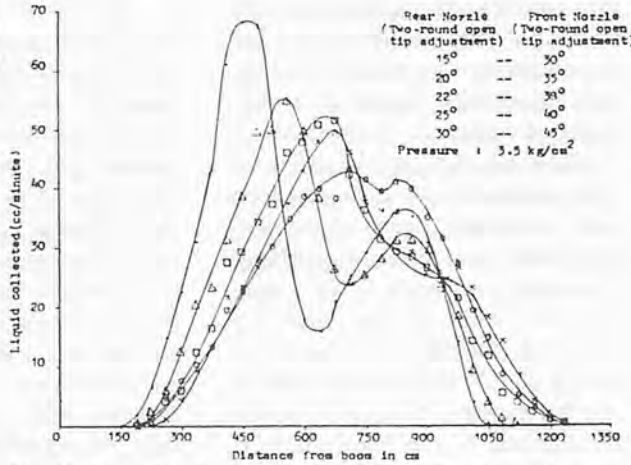

Fig. 11 Spray distribution pattern of the IISR wide-swath spray boom.

discharge at 9.75 m from the nozzle position which is at maximum distance as compared to spray distribution pattern obtained at other nozzle positions of 30, 35, 40 and 45° with tip setting of one-round open and two-round open adjustment. Therefore, the optimum combinations of angles 22° and 38° for rear and front nozzle, respectively, at their optimum settings gave a more uniform spray distribution over the total swath-width covered.

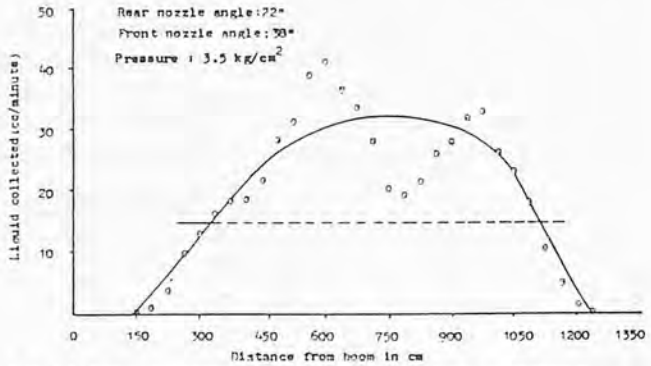

Fig. 12 Spray pattern of wide-swath spray boom at optimum settings.

Conclusions

From the spray distribution pattern of IISR wide-swath boom at different angle positions and nozzle tip settings that the best combination is 22° for the rear nozzle and 38° for the front nozzle at nozzle tip settings of fully tight and one-round open adjustment, respectively. At these optimum nozzle positions and their tip settings of the IISR spray boom, a uniform spray over swath-width of 8.5 m is attained within the total swath coverage of 10.5 m.

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Shrivastava, N.S.L. and Singh, K., 1978, The IISR wide-swath spray boom for spraying tall crops of sugarcane. Journal of Sugarcane Technology 1 (1): 57-60.

Comparative Use of Self-propelled and Tractor-drawn Combines

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Abstract

In this study, a comparative feasibility of the use of self-propelled and tractor-drawn combines was investigated. It was found that the self-propelled combines, being in commercial scale in the country, could harvest wheat and rice quite satisfactorily while the tractor-drawn combine was suitable only for harvesting wheat crop. High field capacity and rate of return were obtained by the self-propelled combines as compared with the tractor-drawn one. It was further established that financing the self-propelled combine for commercial purpose was a safe investment and also its debt-servicing well ensured. The use of tractor-drawn combine was mainly feasible at the owner's farms.

Introduction

The combines are designed and built for harvesting and threshing of grain and seed crops like wheat, rice, corn, sunflower, gram, etc. However, their present use is mainly confined to harvesting of wheat and rice crops in Pakistan. Two types of combines, viz; self-propelled and pull-type, i.e., tractor-drawn, as given in **Table 1**, are in commercial scale in the country.

All combines in commercial scale in the country are of Western origin. A self-propelled combine possesses high capacity although it is much costlier than the pull-type. The use of combines is limited to a short period of time during the year. Presently, these are used for 30 to 40 and 35 to 45 days in wheat and rice harvesting seasons, respectively, and stand idle during the remaining part of the year. However, the pull-type combine has an additional benefit in that the tractor can be used for other farm operations as well throughout the year.

The study was carried out to evaluate the comparative feasibility of the use of self-propelled and the tractor-drawn combines in the country.

Methodology

The study was undertaken during the wheat and rice harvesting seasons in 1987 under the adaptive research programme in Sheikhupura, Pakistan. The area of wheat and rice crops harvested per machine annually was recorded from nine

Table 1 Prices and Specifications of Combines

Type	Country of origin	Specification		Price/unit
		Engine (HP)	Cutting width (m)	(Rs)
A. Self-propelled combine				
1-MF	Brazil	123	4.3	925 000
2-Laverda	Italy	110	4.3	970 000
3-John Deere	Germany	105	4.3	975 000
4-Claas	Germany	100	4.3	980 000
5-New Holland	Belgium	113	4.6	1 050 000
B. Tractor-drawn combine				
1-JF, MS707	Denmark	55-75 HP Tractor	2.1	120 000

owners custom-hiring combines (John Deere, Claas, MF, Laverda and JF) in district Sheikhupura which lies in the rice tract of Pakistan. Information on effective field capacities of machine, labour charges and the havesting rates were also collected from the owners. The survey was carried out to obtain information about the harvesting charges paid by farmers. Accordingly, data were collected from 19 and 5 farmers who had harvested their crops by self-propelled and tractor-drawn combines, respectively.

The representative Massey Ferguson self-propelled combine model MF-3640 and the JF pull-type combine model MS707 drawn with Massey Ferguson tractor model MF-265 were considered in the study. Practical experiment was run on 70 acres of wheat and 50 acres of rice with MF self-propelled combine and 40 acres of wheat with JF tractor-drawn combine to ascertain the effective field capacity of the machines. The time taken by machines to harvest the crops was noted and the effective field capacities were calculated.

Detailed analysis was conducted to determine the operational expenses, earnings and debt servicing. Net return was calculated to compare the profitability of self-propelled combine with the tractor-drawn combine alone as well as inclusive of non-combining use of tractor throughout the year. The computations are shown on **Table 2**.

Table 2 Conditions for Detailed Analysis

Item	Self-propelled combine	Tractor-drawn	
		Combine	Tractor
1. Price (Rs)	925 000	105 000	155 267
2. Life (years)	10	6	10 (10 000 hours)
3. Repair and spare (% of capital cost per annum)	5	5	5
4. Interest (%)	13	13	13
5. Insurance/tax	Rs.15 000/ year	1% of the capital cost per annum.	Rs.425 per year.
6. Depreciation with straight line method at salvage value of:			
i. Machine (%)	10	10	10
ii. Building (%)	5	5	5
7. Yearly Installments	6	6	6
8. Yearly Escalation (%)	10	10	10

9. A shed to house self-propelled combine will cost Rs.50 000 and pull-type combine and tractor Rs.25 000 in total.
10. POL price: As prevailing in the market.
11. POL consumption rate: As given by M/S Millat Tractors Ltd; the dealer of MF & JF combines and MF tractors in Pakistan.
12. Hiring rate of tractor for non-combining operations: Estimated at 10% escalation every year on Rs.88 per hour notified by the Punjab Government Agriculture Department during November, 1986.
13. No manager will be employed as the farmer will look after the machines.
14. No mechanic will be employed. The machines will be repaired from the market.

Table 3 Annual Area Harvested and Effective Field Capacity

Type of combine	No. of owners contacted	Area harvested (Acres/machine)		Effective field capacity (Acres/h/machine)	
		Wheat	Rice	Wheat	Rice
A. Self-propelled					
John Deere, 4.3 m	3	875	700	2-2.75	1.75-2.00
Claas, 4.3 m	2	840	680	2-3.00	2.00-2.25
MF, 4.3 m	1	900	740	2-3.00	1.50-2.25
Laverda, 4.3 m	2	885	680	2-3.25	1.75-2.50
	Average	875	700	2.50	2.00
B. Tractor-drawn					
JF, 2.1 m	1	375	–	1.25	

Table 4 Determination of Effective Field Capacity

Type of combine	Area harvested (Acres)		Time (h)		Effective field capacity (Acres/h)	
	Wheat	Rice	Wheat	Rice	Wheat	Rice
MF self-propelled, 4.3 m	70	50	28	25	2.50	2.00
JF tractor-drawn 2.1 m	40	–	32	–	1.25	

Results and Discussion

Annual Working Hours

The annual crop area havested per machine and the effective field capacity achieved and intimated by the owners of self-propelled combines and tractor-drawn JF combine are summarized in **Table 3**. The self-propelled combines harvested wheat and rice crops quite satisfactorily. The tractor-drawn combine was deployed for wheat harvesting only and it was difficult to use it for rice crop mainly due to traction problem in wet fields and also due to lack of appropriate adjustments in the machine.

The results of the field experiment that determined the effective capacity of MF self-propelled and JF tractor-drawn combines are given in **Table 4**:

It is evident from **Tables 2** and **3** that effective field capacities tally with the data given by the owners of the combines. Accordingly, the annual working hours are:

A. Self-propelled combine:

Wheat = 875 acres x

$$\frac{1}{2.50 \text{ acres/h}} = 350 \text{ h}$$

Rice = 700 acres x

$$\frac{1}{2.0 \text{ acres/h}} = 350 \text{ h}$$

Total = 700 h

B. Tractor-drawn combine:

Wheat = 375 acres x

$$\frac{1}{1.25 \text{ acres/h}} = 300 \text{ h}$$

Annually, the tractor will be used for 300 h with the combine and the remaining 700 h for other operations.

Labour Charges

Table 5 presents the labour charges paid by the combine owners.

As regard the labour charges of JF tractor combine, the owner reported that the tractor operator who was being paid Rs 800/month was also responsible for the combine. However, a helper was provided to the tractor operator at Rs 30/man-day during wheat harvest season only.

Table 5 Labour Charges

No. of self-propelled owners contacted	Pay of combine operator (Rs/month)	Pay of helper (Rs/month)
3	1 800	750
2	2 200	900
3	2 000	750
Average	2 000	800

Annual Revenue

Combine owners charged equal rates for harvesting wheat and rice. Charges claimed by the owners and paid by the farmers are given in **Table 6**.

Charges paid by farmers were considered more authentic and used in further computations. The annual revenues are shown below.

A. Self-propelled combine

1. Wheat

350 h x 2.5 acres/h x Rs.350/acre = Rs.306 250

2. Rice

350 h x 2 acres/h x Rs.350/acres = Rs.245 000

Total = Rs.551 250

Say = Rs.551 000

B. Tractor-drawn combine

1. Wheat

300 h x 1.25 acres/h x Rs.300/acre = 112 500

Say = 113 000

C. Tractor use for non-combining work

700 h x Rs.97/h = Rs.67 900

Say; Rs.68 000

Payment Schedule

The break up of payment sched-

Table 6 Hiring Rate of Combines

Type of combine	Charges claimed by the owners		Charges paid by farmers	
	No. of owners contacted	Charges (Rs/acre)	No. of farmers contacted	Charges (Rs/acre)
A. Self-propelled				
John Deere	2	350	19	350
	1	400		
Claas	1	375		
	1	350		
MF	1	350		
Laverda	2	350		
B. Tractor-drawn				
JF	1	350	5	300

Table 7 Yearly Credit Installments and Interest

On close of year	Machine	Credit (Rs)	Installment (Rs)	Interest at 13% (Rs)
1st	a. Self-propelled combine	925 000	154 167	120 250
	b. Pull-type combine	105 000	17 500	13 650
	c. Tractor	155 267	25 878	20 185
			(7 763 + 18 115)	(6 056 + 14 125)
2nd	a. Self-propelled combine	770 833	154 167	100 208
	b. Pull-type combine	87 500	17 500	11 375
	c. Tractor	129 389	25 878	16 821
				(5 046 + 11 775)
3rd	a. Self-propelled combine	616 666	154 167	80 167
	b. Pull-type combine	70 000	17 500	9 100
	c. Tractor	103 511	25 878	13 456
				(4 037 + 9 419)
4th	a. Self-propelled combine	462 499	154 167	60 125
	b. Pull-type combine	52 500	17 500	6 825
	c. Tractor	77 633	25 878	10 092
				(3 028 + 7 064)
5th	a. Self-propelled combine	308 332	154 167	40 083
	b. Pull-type combine	35 000	17 500	4 550
	c. Tractor	51 756	25 878	6 728
				(2 018 + 4 710)
6th	a. Self-propelled combine	154 167	154 167	20 042
	b. Pull-type combine	17 500	17 500	2 275
	c. Tractor	25 878	25 878	3 364
				(1 009 + 2 355)

ule viz; credit installment and interest payable in 6 years is shown in Table 7.

The first figure in the brackets denotes the amount of installment and interest on the credit of tractor for an annual use of 300 h with pull-type combine. Accordingly, annual installment and interest on the credit of the tractor-drawn combine will be the sum of the 1st figure in the brackets plus the amount indicated against the pull-type combine. The 2nd figure in the brackets is the amount chargeable as installment and interest for the use of tractor for 700 h annually in non-combining operations.

The total interest amounts to:

1. Self-propelled combine = Rs.420 875
2. Pull-type combine = Rs.47 775
3. Tractor = Rs.70 646

Operational Cost

On the basis of assumptions listed under methodology and results enumerated above, operational costs of self-propelled and tractor-drawn combines and tractor alone were calculated which are given in Table 8.

Net Profit

Financial results of a) self-propelled combine; b) tractor drawn combine; c) tractor use for non-combining operations are shown in Table 9.

Table 8 Operational Cost

(Rs/h)

Item	Self-propelled combine	Tractor-drawn combine		
		Tractor	Combine	Total
1. Diesel (10 *l*/h for self-propelled combine and 6 *l*/h for tractor @ Rs.3.86/*l*)	38.60	23.16	–	23.16
2. Lubricants				
i. Engine oil (14 *l*/100 h for self-propelled combine and 7 *l*/100 h for tractor Rs.15/*l*)	2.10	1.05	–	1.05
ii. Transmission oil (12.15 *l*/200 h for self-propelled combine and 28 *l*/600 h for tractor @ Rs.15/*l*)	0.91	0.70	–	0.70
iii. Air compressor/air cleaner oil (0.18 *l*/200 h for air compressor in self-propelled combine and 1 *l*/10 h for tractor at Rs.15/*l*)	0.014	1.50	–	1.50
iv. Hydraulic oil (15 *l*/100 h for self-propelled combine @ Rs.15/*l*)	2.25	–	–	–
v. Steering box oil (0.9 *l*/1 000 h for tractor @ Rs.15/*l*)		0.01	–	0.01
vi. Final drive oil (1.6 *l*/200 h for self-propelled combine @ Rs.15/*l*)	0.12	–	–	–
vii. Brake oil (0.25 *l*/1 000 h for self-propelled combine @ Rs.35/*l*)	0.009	–	–	–
viii. Grease (1/2 kg/10 h for self-propelled combine 1/10 kg/10 h for tractor & 1/2 kg/10 h for pull-type combine @ Rs.28/kg)	1.40	0.28	1.40	1.68
3. Repair and spare	66.07	7.76	17.50	25.26
4. Labour:				
i. Operator	34.29	9.60	–	9.60
ii. Helper	13.71	–	3.00	3.00
5. Interest	60.13	7.06	26.54	33.60
6. Insurance/tax	21.43	0.43	3.50	3.93
7. Depreciation:				
i. Machine	118.93	13.97	52.50	66.47
ii. Building	3.57	0.70	0.55	1.25
Total	363.53	66.31	104.99	171.21
Say	364	66	105	171

Conclusion

1. Self-propelled combine can harvest wheat as well as rice crop satisfactorily. Tractor-drawn combine is suitable for harvesting wheat crop only.
2. Self-propelled combine possesses higher field capacity than tractor drawn one. A self-propelled combine of 4.3 m cutting width has an average effective field capacity of 2.5 and 2 acres/h harvesting of wheat and rice crops, respectively. The average effective field capacity of tractor drawn combine is 1.25 acres/h of wheat harvesting.
3. Self-propelled combine has higher charges than of tractor-drawn one. Presently, the charges of self-propelled combine are Rs.350/acre. Tractor drawn combine is available at Rs 300/acres.
4. The initial investment and operational cost of self-propelled combine is higher than the tractor-drawn one but the rate of return is far higher under the former than the later even including the annual use of tractor for non-combining operations.
5. The annual net profit of the running of self-propelled combine under study varies from Rs.107 000 to Rs.389 000 over the debt service period as compared to Rs.37 000 to 116 000 under tractor-drawn combine inclusive of hiring out of tractor

Table 9 Statement of Annual Income and Debt Services (Rs. ,000)

Item		1st year	2nd year	3rd year	4th year	5th year	6th year
A. Revenue with escalation of 10% per year at compound rate	a.	551	606	667	734	807	888
	b.	113	124	136	150	165	182
	c.	68	75	83	91	100	110
B. Cost of operation with escalation of 10% per year at compound rate:							
a. Rs.364/h x 700 h		255	281	309	340	374	411
b. Rs.171/h x 300 h		51	56	62	68	75	83
c. Rs.66/h x 700 h		46	51	56	62	68	75
C. Gross operating profit (A-B)	a.	296	325	358	394	433	477
	b.	62	68	74	82	90	99
	c.	22	24	27	29	32	35
D. Interest (Table 7)	a.	121	100	80	60	40	20
	b.	20	16	13	10	7	3
	c.	14	12	9	7	5	2
E. Profit (C-D)	a.	175	225	278	334	393	457
	b.	42	52	61	72	83	96
	c.	8	12	18	22	27	33
F. Amount of depreciation:							
a. Rs.122.5/h x 700 h		86	86	86	86	86	86
b. Rs.67.72/h x 300 h		20	20	20	20	20	20
c. Rs.14.67/h x 700 h		10	10	10	10	10	10
G. Total amount available for liquidation of loan (E + F)	a.	261	311	364	420	479	543
	b.	62	72	81	92	103	116
	c.	18	22	28	32	37	43
H. Loan installments (Table 7)	a.	154	154	154	154	154	154
	b.	25	25	25	25	25	25
	c.	18	18	18	18	18	18
I. Net profit (G-H)	a.	107	157	210	266	325	389
	b.	37	47	56	67	78	91
	c.	–	4	10	14	19	25
	b+c.	37	51	66	81	97	116
Percent increase of net profit of 'a' over:							
i. b		189	234	275	297	317	327
ii. (b + c)		189	208	218	228	235	235

Average % increase of net profit of self-propelled combine over:
i. Tractor-drawn combine = 273
ii. Tractor-drawn combine + tractor use for non-combining operations = 219

for non-combining operations. The annual net profit of self-propelled combine is 273% higher than that of the tractor-drawn. Even on comparing the return from tractor drawn combine after adding the gain from the use of tractor for non-combining operations, a 219% increase of net profit exists annually in the use of self-propelled combine during the debt span.

6. For commercial purpose, the self-propelled combine is highly justified. Its financing is a safe investment and debt servicing well ensured.
7. The prospects of custom hiring of tractor-drawn combine are limited and its use seems feasible mainly at the owners' farms. ■

Agricultural Mechanization in Developing Countries

Edited by Merle L. Esmay, Carl W. Hall
Publised by Shin-Norinsha Co., Ltd.

〔Contents〕 Chapterl. Principles of Agricultural Mechanization. Chapter 2. Agricultural Mechanization in Equatorial Africa. Chapter 3. Agricultural Mechanization in Asia. Chapter 4. Agricultural Mechanization in Latin America. Chapter 5. Ownership patterns for Tractor and Machinery. Chapter 6. Drying, Storing and Handling Food Grains in Developing Countries. Chapter 7. Irrigation in Developing Countries. Chapter 8. Education and Training for Agricuitural Mechanization in Developing Countries.

Size: 21cm × 15cm, Page: 234, Price: $9.00 (hard-cover) or 5$ (Soft-cover)...excl. postage

SHIN-NORINSHA CO., LTD.
7, 2-Chome, Kanda Nishikicho Chiyoda-ku Tokyo, 101 Japan

Testing and Evaluation of Improved Yaatra Ox-cart

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Abstract

An improved Yaatra ox-cart developed by the Indian Institute of Management (IIM), Bangalore was procured under CIAE – IIM collaborative programme for testing and evaluation under 'Field/Users Trials'. The cart has been specially designed for the purpose of passenger transport. The cart yoke is fitted with coil spring shock absorber unit which keeps the animals' neck and hump comfortable from shock loads and avoid injuries. The cart is also equipped with helical coil springs mounted cushion unit, slowing down device, tarpauline hood to protect passengers from sun and rain. The Yaata cart was thoroughly tested for its performance on different terrain conditions at various payloads on CIAE farm and in nearby villages of Bhopal using local bullocks. The maximum payload carrying capacity of the cart was 550 kg or 10 adult passengers on tar road and "moorum" road while it was 412 kg and 150 kg on off-the-road land terrain and loose field terrain, respectively, using local bullocks.

Introduction

Unlike many traditional aspects of Indian life, the ox-carts have successfully survived even the massive onslaught of technology, entirely by virtue of the pivotal role the ox-cart plays in the country's economy, particularly in the rural areas.

Even in cities, short-distance haulage of 0.5 to 3 t payloads which do not require emergency movements are economically performed by ox-carts. An estimated 12 million out of a total 14 million ox-carts in India are serving the transport needs of remote rural areas. These carts carry about 20 billion t-km per year representing 10% of freight haulage by railways and 20% by lorry transport which is quite significant for developing but petroleum deficient country like India (1).

There are many research organizations, educational institutions, universities and prominent individuals working in the field of rural transportation. The (IIM) Bangalore is one of them where they have developed an improved Yaatra ox-cart and released to the CIAE, Bhopal for further testing and evaluation under 'Field Trials' as a follow-up. Accordingly, this cart was procured and tested for it's feasibility under local conditions for various engineering parameters. The present paper describes the results of testing of the Yaatra cart along with the comparative performance of the traditional cart. The economics of operation of the improved cart has also been investigated (2).

Materials and Methods

The improved Yaatra cart has been specially designed for the purpose of transporting hospital patients, school-going children, other passengers and fragile goods for use in semi-urban and modern villages (**Fig. 1**). This cart can be used in place of costly taxies, jeeps and vans for a distance up to 20 km or so. The yoke of the cart is fitted with coil spring shock absorber unit which keeps the animal's neck and hump comfortable from shock loads and avoid injuries. Helical coil springs mounted cushion unit, under the angle iron frame work provides comfort to passengers and shock absorption on bad roads (3). The major specifications of the Yaatra cart are given in the Appendix and dimensional details are given in **Fig. 2**.

After having noted the major specifications and making the pre-

Fig. 1 Improved 'Yaatra' ox-cart.

liminary laboratory trials, the cart was thoroughly tested in field conditions of the CIAE farm and nearby villages of Bhopal on different terrain conditions.

Variables Involved in the Study

a) Independent variables – These are type of ox-cart and type of surface.

b) Dependent variables – These include load carrying capacity in kg, draft at various payloads in kgf, speed at various payloads in km/h, power requirement at various payloads in hp and transport cost in Rs/km – g.

Experimental Techniques

The field terrain was ploughed, loose field without any crop. The off-the-road land terrain was the hard crust which forms on the soil surface after completion of earth work. The moorum road consists of a mechanically or manually compacted soft, raddish aggregate of lateritic deposits, either directly spread on the soil surface, or on a layer of stone or broken burnt brick. Sometimes water was sprinkled on the aggregate during compaction. The tar road was a pre-mixed carpet surfacing of stone aggregate and hot cut-back bitumen, and a sealer coat of pre-mixed sand with hot cut-back bitumen consolidated with a roller. The local bullocks called 'Malvi' were used for the measurement of speed on different surfaces at various payloads (**Fig. 1**). The various sizes of bullocks have been categorized based on the power developed by them. A pair of bullocks which could develop power up to 0.8 hp (0.6 kW) were considered to be small-sized, those which could develop between 0.8 hp (0.6 kW) and 1.10 hp (0.8 kW) were considered to be medium-sized while those developing between 1.10 hp (0.8 kW) and up to 1.40 hp (1.0 kW) were considered to be large-sized (4).

Appendix Table Major Specifications of Improved Yaatra Ox-cart

1.	Name of cart	: Improved Yaatra ox-cart
2.	Type of cart	: Double animal drawn two wheeled multipurpose ox-cart
3.	Function	: Transportation of passengers, hospital patients, school children, farm produce, building materials in bags or bulk
4.	Developed at	: Indian Institute of Management, Bangalore
5.	Technical specifications;	
	i) Overall length including beam	: 4 500 mm
	ii) Cart width	: 2 000 mm
	iii) Frame height	: 750 mm
	iv) Wheel type	: M.S. wheel having solid rubber fitted over wheel rim and pretensioned spokes
	v) Wheel diameter	: 1 000 mm
	vi) Type of bearing	: Taper roller bearing
	vii) No. of spokes	: 24
	viii) Axle material	: M.S. rod
	ix) Axle diameter	: 50 mm
	x) Yoke length	: 2 000 mm
6.	Whether braking system provided	: Yes
7.	Test results	
	a) Draft at full load on;	
	i) Field terrain	: 110 kgf (1.078 kN)
	ii) Tar road	: 47 kgf (461 N)
	b) Power requirement at full load on;	
	i) Field terrain	: 2.02 hp (1.51 kW)
	ii) Tar road	: 0.84 hp (0.63 kW)
8.	Tare weight	: 500 kg
9.	Carrying capacity	: 550 kg on loose field terrain
10.	Approximate cost	: Rs. 5 500 or U.S.$550 (Jan., 1981)
11.	Useful life	: 10 years

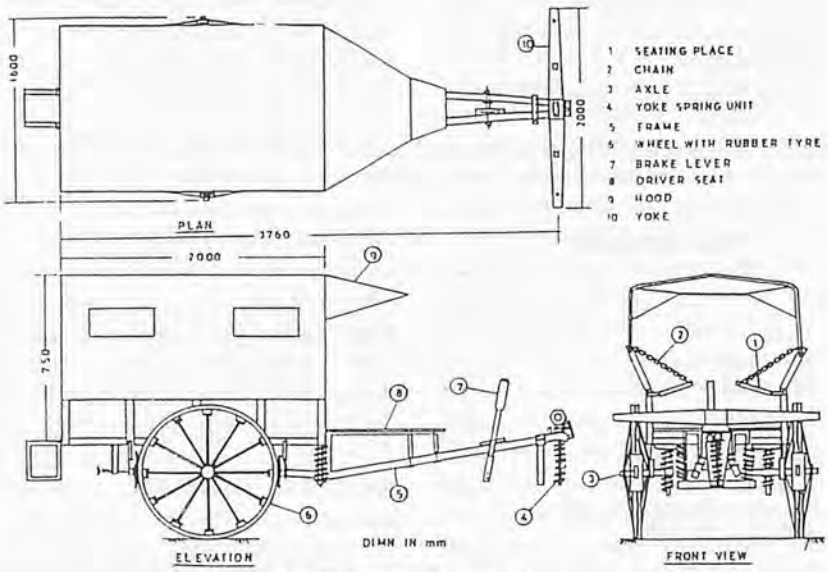

Fig. 2 Details of yaatra cart.

The maximum load carrying capacity of a cart was determined by loading it with uniformly-sized building bricks in stages and running it on different terrains. Beyond 670 kg of load due to considerable wheel sinkage in the ploughed field, bullocks practically showed a sign of fatigue/strain. This was seen from their tired conditions and unwillingness to pull the cart further. At the same time, one wheel spoke of the cart also gave way at the payload of 700 kg. Similar tests were replicated with the same type of wheel spokes and the failure was almost at the wheel spokes in each case at about 670 – 700 kg of load. Therefore, allowing 1.20 as a factor of safety, the safe

carrying capacity of the cart was taken as 550 kg.

The draft was measured by towing the cart with a tractor at different payloads on different terrains without any gradient. The tractor was operated at a constant forward speed of 3 km/h, which is the normal walking speed of bullocks. A special coupling was fabricated and mounted on the yoke of the cart to hold a hydraulic dynamometer. The dynamometer was mounted in between the yoke of the cart and the three-point linkage of the tractor in such a way that the tractor applied pull parallel to the surface of the cart deck. The draft was then recorded from the dynamometer readings (**Fig. 3**).

The speed of the cart was noted by measuring the distance of travel and the corresponding time. The length of each test run was approximately 500 m.

The power requirement of a cart on various terrains at different payloads was calculated by taking average values of draft and speed. The draft and power requirements for the improved cart were compared with the requirements for a conventional cart.

Analysis of Experimental Data

The data were obtained from 10 replications of draft and speed measurements on various terrains at different payloads. These data were analyzed statistically for average, standard deviation and coefficient of variation with the help of an HCL 1 800 computer, and the results are given in **Tables 1** to **5**.

For draft observations, the standard deviation from the average value was in the range of 1.10% to 6.62%. The large variation in draft observations was partly due to the use of the hydraulic dynamometer which has a resolution of about 10% within the range of experimental values.

Fig. 3 Hydraulic dynamometer mounted in between cart and tractor for measurement of draft.

For speed observations, the standard deviation from the average value was in the range of 0.01% to 0.06%. This indicates that the observations on speed measurement were reasonably precise.

The data obtained for average values was further analyzed for determination of regression coefficient and coefficient of determination. Equations of the forms $Y = a + mx$ represent the experimental data very well and the coefficient

Table 1 Measurement of Draft in kgf, Speed in km/h and Power Requirement in hp on Different Surfaces at Various Payloads

Stage of loading	Type of terrain											
	Field terrain			Off-the-road land terrain			Moorum surface			Tar road		
	D	S	P	D	S	P	D	S	P	D	S	P
Tare cart	26	5.30	0.51	19	5.40	0.38	11	5.54	0.23	8	5.62	0.17
25% Load	44	5.08	0.83	30	5.21	0.58	19	5.39	0.38	16	5.45	0.32
50% Load	70	4.70	1.22	42	4.95	0.77	28	5.17	0.54	26	5.30	0.55
75% Load	101	4.36	1.63	60	4.74	1.05	41	5.00	0.76	36	5.18	0.69
Full load (550 kg Pay load)	138	3.95	2.02	80	4.34	1.29	50	4.61	0.77	47	4.80	0.84
Full load (10 adult passengers weighing around 55 kg each)	110	4.45	1.81	75	4.90	1.36	44	5.05	0.82	41	5.20	0.79

Note: 1) D indicates draft in kgf; 2) S indicates speed in km/h; 3) P indicates power requirement in hp; 4) Values of draft speed and power requirement are average of 10 replications.

Table 2 Standard Deviation (S.D.) in % for Draft Observations at Different Payloads on Various Terrains

Stages of loading	Type of terrain			
	Tar road	Moorum road	Off-the-road land terrain	Field terrain
Tare cart	1.90	3.15	3.71	6.62
25% load	2.41	3.31	3.92	5.86
50% load	1.10	3.34	4.47	5.97
75% load	1.78	2.86	4.52	5.48
Full load (550 kg)	1.51	2.91	3.92	5.36

Table 3 Coefficient of Variation (C.V.) for Draft Observations at Different Payloads on Various Terrains

Stages of loading	Type of terrain			
	Tar road	Moorum road	Off-the-road land terrain	Field terrain
Tare cart	23.72	28.33	19.32	25.86
25% load	15.05	17.24	12.98	13.38
50% load	4.21	11.85	10.69	8.52
75% load	4.97	7.00	7.49	5.42
Full load (550 kg)	3.21	5.84	4.91	3.89

Table 4 Standard Deviation (S.D.) in % for Speed Observations at Different Payloads on Various Terrains

Stages of loading	Type of terrain			
	Tar road	Moorum road	Off-the-road land terrain	Field terrain
Tare cart	0.02	0.03	0.04	0.06
25% load	0.02	0.03	0.04	0.05
50% load	0.02	0.03	0.04	0.06
75% load	0.01	0.03	0.04	0.06
Full load (550 kg)	0.01	0.03	0.04	0.06

Table 5 Coefficient of Variation (C.V.) for Speed Observations at Different Payloads on Various Terrains

Stages of loading	Type of terrain			
	Tar road	Moorum road	Off-the-road land terrain	Field terrain
Tare cart	0.41	0.58	0.82	1.05
25% load	0.41	0.54	0.82	0.98
50% load	0.32	0.49	0.84	1.34
75% load	0.27	0.66	0.87	1.45
Full load (550 kg)	0.26	0.65	0.97	1.62

of determination was 0.95 or greater in all cases.

$$Y = a + mx \quad \ldots\ldots\ldots (1)$$

where, Y = Draft in kg (or speed in km/h)

X = Payload in kg

a, m = Constants

Values for constants a and m were obtained and from these values equations were prepared for draft and speed of the improved Yaatra ox-cart for various terrain conditions (**Table 6**). From these equations, values were obtained for draft and speed which were later used for plotting curves between draft and payload as well as speed and payload of the improved ox-cart.

The power required to pull an ox-cart for a given loading condition was calculated from the average values of daft and speed by using the following equation

$$\text{Power, hp} = \frac{Y\,X\,s}{75} \quad \ldots\ldots (2)$$

where, Y = Draft in kg

S = Speed in m/sec

Results and Discussions

The salient features of the improved Yaatra cart is that it is specially designed for transport of passengers. However, it can be used for the transport of goods also. The cart has two mild steel wheels covered with solid rubber padding and pre-tensioned spokes. Taper roller berainga are used in the wheel hub. Steel axle of 50 mm diameter is used. Large diameter wooden yoke fitted with coil spring shock absorber unit keeps the animal's neck and hump comfortable and free from shock loads. A pedal-operated braking system with pole type brakes covered with rubber linings over mild steel plate shoes helps to slow down the speed of loaded cart on downward slopes.

Table 6 Least Square Regression Equations for Draft and Speed Variations on Different Surfaces

Surface	Criteria	
	Draft Kgf	Speed km/h
Tar road	Y = 6.98 + 0.07 (X)	Y = 5.65 – 0.001 (X)
Moorum road	Y = 10.00 + 0.07 (X)	Y = 5.59 – 0.002 (X)
Off-the-road land terrain	Y = 15.96 + 0.11 (X)	Y = 5.44 – 0.002 (X)
Field terrain	Y = 19.34 + 0.21 (X)	Y = 5.36 – 0.003 (X)

Note: 'Y' indicates draft or speed; 'X' indicates payload in kg.

The tare weight of the cart was 500 kg. The maximum carrying capacity of the cart was 550 kg on off-the-road land terrain and on tar and moorum roads. At this payload the cart body did not show any damage and the local bullocks were able to work comfortably.

The draft for pulling the cart by a pair of local oxen varied from 8 kgf to 26 kgf (78 N to 255 N) at no-load, and 47 kgf to 138 kgf (461 N to 1.352 kN) at full loading of the cart depending upon the terrain, the lowest being on tar road and highest on loose field terrain (**Table 1**). The curve plotted between draft and payload indicates the increase in draft with increase in payload (**Fig. 4**). The increase in draft was apparently due to the increase in rolling resistance contributed by soil-wheel interaction, wheel sinkage and axle bearing friction.

By changing the payload to 550 kg from the no-load condition, the ox-cart speed decreased from 5.62 km/h to 4.80 km/h on the tar road. The corresponding speeds for the same loads on loose soil surfaces were 5.30 km/h and 3.95 km/h, respectively (**Fig. 5**).

Taking into account the highest and lowest recorded values of the draft [i.e., 138 kgf (1.352 kN) and 47 kgf (461 N)] on the two surfaces while pulling 550 kg of payload, and using the forward speed values from **Table 1** in equation (2), the power requirements were computed as 2.02 hp (1.51 kW) and 0.84 hp (0.63 kW), respectively.

The values for power requirement were calculated from the values of draft and speed (**Table 1**), and are shown in **Fig. 6**. It is clear that the power requirements for the fully loaded cart on tar road, moorum road and off-the-road land terrain was well within the limit of 1.40 hp (1.0 kW) which a pair of large-sized bullocks can develop. The carrying capacity was limited to 150 kg and 275 kg on field terrain for a pair of small-[0.8 hp (0.6 kW)] and medium-sized [1.1 hp (0.8 kW)] bullocks, respectively.

The draft and power requirements of a conventional cart varied from 10 kgf to 169 kgf (98 N to 1 660 N) and 0.21 hp to 2.44 hp (0.16 kW to 1.82 kW), respectively,

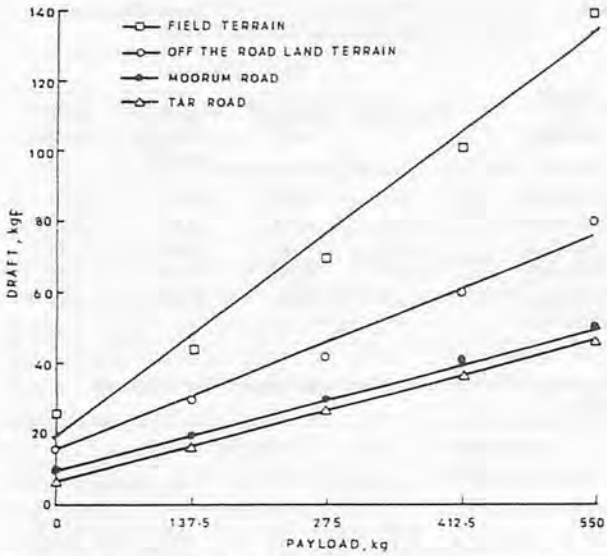

Fig. 4 Effect of payload on draft of yaatra cart on various surfaces.

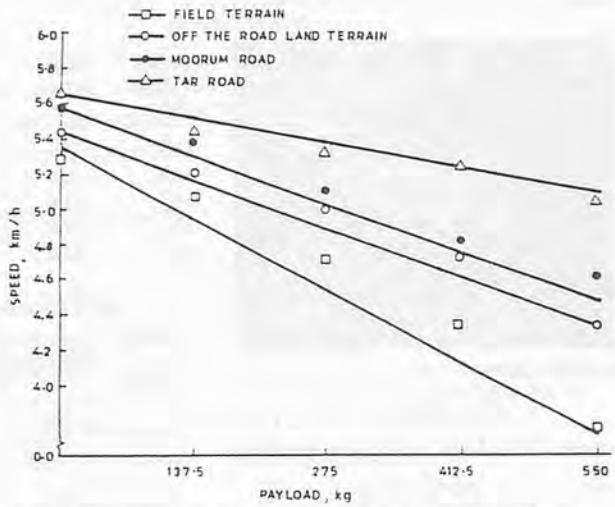

Fig. 5 Effect of payload on speed of yaatra cart on various surfaces.

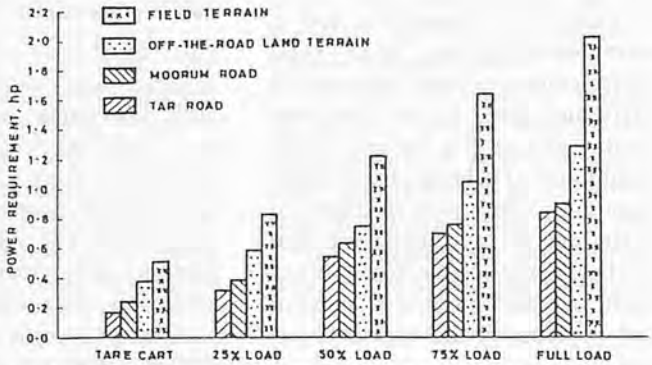

Fig. 6 Power requirement of yaatra cart on various surfaces.

depending on the payload and terrain type. This indicates superiority of improved Yaatra ox-cart in respect of performance over conventional cart. The estimated cost of the improved Yaatra cart is about Rs.5 500 (U.S.$550, January 1981) as compared to Rs.1 200 (U.S.$120) for a conventional cart. The economics of operation of the improved Yaatra cart indicate the costs of transport as Re.0.20/km/100 kg ($0.02/km/100 kg) and Re.0.17/km/100 kg ($0.017/km/100 kg) for a traditional cart.

Conclusion

i) The maximum payload carrying capacity of the improved Yaatra cart was 550 kg on tar road and moorum road while it was 412 kg and 150 kg on off-the-road land terrain and loose field terrain, respectively, using local medium sized bullocks.

ii) The improved cart can be used for multipurpose operations such as passenger transport, transport of loose and low density materials. It is adaptable to carry grain, building bricks, wooden logs, liquids in drums, manure and the like.

iii) The tare weight of an improved Yaatra cart is 500 kg.

iv) The effect of type of terrain and amount of payload was quite significant. The draft was higher on a deformable field terrain as compared to not-so-deformable moorum and tar road surfaces. The load factor also plays an important role in determining draft. The draft requirement for pulling the loaded cart was more than that of the tare cart. This indicates that the draft increased with an increase in payload because of ground surface and axle bearing friction.

v) The estimated cost of the improved Yaatra cart is about Rs.5 500 (U.S.$550) Jan., 1981. While the cost of transport is Re 0.20/km/100kg ($0.020/km/100kg).

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Modern Food Grain Silos in Bangladesh

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Abstract

There are four modern food grain silos in Bangladesh, placed at Chittagong, Ashugang, Demra and Santahar. Their total capacity is 232 000 t. These silos are cylindrical bulk storage structures and their design procedure is more or less similar, except the variation in number and size of bins in each unit.

These government-owned storage structures are under the Food Department. They collect and store food grains in four vertical grain silos, at central storage and local storage depots in different districts and sub-divisions of Bangladesh. From the comparative studies of different grain storage structures in respect of losses, it is found that the maximum storage losses occur at the Government silos, which may be as high as 20% of the grain stored.

Introduction

The task of providing food to the rapidly growing population in Bangladesh is second to none in importance and urgency. In order to mitigate this formidable challenge of growing food scarcity and to find ways and means of achieving self-sufficiency in food, post-harvest grain storage is of great importance in making food grain availability. The government is experiencing a food deficit to the expent of 15 to 25% of the total requirement (Mandal and Samajpati, 1980). The storage facility of food grain is intensified, as the population rate increases faster than the current rate of production of food. In achieving socio-economic development it is necessary, not only to increase the production but also to minimize grain loss.

It has been reported that processing and storage losses of paddy and wheat in Bangladesh may be as high as 20% of the total production (Samajpati, 1983). Fazlul Huq (1980) made a systematic survey in the Comilla district of Bangladesh. The average quantitative storage losses are shown in **Table 1**.

Table 1 Average Quantities Stored, Storage Periods and Losses

Store type	Commodity	Stores sampled (nos.)	Quantity initiallry stored (kg)	Storage period (months)	Insect loss (%)	Rodent loss (%)	Total weight (%)
Dole	Raw paddy	36	60.2	4.45	0.92	1.45	2.37
Dole	Parboiled rice	17	109.9	2.68	0.38	1.28	1.66
Motka	Raw paddy	2	36.8	4.23	0.79	0	0.79
Motka	Parboiled rice	11	38.0	2.41	0.21	1.18	1.39
Bag	Raw paddy	16	30.7	4.05	1.23	2.24	3.47
Bag	Parboiled rice	3	35.4	1.92	0.08	0.99	1.07
Gola	Raw paddy	3	275.4	4.82	1.92	0.11	2.03
Gola	Parboiled rice	1	251.5	2.30	0.54	1.69	2.23
Chest	Raw paddy	1	185.9	4.20	0.87	0.64	1.51
Chest	Parboiled rice	2	325.7	4.20	0.43	0.85	1.28
Khari	Raw paddy	3	124.5	3.69	0.58	1.32	1.9
Drum	Raw paddy	2	59.5	4.73	2.49	0	2.49

Source: Fazlul Huq, 1980.

Food Grain Storage Planning

Before planning a food grain storage and distribution system in Bangladesh, various factors should be considered. The inflow of food grain to the Government system comes from two sources: domestic production and imports. In the past, the latter source has accounted for all but a small proportion of the total flow. Government involvement in domestic production and procurement is very negligible and is generally controlled by traders

and dealers. However, the Government does collect food grains like rice and wheat each year, and after storage in silos and godowns for a few months the cereals are distributed to the general public. The silo positions are shown in **Fig. 1**.

Because of the difficulty of estimating actual production for a particular season with accuracy as well as the size of population to be supplied, the actual procurement from the farmers varies widely from year to year and has done so for a long time, but in recent years increasing imports have meant larger supplies for distribution. The first five-year development plan (1973-78) represents an idea of the trend in rice production. The plan program contains two major components: expansion of the irrigated acreages of high-yielding varieties and expansion of the rainfed acreages of high-yielding varieties. Irrigated land was expected to account for some 80% of the total increase and a net increase in the cultivated acreage of 4.6% over the benchmark was also expected. But in actual fact the plan was not fruitful for various reasons. Major difficulties in storage planning include the following:

a) Absence of adequate data on production, prices, transport and storage costs, market flows and existing storage facilities.
b) Official ignorance of the marketing system and marketing methods, together with misconceptions about middlemen, hoarding, speculation, etc.
c) Lack of a clear policy regarding producer and consumer interests, and the responsibilities of the State and of private trade.
d) Problems caused by shortage of funds.
e) Shortage of technical experts.

The flow diagram in **Fig. 2** gives an idea of the production and imports of food grain and their flow through the Government and private organizations to the end-users; namely, the consumers. Imports of wheat only could make up the food deficit and these imports might be distributed through a rationing system (Carl Bro International, 1975).

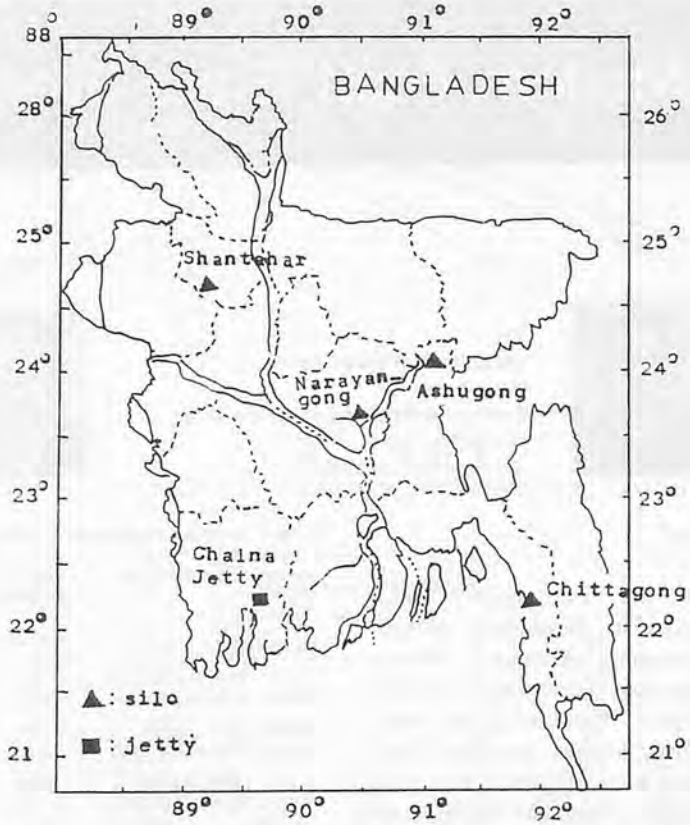

Fig. 1 Location of silos and new jetty (Source: Carl Bro International, 1975).

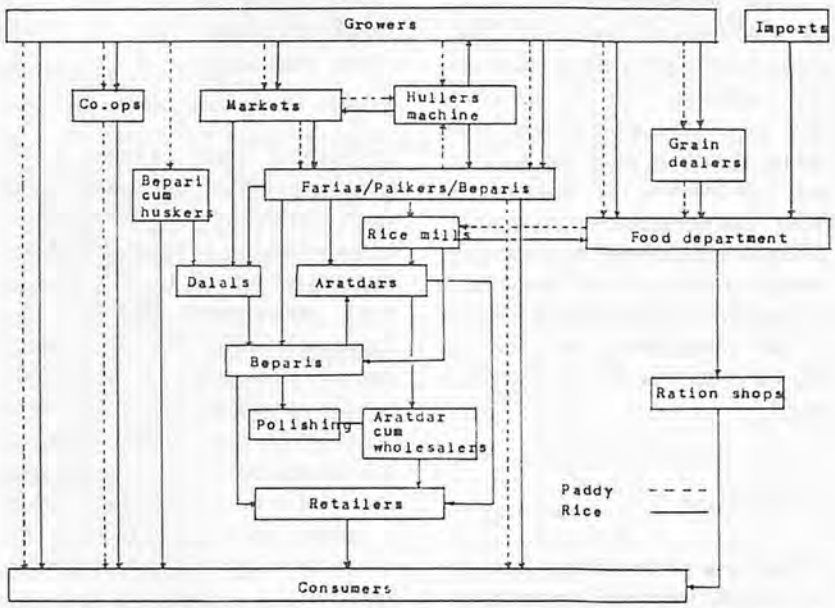

Fig. 2 Marketing channels of paddy and rice in Bangladesh (Source: The Economist Intelligence Unit).

Food Grain Procurement and Storage

The problem of warehousing is of great importance in the procurement and storage of food grain in Bangladesh. The inputs, whether procured locally or from other sources, are to be stocked and distributed to the consumers throughout the country. Farm outputs also require storage facilities at wholesale and retail distribution centres. Government procurement of foodgrains has to date accounted for a very small part of the total quantities of domestic food grains marketed. The bulk of grain produced is consumed by the producer without entering the market system. If market disposals are equated by a very crude equation with 20% of available production, Government procurement accounts for some 3% only of the total sales. **Table 2** shows the grain procurement in 1967-74.

According to Carl Bro International (1975), the food grain system is frequently overlapping as far as management and policy are concerned. However, food silo positions with their storage capacities is shown below. The grand total capacity is 232 000 t.

1. Chittagong	104 000 t
2. Narayanganj	51 000 t
3. Ashuganj	51 000 t
4. Santahar	26 000 t
Total	232 000 t

Table 2 Food Grain Procurement, 1967-74

(Unit: 1 000 t)

Years	Available production	Marketed production (1)	Procurement (2)	as % of (1)
1967	8 532	1 764	4	0.4
1968	9 947	1 994	22	1.1
1969	10 130	2 026	9	0.4
1970	10 724	2 148	6	0.3
1971	9 970	1 994	6	0.3
1972	8 899	1 778	–	–
1973	9 017	1 803	–	–
1974	10 620	2 124	71	3.3

Source: Agricultural Directorate, Food Department.

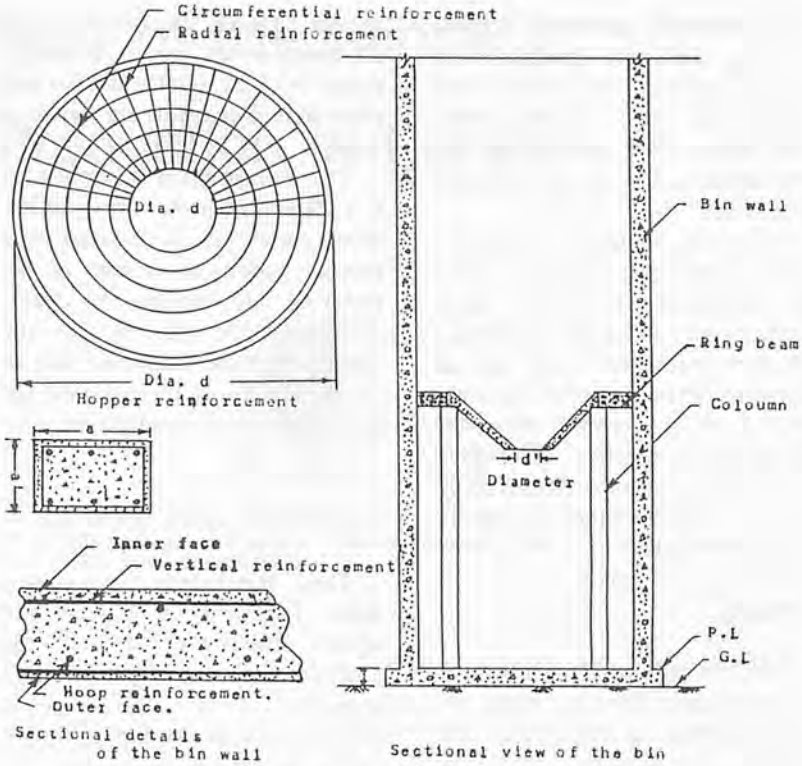

Fig. 3 Sectional view of the grain silo.

All the above-mentioned four silos are circular, deep, vertical, reinforced concrete grain bins with some other auxilary units like head house, delivery chamber etc. These are constructed by the slip form method and provided with pile-supported foundation. The capacity of these four silos varies but then design procedure is more or less similar, except the number and size of bins. All these bins have hoppered bottoms **(Fig. 3)** for handling grains and are self-cleaning. The location, operating principle, loading and unloading conditions and capacity of the silos are as follows:

Chittagong

The silo in Chittagong port is on the bank of the Karnaphuli River. The pneumatic unloading equipment consists of two mobile gantries with a rated capacity of 200 t/h, each divided into two suction pipes and one stationary gantry with a capacity of 200 t/h. This gantry is also provided with bulk loading pipe to ships with a capacity of 200 t/h. The conveying equipment consists of belt conveyors and bucket elevators. There are four hopper scales, each with a capacity of 30 t per draft. The scales are manually operated. The grain cleaner, with a capacity of 75 t/h is placed in the head house underneath the upper bins.

Grain can be delivered either in bulk or bags. Bulk grain is conveyed from the storage bins, elevated to the head house, weighed and then loaded directly into barges or coastal vessels, railway wagons or trucks. Bagged grain can be supplied either to railway wagons or trucks.

Narayanganj

The silo is located at Lakhya River, about 15 miles from Dhaka. Grains can be received in bulk either from ships or railway cars.

The pneumatic equipment consists of two stationary gantries with a rated capacity of 200 t/h each, divided on two suction pipes. The intake from railway cars has two hoppers and a total capacity of 200 t/h.

Conveying equipment, scales and grain cleaners are similar to those in Chittagong. There are three hopper scales and four bagging and weighing machines. Grain can be delivered either in bulk or bags. Bulk grain is conveyed from the storage bins, weighed and loaded into railway wagons. Bagged grain can be supplied either to railway wagons or trucks.

Ashuganj

The silo is located on the bank of the Meghna River and along the Dhaka-Chittagong railway line. The facilities are generally similar to those in Narayanganj.

Santahar

The silo is located at the main railway line from Khulna and half a mile south from the Santahar railway station.

Conveying equipment, scales and grain cleaners are similar to those of the other silos. There is a bulk intake from railway wagons with a rated capacity of 200 t/h, divided on three intake hoppers. Two hopper scale and three bagging and sewing machines are provided. Bagged grains can be supplied either to railway wagons or trucks. Bulk grain is conveyed from the storage bins, weighed and loaded in to railway wagons.

The Bangladesh government has to import sufficient quantity of food grains, mainly wheat, to meet the deficit and these are generally distributed through a ration system. Losses due to differences between supplied and received quantities would be minimized by using continuous weighing of all grains, passing through the facilities. The estimated losses during a storage period of 6-12 months in silos and rehabilitated godowns are shown in Table 3.

The average grain losses in silos is 7.7% and in godown it is 18.2%. These losses can be reduced by a shorter period of storage in the godowns and storing the major buffer stock in silos. In silos, the losses would be minimum due to the possibility of turning over the grain and effective fumigation.

Table 3 Different Sources of Government Owned Storage Foodgrain Losses (%)

Source/ cause of loss	Silo		Rehabilitated godowns	
	Wheat	Paddy	Wheat	Paddy
Insect	10.0	5.0	15	12.0
Moisture	0.1	0.1	2.5	1.5
Rodent	–	–	2.5	2.5
Pilferage	0.1	0.1	0.2	0.2
Total	10.2	5.2	20.2	16.2

Source: Carl Bro International, 1975.

Observation and Comments

The Bangladesh government stores 16% and the farmers and private dealers store 86% of the total grain produced (Mandal and Samajpati, 1980). The responsibility of ensuring an uninterrupted supply of food grain for the consumers implies having adequate stocks, conveniently available at all times. But deteriorations have been found to occur even in the best storage structures like modern food grain silos. According to Carl Bro International, the estimated average losses of wheat and paddy in grain silos, during a period of 6-12 months was 7.7%.

The government policy is to maintain a year-round stock of more than one million t of food grain, 600 000 t as a buffer stock and 400 000 t as an operational reserve. The buffer is needed to moderate the seasonal price fluctuation within a specific range through open market sales of food grain during the months of August to October. Procurement programmes are to be implemented in such a way that they permit the farmers to sell their products at fair price, minimize delay at the procurement centres and ensure immediate cash payment.

During the Aman season, the major portion of the target quantities has to be procured, because for the rest of the seasons, the procurement of Boro, Aus paddy and wheat is normally poor. In order to realize the target, the Government food procuring organizations should keep the procurement price in line with the market price of paddy and wheat. This will give an incentive to the common farmers to sell their cereals to the Government agents.

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Possibilities of Mechanizing Paddy Production in Kenya

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Introduction

Agricultural mechanization in paddy production is being initiated in developing countries like Kenya. Appropriate technology is the emphasis considering that there are many small-scale farms wherein mechanization *per se* may not be feasible.

Kenya has a population of about 21 million and a growth rate of about 3.5% per year. Kenya has a total land area of 569 250 km^2. The arable area is 18 500 km^2. Much of the other area is arid or semi-arid. The agricultural sector accounts for some 25% to 30% of Gross Domestic Product (GDP), compared with 12% to 13% from manufacturing, and 14% to 15% from government sector (**Table 1**). Some 58.6% of the total income is being obtained from exports of cash crops; coffee and tea (**Table 2**) which are grown under large-scale farms with governmental support.

Paddy yield in Kenya is one of the highest in the world (**Table 3**). However, this country has had to import rice to meet the demand of a growing population. This quantity of imported rice is increasing. The changes in quantity of imported rice, marketed rice and rice consumption are shown on **Table 4**.

Table 1 Gross Domestic Product (GDP) by Industrial Origin at Current Prices and Percentage Distribution

(Unit: million K£, (%))

Item	1984	1985	1986
Traditional economy	227 (6.3)	293 (7.0)	318 (6.6)
Monetary economy			
Agriculture	1 122 (30.9)	1 241 (29.6)	1 400 (29.0)
Manufacturing	470 (13.0)	528 (12.5)	587 (12.1)
Electricity/water	52 (1.4)	57 (1.4)	64 (1.3)
Construction	132 (3.6)	162 (3.9)	187 (3.9)
Trade, etc	659 (18.2)	770 (18.4)	939 (19.4)
Finance & others	443 (12.2)	517 (12.4)	581 (12.0)
Government	522 (14.4)	619 (14.8)	757 (15.7)
Total GDP	3 627 (100)	4 187 (100)	4 833 (100)

Note: 1K£=20 Kenya Shillings=1.2 US.$.
Source: Economic Survey 1987, Central Bureau of Statistics, Kenya.

Table 2 Keynya's Major Export Items

(Unit: million K£, (%))

Item	1984	1985	1986
Coffee	203.7 (27.0)	230.7 (29.4)	388.5 (40.6)
Tea	198.5 (25.1)	191.7 (24.4)	172.8 (18.0)
Petroleum products	131.6 (17.5)	116.5 (14.8)	99.0 (10.3)
Cement	17.5 (2.3)	15.4 (2.0)	13.4 (1.4)
Pineapples, canned	25.9 (3.4)	24.4 (3.1)	24.2 (2.5)
Beans	2.5 (0.3)	0.6 (0.1)	6.7 (0.7)
Sisal	12.6 (1.7)	14.4 (1.8)	10.9 (1.1)
Others	171.5 (22.4)	191.4 (24.4)	242.5 (25.4)
Total	754.8 (100)	785.1 (100)	958.0 (100)

Source: Economic Survey 1987, Central Bureau of Statistics, Kenya.

Table 3 Paddy Yield in the World

(Unit: t/ha)

Country	1974-76	1980	1981	1982
Kenya	5.3	4.8	4.9	4.8
Japan	5.8	5.1	5.6	5.7
Malaysia	2.7	2.8	2.9	2.6
Thailand	1.8	1.9	2.0	1.9
India	1.7	2.0	2.0	1.7
Average of developed countries	5.4	4.9	5.3	5.3
Average of developing countries	2.4	2.7	2.8	2.8

Source: Production Year Book by FAO, 1983.

Table 4 Changes in Quantity of Imported Rice, Marketed Rice and Rice Consumption in Kenya

Year	Imported (t)	Marketed (t)	Total (t)	Consumption per capita (kg)
1965-70	1 600	11 400	13 000	1.3
1971-75	2 700	21 100	23 800	1.9
1976-80	2 300	25 200	27 500	2.0
1981	4 600	27 300	31 900	2.0
1982	11 900	25 600	37 500	2.1
1983	44 800	24 200	69 000	3.7
1984	96 200	24 000	120 000	6.1

Source: Central Bureau of Statistics, Kenya.

Objective

This paper reviews the current situation of paddy production in Kenya from a survey of the production operations. Operation bottlenecks are identified with the aim of introducing appropriate mechanization technology to the farmers.

The production operations are typical of developing countries. The proposed mechanization is envisaged to set a sustained, high level of paddy yield.

Rice Production Area

The National Irrigation Board (NIB) which was established by the government of Kenya in 1966 is responsible for the development, control and improvement of all the irrigation schemes in the country. There are six irrigation schemes under the NIB: Perkerra, Tana, Mwea, Ahero, West Kano and Bunyala. Rice is grown in four of these irrigation schemes, whose locations are shown in **Fig. 1**.

The climate of these areas is semi-humid. In the Mwea scheme, an altitude of 1150 m, the climate is cooler than expected for a latitude just south of the Equator. The monthly average temperature is between 20°C and 23°C. The maximum temperature which occurs in March is over 31°C and the minimum in January is around 15°C. The average annual rainfall is about 940 mm with peaks in April (281 mm) and November (147 mm). The relative humidity is between 52% and 67%. The climates of Ahero, West Kano and Bunyala are similar where the monthly average temperatures are between 21°C and 23°C, and the average annual rainfall is about 1170 mm with peaks in March (123 mm), April (181 mm) and May (132 mm). The relative humidity is between 62% and 75% which is slightly higher than in Mwea.

The soils of the four schemes are vertisols (black cotton soil). These are poorly drained, very dark grey, and heavy clay with negligible permeability. The soil cracks when dry and swells when wet.

Irrigation water is drawn from rivers, lakes and basins. The water is usually pumped, making it the most expensive operation. In the Mwea scheme, water is obtained from the Thiba and the Nyamindi Rivers, both being the tributaries of the Tana River. In the Ahero scheme, water is obtained from the Nyando River. In the West Kano scheme irrigation water comes from the Lake Victoria and

Fig. 1 Locations of the rice irrigation scheme areas.

for the Bunyala scheme, the water is drawn from the Yala swamp of the Nzoia River.

Rice varieties grown in the Mwea scheme are Sindano, Basmati 217 and BG90-2 which produce some of the highest yields in the world. In the Ahero, West Kano and Bunyala schemes, the varieties are those of the IR series, these also produce high yield levels compared to the Philippines. The paddy yield in Mwea is much higher than that of the other three irrigation schemes.

Farmers

Farmers in each irrigation scheme areas are tenants who are supposed to be given 1.2-1.6 ha (4 acres) of paddy field by each irrigation scheme office. Cropped area, number of tenants, mean yield of rice and payment for tenants of the four schemes are shown in **Table 5**. The staff of the irrigation scheme office provides the following: land preparation by tractor, fertilizer and pesticides, drying of harvested paddy, and bag and transport the dried harvested paddy to the National Cereals and Produce Board (NCPB), manage irrigating water and direct the operations of the tenants.

The tenants are responsible for completing the rice production, which is from nursery bed preparation through harvesting and maintaining the water channels.

Though the harvested paddy is supposed to be brought to the irrigation scheme office, which has a spacious drying place, tenants do not hand over all harvested paddy to the office. Some harvested paddy are kept by tenants for home consumption.

A wage is paid to every tenant by the irrigation scheme office. For instance, a tenant in Ahero gets Ksh 365 per month (16 Ksh = 1 US$, Nov. 1987). This amount will enable the farmers to buy basic foodstuff such as maize flour, vegetable and occasionally meat or fish.

Table 5 Some Statistics of the NIB Rice Schemes

Scheme	Area (ha)	No. of tenants	Yield (t/ha)	Payment (Ksh/year)
Mwea	5 830	3 234	4.7	12 776
Ahero	840	519	4.5	9 960
Bunyala	213	131	5.1	10 920
West Kano	450	553	4.6	5 801

Note: 1 US.$=16.5 Ksh
Source: National Irrigation Board Data for 1984/85.

There is a variation in paddy yields among tenants. For example, one tenant produces 25 bags of paddy per acre, but another produces only 15 bags (1 bag = 75-80 kg). This is because proper operation produces high yields and is dependent on the tenant's management.

There is a protracted system of succession among the tenants. In Ahero, the first son of a tenant will be his successor. Therefore, the rest of the sons have to find other jobs. However, if the first son dies, unless he has had some sons who can succeed him, the second son can take over the paddy field which is given by the irrigation scheme office.

Mechanical Operations and their Problems

Most operations in paddy production in Kenya are done manually with hand tools and by oxen-power except land preparation, which is done by tractors that are provided by each irrigation scheme office.

Land Preparation

This is presently done by the irrigation scheme office by use of tractor rotavation. During land preparation, tractor's bogging-down is a serious problem **(Fig. 2)** which occurs due to difficulty in water control and poor drainage. The bogging-down problem causes delay in land preparation and render the rotary cultivators, useless gears and electrical systems such as generators and batteries. The generators, the batteries and the starters are removed from the tractors which are then pulled to start their engines by a vehicle before working every morning. When the bogging-down occurs, another tractor in the paddy field has to pull the bogged-down tractor out **(Fig. 3)**, hence, waste of time and fuel that makes

Fig. 2 The bogging-down problem.

Fig. 3 Pulling a bogged-down tractor out.

Fig. 4 Nursery bed preparation by using oxen-power.

the cost of land preparation higher than any other operations. Spare parts of the tractors are so costly which is another major problem.

With nursery bed preparation, farmers sometimes use oxen-power. (Fig. 4). But it cannot be estimated how long the ploughing can be completed, because the work depends on how the oxen are trained by farmers. There is a need at least for three people to do this system of ploughing: one, to hold the plough and the other two, to control the oxen. Leveling is also done by oxen-powered leveler. After leveling, the seeds are broadcast.

Transplanting

This operation (Fig. 5) is normally done when tenant's children are on vacation from schools. They can be indispensable labour, because transplanting is hard work for farmers. In this hard transplanting system, the rows of seedling are not straight. If mechanized weeding is contemplated in this system, the rows will have to be straight.

Weed Control

Before transplanting, the paddy fields are flooded to prevent the germination of weeds. This is the cheapest and best way to control weeds. Weeding in these irrigation schemes is not done by herbicide at all but manually. Some tenants do not care to weed, therefore, weeds still grow at harvesting time. Manual cultivators cannot work properly because rows of seedling are not transplanted straight.

The matchet, shown on Fig. 6, is a universal chopping tool, widely used in tropical and sub-tropical regions. The slasher is also used for weeding and maintain channels and paths which divide paddy fields.

Harvesting and Threshing

Harvesting is done by using the sickle (Fig. 7). This operation (Fig. 8) is one of the hardest operations akin to transplanting. Although the work of the sickle is very slow, it is still used widely, particularly in regions where rice is an important crop. This is because in reaping of crops such as rice, the grains easily shatter hence, cannot be achieved by faster working tools or machines.

Threshing is generally the women's task (Fig. 9). Harvested paddy is beaten against a mass of straws (Fig. 10), which is made in a paddy field to thresh. As such there is always head loss problem.

The other problem, which does not make combine harvesters suitable for driving on paddy fields is that the soil is still moist at harvest as this occurs during the rainy season.

Harvested paddy is transported by trucks to drying places near the irrigation scheme office. The paddy is dried on concrete floor until the moisture content of paddy reaches a safe storage moisture level of about 14%.

Fig. 5 The transplanting.

Fig. 6 A matchet.

Fig. 7 A sickle.

Fig. 8 The harvesting.

Fig. 9 The threshing.

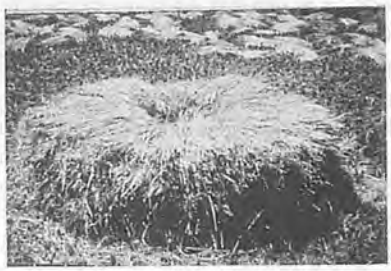

Fig. 10 A mass of straws.

Conclusion

Mechanization in rice production achieves a faster rate of work. However, a greater understanding of the operations is needed in order to justify the mechanization of paddy production.

In land preparation, the problem of tractor bogging-down can be solved with proper timing of the operation. There is a relationship between bogging-down, the field's hard pan (soil carrying capacity) and the time of flooding the fields prior to tillage. This relationship

must be established and utilized to solve the problem.

The system of double cropping must be undertaken only if the right number of tractor units per scheme can be obtained in order to best preserve the hard pan. Also, places where bogging-down had occured previously must be allowed time to rejuvenate. The bogging-down problems are minimum in the Mwea scheme because of the single cropping practice. This practice allows the hard pan to develop before the tractor ploughs the field.

In transplanting and weeding, the introduction of mechanization should promote high crop yields as properly-spaced seedlings will be transplanted per unit area and less competition from weeds, as row transplanting will facilitate the introduction of row type weeders.

In harvesting, the introduction of harvesters, is rather an expensive and specialized operation. It is envisaged that manual harvesting with such tools as the sickle will still play an important role in Kenya. Grain losses, however, during harvesting and threshing must be minimized. Simple, improved technologies of threshing, transporting and drying must be addressed.

There is greater mechanization of rice production in Asia than that in Kenya, and indeed in Africa. Small-size machinery such as manual rice planters, small-engined harvesters and threshers which have been designed and modified at IRRI in the Philippines for small rice producers in Asia, are beginning to be adapted for the Kenyan situation. Japanese tools of rice production might be suitable for Kenyan situation. For example, a Japanese rolling wooden transplanting gauge marker **(Fig. 11)** should be acceptable for proper transplanting guide for making straight rows.

A period of introduction and acceptance of these devices must be expected and further modifications are anticipated. An area where mechanization should be introduced immediately is the area of animal-drawn implements such as planters. Very little animal-drawn rice production implements are known in this region.

Fig. 11 A Japanese rolling wooden transplanting gauge marker.

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Potentials for Computer-aided Farm Machinery Decisions in Pakistan

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Abstract

In Pakistan, there appears to be considerable potential for reducing machinery costs by making farmers and farm advisors more aware of the factors that should be considered in decision-making. In New Zealand the availability of the Machinery Advisory Service (MAS) based at Massey University has enabled farmers, growers, advisors, bankers and machinery dealers to obtain assistance with their decision-making. The MAS uses a micro-computer programme that utilizes technical specifications of the machines and financial factors as inputs to evaluate the likely financial outcomes of decisions made by people in the machinery industry. In Pakistan, such a service, if established, would enable farm machinery advisors, dealers, financial institutions and farmers to include economic reasoning when making machinery management decisions rather than considering mainly social reasons.

Introduction

The rapidly increasing adoption of high-yielding crop cultivars and the use of chemical fertilizers, pesticides and irrigation has enhanced cropping intensity and farm productivity in Pakistan since the early 1970s. Combined with these biological factors, the increased in-flow of money from expatriate nationals overseas has expanded the purchasing capacity of small farm holders. Over recent years this relative prosperity has also led to increased investment in farm mechanization. The last census (1983-84) recorded approximately 158 000 agricultural tractors. The projected tractor population in 1987-88 is estimated to be 218 000 (Mustafa et al, 1984).

A large number of tillage equipment, both imported and locally manufactured, has also been purchased for use with these tractors. Stationary grain threshers and, in recent years, tractor-mounted reapers have also become common. Increased use of farm power and equipment is, undoubtedly, improving the working conditions of farm workers and their families who comprise 52% of the total population in Pakistan (Anon, 1985). Increased farm power is also expected to lead to increased labour productivity and generally improved utilization of soil resources for crop production.

While overall increases in crop production would assist reaching self-sufficiency in important crops, they would not necessarily lead to higher farm incomes because the average land holding is small at about 4.7 ha/farm (Anon, 1985). It has often been argued whether or not it was appropriate, for sociological reasons, to replace the traditional animal-based draft power system with fully or partially mechanized agricultural systems.

In many instances, powered farm equipment has been purchased as a symbol of social status rather than for sound economic reasons. Agricultural engineers have generally favoured increased farm mechanization. In the past such engineers have been in conflict with agricultural economists and sociologists who used financial cost analyses and social impact on rural populations as reasons to disapprove of mechanization. It appears that a lack of understanding of cash out-

Fig. 1 The microcomputer used.

goings for both the fixed and operational costs of machinery often lead to substantial indebtedness and social problems on the part of farmers. The rural lending agencies (e.g., agricultural banks) have also suffered financial losses by not being able to fully recover their dividends and/or principals. However, the drudgery of farm work and the welfare of farmers never seemed to be considered in the economic equations. Furthermore, the implications of long-term knowledge-gain, although difficult to quantify, are likely to be substantial on a national scale, but these appear to have not been fully accounted for.

Under fully or partially mechanized agriculture, investment in equipment is one of the major costs on farms. Attempts to improve farm incomes can be related to the utilization of machinery. If machinery is owned, consideration should be made of extra income earned by hiring it out. At present there is little or no objective financial and technical advisory services available in Pakistan to assist on-farm machinery management. As economic pressure increase due to higher input costs, farmers require advice on both technical and financial aspects of investment in agricultural machinery. Therefore, machinery advisors, dealers, rural loan agencies and farmers need to be able to familiarize themselves with the factors that affect the true cost of machinery ownership and contracting. Since farmers, particularly those on small holdings, are unlikely to make complicated decisions regarding investment in machinery, it is up to their advisors to provide this assistance.

Decisions based on a better understanding of the technical and financial factors involved would result in savings at a national level. Furthermore, this situation might lead to greater investment in other farm inputs, e.g., fertilizers and pesticides in cropping systems, when the true costs are understood.

The MAS has used a computer programme called the Machinery Investment Programme (MIP) which was first developed at Hawkesbury Agricultural College, Australia (Gamble et al, 1984). The package has been modified at Massey University for use in New Zealand conditions. The MIP also has potential for small farm holdings in developing countries. Agricultural research institutions and estate farms could also utilize the package for their machinery decision-making.

The MIP can help answer important questions such as:

* What is the real cost of buying a particular machine?
* Should a new or secondhand machine be purchased?
* How often should a machine be replaced?
* Would it be cheaper to custom-hire a machine rather than buy one?
* What sizes of machine(s) should be bought?
* What would be the cost of jointly buying or sharing a machine with other farmers?

The computer programme can help answer questions provided realistic input values were used and the output information is interpreted correctly. Sound operational knowledge of the programme is required to undertake these exercises. The programme is considered user-friendly having self-prompting instructions. An instruction manual is provided with the package.

How the Computer Programme Works

Example: A cost model for a 35 hp (26 kW) tractor

Initially, the user is asked to select one of the following three options:

a) cost of ownership; b) cost of a contractor; and c) comparison of ownership with a contractor.

Option (c) has been selected for this example. Input values were entered in response to questions asked by the computer programme (inputs 1-24), **Table 1**. Realistic input values may be obtained from

Table 1 35 HP (26 kW) Input Values

(1)	Cost of machine	Rs 128 000
(2)	Investment allowance rate	0%
(3)	Tax depreciation rate	0%
(4)	Life of machine	10 000 h
(5)	Resale value	Rs 80 000
(6)	Shelter charge per annum	Rs 200
(7)	Insurance charge per annum	0%
(8)	Work rate	1 ha/h
(9)	Fuel consumption rate	7 *l*/h
(10)	Cost of fuel	425 (Paisa/*l*)
(11)	Cost of labour	Rs 5/h
(12)	Diminishing balance depreciation	10 = No – 1 = Yes
(13)	Variable repair costs	

Year	Rs/h
1	5
2	10
3	12
4	15
5	20

(14)	Simple interest rate	12%
(15)	Inflation rate – general	6%
(16)	Inflation rate – fuel	4%
(17)	No of years to analyze	5 years
(18)	Maximum hours per annum	1 200 h
(19)	Increment step size	100 h
(20)	Tax rate	0%
(21)	Contractor charge rate	Rs 85/h
(22)	Contractor yield loss	0 t/h
(23)	Returns after marketing	Rs/t 0
(24)	Inflation rate returns	0%

Fig. 2 A 35HP tractor.

technical manuals, machinery dealers, past experiences and financial institutions. For this example, the input values have been estimated as accurately as possible. The programme allows quick re-entry of different values, so that the effects of changes to input values can be readily investigated at low cost to the purchaser.

The cost of the machine (input 1) was the purchase price of the tractor. It the costs of keeping an existing machine were required, the cost of the machine would be the present market value. Zero values were entered for investment allowance, tax depreciation and taxation rates (inputs 2, 3, and 20) since these do not apply to most small farm holdings in Pakistan.

Machine life has been estimated at 10 000 h for a medium-sized, 2 wheel-drive tractor at assumed work rate 1 ha/h (inputs 4 & 8). An estimate of the likely resale value in 5 years time (input 5) has been entered. This value would generally be obtained from machinery dealers based on the likely hours of machine use during the period of ownership.

If the machines are stored in a garage or shed, to reduce machinery corrosion, a shelter charge needs to be entered (input 6). Often, shelter may be shared with other equipment, in which case a proportion of costs, e.g., interest, maintenance, depreciation, would be charged against the machines.

In Pakistan, lock-up shelters (garage) are often provided for tractor storage and safety as there are usually no insurance policies taken out against theft or vandalism. Therefore, insurance has been entered as zero (input 7).

Realistic rates of fuel consumption can be estimated if machine performance is known. However, fuel consumption is related to field conditions, and the operator's experience and mechanical knowledge. These factors vary widely. Hence, an average of 7 l/ha fuel consumption rate has been used and a fuel cost of 425 Paisa/l (inputs 9 and 10).

Labour cost is a realistic charge regardless of whether payment is made to an operator or the machine is owner-operated (input 11). However, the labour cost of owner-operation might vary depending on other jobs that could be carried out elsewhere on the farm (the opportunity cost).

Diminishing balance depreciation (input 12) allows diminishing balance or prime cost depreciation for income tax purposes. For the small farmholder, income tax seldom applies. In this example, it did not matter which method was used because tax rate was 0%.

Repair costs can be entered using one of three methods: constant repair cost per hour, variable costs for each year, or a percentage of machine purchase price. In this example, repair costs have been assumed to increase with age. Hence, a value that varies for each year has been entered up to the maximum number of years the machine was analysed (input 13).

Dividends (interest rates) may relate to borrowed money, hire purchase or personal funds used for the purchase of machines. Dividend rate may depend on the country's economic situation in the case of mortgage money or on the opportunity cost of personal funds, i.e., what else could these funds, be used for (input 14).

The annual general inflation rate and the maximum use (Singh, 1987) have been estimated as likely average for the next 5 years for this example (inputs 15 and 18). Fuel inflation can be at a different rate to general inflation (input 16). The smallest part of yearly cultivated area to be analysed has been set to 50 ha in this example (input 19).

Contractor (custom hire) charges have been entered at Rs 85/ha for hiring a tractor, cultivator and operator (input 21). These charges may also vary significantly depending upon farm location and availability of equipment.

A yield loss of 0 t/ha has been included (input 22). This yield factor is an estimate of the likely change in yield caused by using a contractor. It can be positive (yield loss) or negative (yield gain) depending on the farmers' particular situation. The yield loss (or gain) is added to (or subtracted from) the contractor charge. Minor yield changes can cause a large change to contracting charges. For example, it is well known that crop production losses of up to 30-40 kg/day/ha may occur when wheat has been planted later than November 20 because soil temperatures fall sharply and reduce or delay seed germination and plant establishment particularly in post-rice fields in northern Pakistan. Also, during the peak sowing season, the quality of seedbed preparation by a contractor may be less than satisfactory which might lead to reduced crop yields. On the other hand, a skilled contractor operator for farm operations such as crop harvesting or processing may do a better job than an unskilled owner-operator.

Crop returns after transportation and the inflation rate of these returns have been included as nil (inputs 23 and 24) since no yield loss has been assumed.

Expected costs and savings over the 5-year of machine ownership are shown (**Table 2**). Taxation savings from depreciation are zero as no tax payments were considered

(A). Annual fixed costs (B), including shelter, depreciation and interest were constant over the period of machine use no matter how many hours the machine has been used. It should be noted that if the machine had been used over a longer or shorter period, the fixed costs would be lower or higher, respectively. The resale value of the tractor was estimated to be Rs 107 058 at the end of five years (C). Items D, E, F and G would only be relevant when tax is payable by machinery owners.

The average variable or running costs of the machine (labour, repairs, fuel and lubrication) after inflation and tax are presented in **Table 3** for varying amounts of yearly use up to 1 200 h.

Table 4 shows the average annual total costs (both variable and fixed) after inflation and tax for varying amounts of annual use. Variable costs per h were Rs 57.9 while fixed costs were lowered from Rs 188.9 to Rs 15.7 as machine use was increased from 100 to 1 200 h. The total costs per h, therefore, decreased from Rs 247.2 to Rs 74.0 for 100 and 1 200 h, respectively.

The average annual cost of cultivation for example using a contractor was Rs 98.4 (**Table 5**). Untimely costs might be a large proportion of the contracting charge. Therefore, extreme care is needed when entering yield losses or gains due to hiring a contractor.

Table 6 gives the comparative cost differences between machine ownership and contracting. These results can also be presented in graphic form. The intercept of the ownership and contract hire curves (break-even point) is shown at 457 h. This shows clearly that owning the tractor was only economical if 457 or more tractor-hours were used annually. The programme does not make any distinction between whether or not the machines were used to cultivate the owner's property or to custom hire out to earn cash income. In locations where there are more tractors, it might be cheaper to use contractors rather than to own machinery because of the competition between contractors to attract business. In these situations, any savings could be put towards other biological inputs, e.g., fertilizers, or pesticides.

The computer user can quickly

Table 2 Expected Costs and Savings

(A)	Taxation saving from tax depreciation rate	Rs 0.00
(B)	Annual fixed costs after tax saving	Rs 18 892.4
(C)	Trade-in or scrap value of new machine at end of specified life using estimate	Rs 107 058
(D)	Book value of new machine at end of specified time	Not applicable
(E)	Difference between trade-in value (C) and book value (D)	Not applicable
(F)	Tax payable (+) or tax deduction due (–) on difference	Not applicable
(G)	Salvage value after tax	Not applicable

Table 3 Average Annual Variable Costs (Rs) after Inflation and Tax

Hectares	Labour	Repair	Fuel	Lube	Total	Used hours
100	589.71	1 417.12	3,322.06	498.31	5 827.2	100
200	1 179.43	2 834.25	6 644.62	996.62	11 654.4	200
300	1 769.14	4 251.37	9 966.17	1 494.93	17 481.6	300
400	2,358.85	5 668.50	13 288.2	1 993.23	23 308.8	400
500	2 948.57	7 085.62	16 610.3	2 491.54	29 136	500
600	3 538.28	8 502.74	19 932.3	2 989.85	34 963.2	600
700	4 128.00	9 919.87	23 254.40	3 488.16	40 790.4	700
800	4 717.71	11 337	26 576.5	3 986.47	46 617.6	800
900	5 307.42	12 754.1	29 898.5	4 484.78	52 444.8	900
1 000	5 897.14	14 171.2	33 220.6	4 983.09	58 272	1 000
1 100	6 486.85	15 588.4	36 542.6	5 481.39	64 099.2	1 100
1 200	7 076.56	17 005.5	39 864.7	5 979.7	69 926.5	1 200

Table 4 Average Annual Total Costs (Rs) after Inflation and Tax

Costs h	Variable		Fixed	Total	
	/annum	/h	/h	/annum	/h
100	5 827	58.27	188.92	24 719.4	247.19
200	11 654	58.27	94.46	30 546.4	152.73
300	17 481	58.27	62.97	36 373.4	121.24
400	23 308	58.27	47.23	42 200.4	105.50
500	29 135	58.27	37.78	48 027.4	96.05
600	34 962	58.27	31.49	53 854.4	89.76
700	40 798	58.27	26.99	59 681.4	85.26
800	46 616	58.27	23.62	65 508.4	81.89
900	52 443	58.27	20.99	71 335.4	79.26
1 000	58 270	58.27	18.89	77 162.4	77.16
1 100	64 097	58.27	17.17	82 989.4	75.44
1 200	69 924	58.27	15.74	88 816.4	74.01

Table 5 Average Annual Costs (Rs) after Inflation and Tax

Hours	Untimely costs	Contract costs	Total costs	Per h costs
100	0.00	9 844.39	9 844.39	98.44
200	0.00	19 688.8	19 688.8	98.44
300	0.00	29 533.2	29 533.2	98.44
400	0.00	39 377.5	39 377.5	98.44
500	0.00	49 221.9	49 221.9	98.44
600	0.00	59 066.3	59 066.3	98.44
700	0.00	68 910.7	68 910.7	98.44
800	0.00	78 755.1	78 755.1	98.44
900	0.00	88 599.5	88 599.5	98.44
1 000	0.00	98 443.9	98 443.9	98.44
1 100	0.00	108 288	108 288	98.44
1 200	0.00	118 133	118 133	98.44

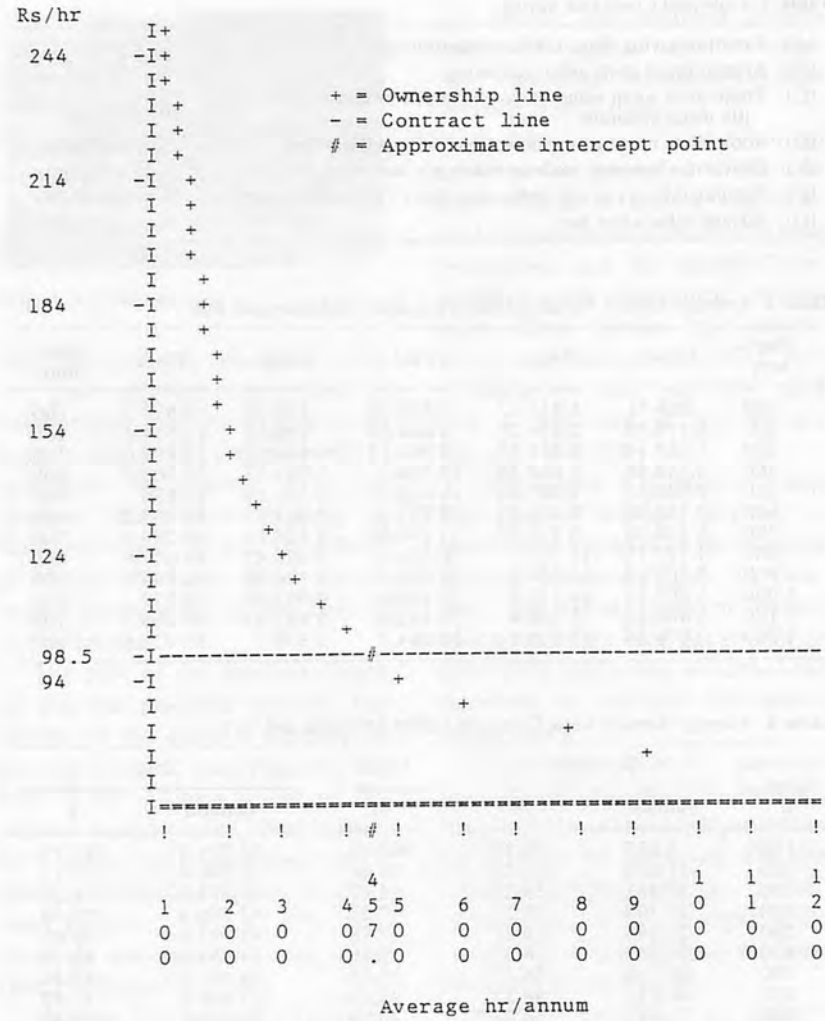

Fig. 3 Comparative graph.

change any of the input values and re-run the programme to test the effects of these changes on overall costs. The programme can be used for virtually any farm machinery cost analyses provided realistic input values are available, and the computer user is skilled at interpreting the results for the machinery purchaser.

Table 6 Average Annual Costs (Rs) per H

Hectares /annum	Owning /h	Contract /h	Difference /h
100	247.19	98.44	148.75
200	152.73	98.44	54.29
300	121.24	98.44	22.80
400	105.50	98.44	7.06
500	96.05	98.44	−2.39
600	89.76	98.44	−8.68
700	85.26	98.44	−13.18
800	81.89	98.44	−16.55
900	79.26	98.44	−19.18
1 000	77.16	98.44	−21.28
1 100	75.44	98.44	−23.00
1 200	74.01	98.44	−24.43

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Cotton Cultivation in Haryana State, India

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Introduction

Cotton is a major cash crop of Haryana State. It is cultivated in about 410 000 ha (1983-84) which is 6% of the total cropped area in Haryana. Its average lint production was recorded to be 238 kg/ha (1983-84) whereas the all-India average for the same year was 142 kg/ha only. Though Haryana has 5.2% of the total area under cotton in India, it produced 8.7% of the total lint producted. However, there is not much to feel complacent about it as the unit yield of cotton in Haryana is quite low as compared to that of the other major cotton-growing countries. Besides, the yield potential of the prevalent cotton varieties is quite higher than what is being achieved at present. It calls for an investigation of the various parameters which influence the unit yield.

Better cultivation practices, plant protection measures and balanced dose of fertilizers play a significant role in augmenting the yields. Nevertheless, the adoption of improved processes and modified implements is equally important. Better germination and proper plant stand, interculturing and effective plant protection measures which are the pre-requisites for good crop yields can be accomplished by the use of innovative farm tools and machines.

Research conducted in this respect reveals that decisively higher yields can be obtained by the vigorous introduction of improved tools and techniques. However, it is confronted by technological, economical, physical and social constraints which have to be overcome in order to achieve and maintain production at par with the other leading countries producing cotton. This means that the various operations needed for raising cotton crop yield have to be mechanized not necessarily with the costly automatic equipment but with suitable (effective and hazard-free) improvised implements suited to local conditions. This will ensure the proper and effective application of inputs like seed, fertilizer, insecticides, etc, hence maximize the unit yields and augment cultivators benefits.

Seedbed Preparation

The seedbed preparation and planting operation take up nearly 20% of the energy required from sowing to marketing and hence the choice of type of implement for seedbed preparation will determine the economics of cotton production. The seed bed should be suitably prepared so as to ensure proper germination and effective utilization of irrigation water. The requirements of a good seedbed are:

i) Fairly deep cultivated, fine and well pulverized;
ii) Ample moisture at the time of sowing so as to ensure good germination and plant stand;
iii) Clear of trash, straw, roots, grasses and stubbles of previous crop which may hamper mechanical sowing;
iv) Levelled for efficient and judicious use of irrigation water and effective working of sowing machines; and
v) Properly packed and planked

to achieve fine tilth and to conserve moisture in the soil.

The first dry cultivation should be done by mouldboard/lister plough, which should enable deep cultivation of soil that is ideally suited for cotton cultivation. For medium and light soils, disc harrow may be used for the first opening of the soil. If the soil is very hard and infested with roots, shrubs and stubbles, disc plough should be used. Sub-soil plough may be used before the primary tillage operation if necessary. Secondary tillage may be performed by disc harrows/cultivators. The planker should be frequently used for breaking the clods and conserving the moisture.

For levelling the fields, land levellers/graders should be used. The buck-scraper is an improved version of bullock-drawn leveller (**Fig. 1**) which is very effective and efficient for land levelling operations. Land plankers of sufficient width may be used for fine levelling and smoothening of the field. Bund formers can be conveniently used for making irrigation bunds.

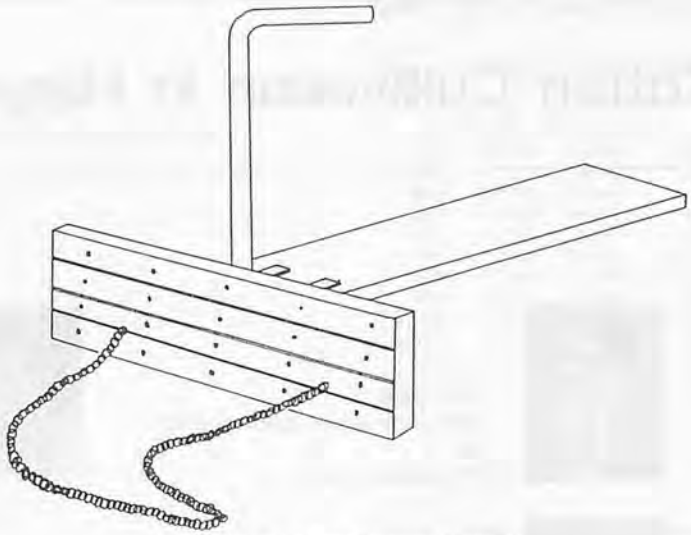

Fig. 1 Bullock-drawn improved leveller.

Sowing and Planting

Sowing of cotton crop and establishing proper plant stand is the most crucial requirement in cotton cultivation. Field survey conducted at Haryana Agricultural University for the two major cotton districts has shown that the plant stand as generally obtained by the farmers is less than the optimum value of 55 000 plants/ha (**Table 1**).

Table 1 Plant Population in Cotton Crop at Farmers' Fields

Year	Plant population/ha in leading cotton districts, Haryana	
	Sirsa	Hisar
1979-80	42 290±5 190	38 480±3 880
1980-81	36 013±2 465	31 247±4 084
1981-82	45 502±3 085	42 284±3 936

Low plant count is mainly due to an equally low seed rate used by farmers. Due to their traditional inhibitions, farmers are using 10-12 kg/ha of fuzzy cotton seed. Research study conducted in this respect has shown that in order to obtain an optimum plant stand, 20-22.5 kg of acid-delinted cotton seed should be used (**Table 2**).

Table 2 Effect of Seed Rate on Cotton Crop Plant Population

Seed rate (kg/ha)	Plant population/ha	
	Before thinning	After thinning
10	65 551	29 859
12.5	75 272	31 595
15	82 633	35 067
17.5	96 313	40 483
20	116 250	49 861
22.5	130 707*	55 000*

* Figures, obtained by extrapolation
** Acid-delinted cotton seed with lab. germination of 59% was used for the research study. ** Tractor-operated seed-cum-fertilizer drill was used in sowing the cotton crop.

The sowing of fuzzy cotton seed has been recognized as another factor which gives rise to poor plant population in cotton. Fuzz content around the cotton seed obstructs the process of cleaning and grading of the seed. Besides, fuzzy seed cannot be sown by seed drills/seed planters. It is very essential that the outer fuzz of cotton seed is removed before it is sown and this is accomplished by acid-delinting process.

Acid-delinting of Cotton Seed

Acid-delinting process involves taking a fixed quantity of seeds and mixing them with proportionate quantity of concentrated sulphuric acid for such a time until the entire cotton fuzz is burnt. Then the seeds are thoroughly washed in clean water and rinsed in lime solution. During the acid-delinting process, the light, floating seeds are separated from the heavy, healthy seeds. Acid-delinting of cotton seed has the following advantages:

i) Ensures complete removal of fuzz around the seed which is not possible otherwise by mechanical ginning;
ii) Seed emergence is improved as only the dense, mature and viable seeds are selected in the process;
iii) Acid-delinted seeds can readily be sown by seed drills/seed planters which ensure proper crop stand and economizes the seed rate;
iv) Screens seed borne diseases; and
v) Hastens the germination process which ensures proper plant population.

The detailed information on

acid-delinting process is shown in **Table 3**.

A comparison of acid-delinted, unsoaked (T_1), acid-delinted soaked (T_2) and conventionally treated (with cow dung and ash) using H14 variety seed is given in **Table 4**.

The highest yield was obtained in the treatment T_1 (acid-delinted unsoaked seed) which is highly significant over T_2 and T_3. The lowest yield was obtained in case of T_3 (conventionally treated seed) due to poor seed emergence and hence poor crop stand.

Consequently, the Haryana Agricultural University has developed mechanical delinters for carrying out the acid-delinting process. On the basis of their capacity, these delinters are classified as small, medium and commercial grade **(Fig. 2)**. A commercial grade cotton delinter in operation is shown in **Fig. 3**. For large-scale acid delinting of cotton seed, fully automatic continuous type delinting plants are available in the country.

Table 3 Characteristics of Cotton Seed Acid-delinting Process

Particulars	Fuzz content of cotton seed		
	High	Medium	Low
Concentrated sulphuric acid required per kg of fuzzy seed (cc)	100-115	80-90	60-70
Time of mixing (min)	12-15	7-8	5-6
Slacked lime required per kg of fuzzy seed (g)	20	20	20
Minimum drying time under bright sun (h)	4	4	4
Seed emergence of delinted and graded seed	Above 80%		
Recovery of good quality seed (%)	70-80		

Table 4 Comparative Seed Yields of Three Cotton Seed Treatments (kg/ha)

Replications	Treatments		
	Acid-delinted unsoaked	Acid-delinted soaked	Conventionally treated
R_1	1 728	2 162	1 730
R_2	2 095	1 726	1 295
R_3	2 060	1 758	1 735
Mean	1 961	1 882	1 586

Fig. 2 Medium-size acid delinter.

Fig. 3 Commercial grade cotton delinter in operation.

Sowing Machines: Seed Drills/ Planters

The acid-delinted cotton seed should be properly sown by the sowing machines in order to maintain plant-to-plant and row-to-row distances. The planter also ensures minimum thinning, hence saves labour. The farmers in the cotton growing districts of Haryana generally follow cotton/wheat, bajra wheat rotation and own seed-cum-fertilizer for sowing the wheat crop. Field experiments conducted on the use of seed-cum-fertilizer drill **(Fig. 4)** for sowing cotton crop show that the drill can be used successfully for sowing the cotton crop as well. **Table 5** compares the performance of the use of seed-cum-fertilizer drill and the local wooden plough "pora".

Table 5 above further shows that greater yields ranging from 16.98% to 52.91% (average 33.34%) can be

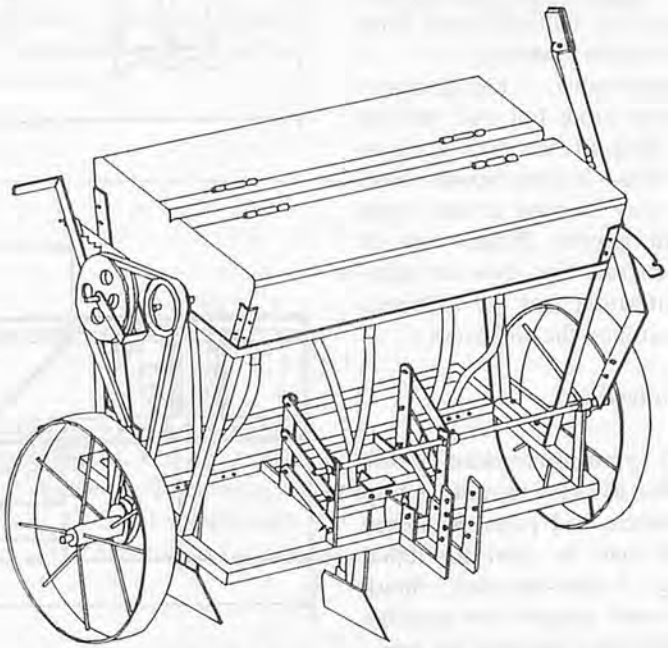

Fig. 4 Bullock-drawn multicrop seed-cum-fertilizer drill.

Table 5 Germination and Crop Yields of Cotton Sown by Seed-cum-fertilizer Drill

Seed rate	Seed-cum-fertilizer drill			Crop yield with local plough	Increase
	Plant count before thinning per ha.	Plant count after thinning per ha	Yield kg/ha	kg/ha	%
25	101 222	49 294	1 662	1 270	30.86
23	75 555	55 111	1 625	1 312	23.85
20	83 592	55 444	1 812	1 275	42.11
20	83 592	55 407	1 575	1 030	52.91
18	76 444	54 518	1 550	1 325	16.98

achieved by the use of seed-cum-fertilizer drills. This increase in yield was due to better plant germination and stand.

The ridger-cum-seeder can also be used successfully for the seeding of acid-delinted cotton seed as it ensures better management and drainage of excess water if any.

Interculturing and Row Crop Cultivation

The first dry hoeing should be done with the wheel hand hoe (Fig. 5) the use of which depends upon soil conditions. Subsequent hoeings can be done by bullock-drawn weeders with adjustable tynes. Field studies carried out at the Haryana Agricultural University shows that bullock-drawn blade harrow gives better performance compared to bullock-drawn three tyne cultivator (Table 6).

Tractor-drawn, high-clearance cultivators using full and one-half sweeps (Fig. 6) has given good results. The bullock-drawn lister plough may be used at later stages of plant growth. Ridger may be used between the rows for inter-row cultivation and for collecting the soil around the crop rows.

Plant Protection

Plant protection measures are imperative in saving the cotton crop from insects and pests. Knapsack sprayers may be used for liquid spraying. Engine-operated, shoulder-mounted sprayers are available which are ideal for spraying operations. Since they are very precise in

Fig. 5 Wheel hand hoe.

Table 6 Performance of Bullock-drawn Weeders in Cotton Crop

Name of weeder	Weeding efficiency %	Plant damage %	Man-h/ha	Cost of weeding Rs/ha
Blade harrow	76.8	12.16	6.63	15.15
Three tyne cultivator	67.4	9.7	6.94	17.35

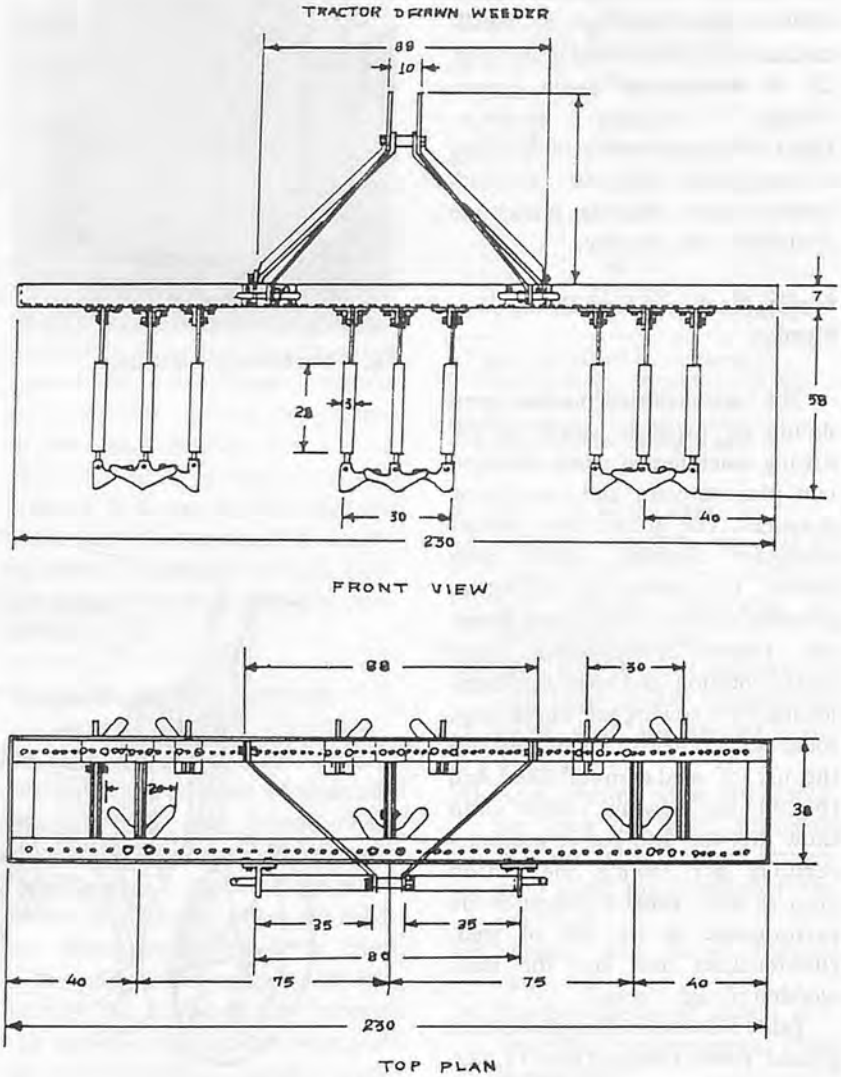

Fig. 6 Tractor-drawn weeder.

their operation, good care is required in their use. Plant protection measures can be accomplished by aerial spraying. Where dusting is to be done for the control of pests, manually-operated crop dusters are quite effective.

Picking

At present, the entire cotton crop is picked manually by employing human labour. It has been investigated that maximum energy is consumed in picking operation. Labour shortage is acute in the picking season with the result that great difficulty is experienced by the farmers in picking the cotton. It calls for the introduction of cotton pickers. Mechanical pickers as used in other cotton growing countries may not be practical because of plant height. Besides, defoliation has to be done prior to mechanical picking. Light weight back shoulder mounted pneumatic pickers suitably designed for Indian conditions would be quite effective (Fig. 7). Research work need to be directed towards developing portable type cotton pickers.

Stalk Disposal

At present, the stalk is disposed of by cutting it with axe or "kasola". It may damage the tractor tyres if the first tillage operation after the stalk disposal is accomplished by tractor. Manual root pullers have been developed and can be effectively used. Tractor-drawn shredders (Fig. 8) can be successfully used for cutting the cotton stalk.

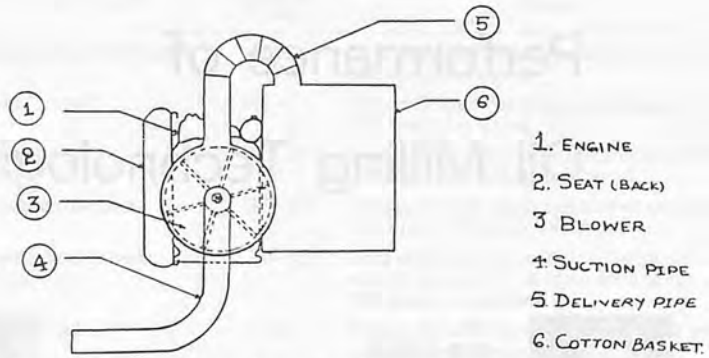

Fig. 7 Side elevation of proposed cotton picker.

Fig. 8 Tractor-drawn shredder for cotton stalk disposal.

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ERRATA

AMA Vol. 19, No. 2, Spring 1988 "Development and Fabrication Techniques of Improved Grubber", P. 46, Col. 1, Line 1 should read:

The dimensions L_1, L_2, L_3 and α

Performance of Oil Milling Technologies in India

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Abstract

The existing oil milling plants were visited to collect information on plant performance. In addition to direct measurements, plant records were consulted and discussions held with the managerial and technical staff to obtain the required information on oil recovery and energy requirements. The average recovery of oil in mechanical extraction was 73% except in the case of cotton seed for which it was only 60%. Solvent extraction, however, offers the maximum scope for enhancing oil recovery to almost 100%. The energy requirement of solvent extraction was greater than the mechanical extraction. Means and ways are suggested to improve oil recovery and energy requirements.

Introduction

Fats and oils are necessary ingredients in the diet. They are a concentrated source of energy and the supply per unit weight is more than double the energy furnished by either protein or carbohydrates. Vegetable oils have to be included in the daily diet to obtain the necessary amounts of fatty acids. The net availability of edible oils, including "vanaspati" and animal fats in India is about 5 kg /capita/ year. This is far below the average requirements of about 14 kg/capita/ year. Even to maintain this low level of edible oil consumption, the country has to import large quantities of vegetable oils costing Rs. 5 000 to Rs. 10 000 million every year.

The availability of edible oils from indigenous sources is planned to be increased by raising the production of edible oil seeds. The availability of edible oils can also be increased through improvements in oil milling technology. In general, a shift to superior technology requires higher energy expenditure.

This study was undertaken in order to determine the magnitude of additional oil recovery and energy expenditures if advanced milling technology was used to process edible oil seeds at the estimated production level in 1983-84. The specific objectives were:

1. To determine the commercial and non-commercial energy needs and energy economics of different oilseed processing technologies.
2. To study the feasibility of improving the prevailing oilseed processing technologies to project changes in energy needs and energy economics as a result of suggested improvements.
3. To analyze the probable effect of suggested improvements on operational pattern and employment potential of the oilseed milling industry.

Methodology

Although Punjab is not a major oilseed producing state, substantial quantities of important oilseeds like groundnut and mustard are grown and processed locally. The "vanaspati" and solvent extraction industries are also well established in the State. The oil milling practices are almost the same throughout the country. For the purpose of this study it was assumed that the data on oil recovery

and energy expenditure collected from different types of oil mills in Punjab could be used for the purpose of projections at the national level. Further, the expected oilseed production in 1983-84 (Kempanna, 1982) was used as the base for oil recovery and energy expenditure analysis.

The study sample comprised 7 types of oil milling units as given in Table 1.

Table 1 Composition of Study Sample

Type of unit	Capacity (t/day)	Remark
Animal-operated "ghani"	0.05	Data collected for mustard milling; 180 work days/year
Power "ghani"	0.5–1	Data collected for mustard milling; 180 work days/year
Expeller	10–20	Data collected for mustard and groundnut milling; 200 work days/year
Solvent extraction	30–50	Data collected for extraction of oil from rice bran; 300 work days/year
Expeller and solvent extraction	30–40	Data collected for milling of groundnut and extraction of oil from groundnut cake, 300 work days/year
"Vanaspati"	50	Data collected for hydrogenation of palm oil; 300 work days/year
Refined oil	50	Data collected for groundnut oil; 300 work days/year

The plants were visited by the study team to record the state of technology in each unit and collect information on plant performance. In addition to direct measurements, plant records were consulted and discussions held with the managerial and technical staff to obtain the required information. Due to poor standards of record keeping in the smaller plants ("ghanis" and expellers) there were many information gaps. Efforts were made to obtain complete information on at least one unit of each type. The information on energy inputs were classified as follows:

Commercial energy inputs

a. Direct – Electricity purchased from outside, fuel oil, coal
b. Indirect – Chemicals, lubricants, machinery, structures

Non-commercial energy inputs

a. Direct – Labour, animal draught energy, residues used as fuel
b. Indirect – Mud and thatch sheds

The above information was recorded separately for primary process of oil extraction and the secondary process of oil refinement and hydrogenation. The indirect energy inputs were quantified on the basis of data and assumptions shown in Table 2.

Table 2 Indirect Energy Inputs-Assumptions

A. Machinery

Type of unit	Weight (t)	Energy cost (GJ/t)	Life (yrs)	Energy input (GJ/yr)
Animal drawn ghani (expeller)	0.1	25	10	0.25
Power ghani (expeller)	1.0	82	15	5.5
Expeller	20.0	82	20	82.0
Solvent extraction	50.0	82	20	205.0
Expeller with solvent extraction	75.0	82	20	307.5
Refinery	10.0	82	20	41.0
"Vanaspati"	100.0	82	20	410.0

B. Structures

Type of unit	Type of structure	Area (m^2)	Energy cost (GJ/m^2)	Life (Yrs)	Energy input (GJ/yr)
Animal drawn "ghani"	Mud and thatch	20	0.24	3	1.6
Power ghani	Bricks	25	10.0	25	10.0
Expeller	Bricks	400	10.0	25	160.0
Solvent extraction unit	Bricks & steel	1000	14.0	30	466.7
Expeller with solvent extraction unit	–do–	1500	14.0	30	700.0
Refinery	–do–	100	14.0	30	46.7
"Vanaspati"	–do–	1000	14.0	30	466.7

C. Chemicals and lubricants

Item	Energy cost (GJ/t)
Lubricants	48.4
Solvent	48.7

In estimating the direct energy input, the energy equivalents of one man day was taken as 15.7 MJ and that of one draught animal day as 64.6 MJ in accordance with the recommendations of the Combined Annual Workshop of the ICAR on Energy Research in Agriculture, 1983. Although both internal combustion engine and electric motor are used in oil mills to supply mechanical power, for simplicity and easy comparison the estimation of direct commercial energy was made using the assumption that electric supply was available to all the mills. There was a great deal of variation in the solid fuel (coal, rice husk, groundnut shells) consumption to produce the process steam in expellers of the same capacity. Differences in boiler management made are comparison of steam consumption in different plants impractical. The records of coal consumption for process steam production in the solvent extrac-

tion plant, refined oil plant and vanaspati plant were dependable and boiler designs and management practices were comparable. It was, therefore, decided to work out the process steam requirements of the expeller units theoretically and estimate the coal consumption on the assumption that the process steam subsystem had an overall efficiency of 50%. In the case of solvent extraction unit and refined oil and hydrogenation plants, the actual consumption of coal was made. The calorific value of coal was taken as 25 MJ/kg and that of residues as 16 MJ/kg.

Table 3 Recovery of Oil

Raw material	Oil content (%)	Recovery %			
		Mechanical extraction			Solvent extraction
		Animal-drawn ghani	Power-ghani	Expeller	
Cotton seed	18.5	–	–	59.5	–
Mustard	43.0	65.1 (28.0)	74.4 (32.0)	78.0 (33.5)	
Groundnut cake (from expeller)	9.0	–	–	–	94.4 (8.5)
Cotton seed cake (from expeller)	7.5	–	–	–	97.3 (7.3)
Groundnut	49.0	–	–	81.6 (40.0)	–
Rice bran					
a. Raw	13.0	–	–	–	98.5 (12.8)
b. Parboiled	25.0	–	–	–	99.0 (24.75)

Results and Discussion

Oil Recovery and Losses

The observations on oil recovery from different raw materials are given in Table 3.

Substantial amount of oil is lost in the cake in mechanical extraction. The loss is even greater in the traditional animal powered "ghanis" compared with the loss in expellers or power "ghanis", which occupy a position between animal-powered ghanis and expellers in oil recovery. Almost the entire quantity of oil contained in the oilseed is recovered if the oil cake obtained from mechanical extraction is further processed through solvent extraction. In order to compute the oil loss and to estimate the potential for additional oil recovery, it would be necessary to have reliable data on the quantity of oilseed processed in different types of milling units in the country. Such data is not available. The study team arrived at its own estimate based on the following:

1. The average oil content of the edible oil seeds, excluding cotton seed, is 45%. The oil content of groundnut and rape and mustard, the most important oil seeds, is the basis of the above assumption.

Table 4 Estimates of Increase in Edible Oil Availability as a Result of Technological Improvement at 1983-84 Production Level

Material	Quantity (MT)	Recovery using existing technology (MT)	Additional recovery du to improvement in mechanical extraction (MT)	Additional recovery from solvent extraction (MT)
Conventional oilseeds* (groundnut kernel, rape, mustard, sesamum, sunflower tec.)	8.5	2.79	0.27	0.75
Cotton seed*	2.4	0.27	0.02	0.15
Rice bran from raw rice**	1.25	–	–	0.16
Rice bran from parboiled rice**	1.25	–	–	0.31
Total		3.07	0.30	1.32

*90% of production; **25% of production estimated at 5MT from 85MT of paddy.

2. Considering the present population of "ghanis" and expellers the average recovery of oil in mechanical extraction is 73% except in the case of cotton seed for which it is only 60%.

The improvement in the mechanical extraction techniques through a shift from "ghanis" to expellers and by incorporating the proper preheating of oil seeds and control of pressure can raise the average recovery in mechanical extraction from 73% to over 80% for groundnut, mustard, etc and from 60% to 65% for cotton seed. Solvent extraction, however, offers that maximum scope for enhancing oil recovery to almost 100%.

Table 4 shows an estimate of the feasible increase in edible oil availability at the 1983-84 production level (projected) with 100% expeller extraction and 100% expeller extraction plus solvent extraction, utilizing the total quantity of conventional oilseeds, cotton seed and 50% of the rice bran as raw material. It has been assumed that the present contribution of solvent extraction technology and of rice bran to the production of edible oil is nominal. Also, it is considered impractical to stabilize the rice bran, a prerequisite for the production of

edible rice bran oil, and, therefore, only half of the estimated rice bran produced per year has been considered as the available quantity for edible oil extraction.

The use of improved technology in mechanical extractions can increase the oil recovery from major oil seeds by about 10%. Solvent extraction can yield a further increase of 27.7% in the recovery of oil from the same source. A combination of improved mechanical extraction and solvent extraction can, therefore, increase the recovery from conventional edible oilseeds by over one-third. Extension of solvent extraction technology to recover edible oil from stablized rice bran to the extent of half of the total production of rice bran can increase the availability of edible oil by 50%. The additional 1.6 MT of edible oil recovered due to improved mechanical extraction and solvent extraction technology would mean 2 kg additional edible oil/capita/year for a population of 800 million. At a price of Rs. 6 000 per t, it would represent a saving of Rs. 9 600 million per year in foreign exchange. The solvent extraction technology while contributing the major share of the additional oil makes the improvement in mechanical extraction technologies less critical because the oil cost due to inadequate mechanical extraction will be recovered in solvent extraction.

Table 5 Commercial Energy Requirements of Oil Extraction (GJ/T oil)

Type of energy	Ghani		Expeller		Solvent extraction		Expeller plus S.E.	
	Animal	Power	Mustard	G/nut	Cotton seed	Rice bran	G/nut cake***	G/nut
Direct								
Electricity	–	0.98	1.60	0.93	4.65	0.82*	1.15	1.11
Coal	–	–	0.37	0.31	1.14	14.60*	20.47	6.10
Indirect								
Machinery	0.10	0.19	0.08	0.07	0.25	0.09*	0.12	0.05
Chemicals	–	–	–	–	–	2.90*	0.12	0.05
Structure	–**	0.43	0.20	0.17	0.60	0.20*	0.27	0.08
Total	0.10	1.60	2.25	1.48	6.64	18.61	25.99	8.50

*Average of bran from raw and parboiled rice. **Mud and thatch structure.
***From expeller, with 9% oil.

Table 6 Additional Requirements of Energy for Increasing Edible Oil Recovery through Solvent Extraction (1983-84)

Type of energy	Conventional oilseed cake	Cotton seed cake	Rice bran	Total
Electricity (10^3 kWh)	239 583	106 263	107 055	452 901
Coal (T)	614 100	272 374	274 480	1 160 954
Machinery (GJ)	90 000	39 918	42 300	182 218
Chemicals (GJ)	2 985 000	1 323 946	1 363 000	5 671 946
Structure (GJ)	202 500	89 815	94 000	386 315

Energy Requirements

Most of the improvements in milling technology result in additional requirements of energy, primarily the commercial energy. With increasing gap between the supply and demand of commercial energy, the additional requirement of energy needs to be carefully examined in order to determine the feasibility of incorporating different improvements in oil milling technology. Table 5 gives the commercial energy requirements of different types of oil making units.

The requirements of direct commercial energy depend both on the extraction technique and the characteristic of the raw material. The consumption of direct commercial energy per t of mustard oil in a powered "ghani" is only 61% of the consumption in an expeller unit. Cotton seed requires the largest inputs of direct commercial energy for mechanical extraction of 1 t of oil while groundnut requires the lowest amount of energy.

Solvent extraction per t of groundnut oil requires twice as much energy as mechanical extraction in a expeller. Some of these differences can be attributed primarily to the differences in the oil content of the raw material. For example, both cotton seed and groundnut cake contain lower percentage of oil compared to groundnut kernel. Larger quantities of cotton seed and groundnut cake have to be processed to obtain 1 t of oil compared to the groundnut kernel processed in the expeller unit to obtain the same quantity of oil. Process steam, not used at all in the "ghanis" and accounting for only a small share of the commercial energy input in expellers, constitutes the largest share of commercial energy input in plants using solvent extraction technique. The indirect energy requirement for solvent extraction processes are much higher compared to mechanical extraction because of the hexane loss. The machinery and structures' energy cost in expeller plus solvent extraction plant is lower compared to 'power ghanis' and expellers because of a more fabourable scale of operation. The additional requirement of commercial energy for maximizing oil recovery shown in Tables 4 and 5 is summarized in Table 6.

The shift from "ghani" to expeller though advantageous if only mechanical extraction is practised, loses its importance if solvent extraction is made an integral and essential part of oil milling as the oil left over from mechanical extraction will be recovered in the

solvent process. The additional energy requirements was, therefore, estimated only for solvent extraction of all edible oil seeds. Substantial commercial energy inputs have to be made to increase the edible oil recovery through technological improvements.

The additional requirement for electricity in increasing the edible oil recovery through solvent extraction process, though not very large, would still requires the installed capacity of 60 to 70 MW. The additional requirement for coal exceeding 1 million t is quite considerable. However, the requirement of coal can be reduced to a great extent by making efficient use of milling residues, particularly groundnut shells. Some 5.8 million t of groundnut (out of 7.3 million t projected production in 1983-84) would yield about 1.74 million t of groundnut shells, the heating value of which would be comparable with what can be obtained from 1 million t of coal. Due to the problem of collection, it will not be feasible to use groundnut shells as boiler fuel in all the solvent extraction plants throughout the year. However, it should be practical to replace up to 50% of coal with groundnut shells representing a saving of over Rs. half billion per year in commercial fuels. The requirement of chemicals, particularly n-hexane, is also quite large exceeding 120 000 t of this solvent. However, the possibility of increasing the edible oil availability by at least 50% should, in the interest of energy economy, more than justify the annual investment of the above quantities of commercial energy in the establishment of adequate capacity for solvent extraction of edible oils.

Employment

The installation of adequate capacity for the extraction of edible oil from conventional oilseed cake, cotton seed cake and from 50% of the rice bran produced each year would create additional employment. It was observed that on the average 108 man days of labour were needed to process 100 t of oil bearing material in the solvent extraction plants. On this basis, the additional employment generated through the establishment of solvent extraction capacity described above comes to about 11 million man days to provide round the year employment to 37 000 workers.

Refined Oil and "Vanaspati"

The use of hydrogenated oils, commonly called "vanaspati" in India has been increasing steadily over the last 4 to 5 decades. The use of refined oil, which is often preferred for health reasons, is also picking up. The process of oil refinement in a plant of 50 t/day capacity requires 70-80 kWh of electric energy per t of oil. The coal requirement for process steam was about 0.5 t per t of oil. The process steam requirements of hydrogenation in a plant of comparable capacity was not very different. But the requirement for electrical energy was observed to be about 300 kWh/t of oil. Further, the hydrogenation process used over 60 m^3 of hydrogen and large quantities of nickel for each t of oil.

Additional Observations

Thermal efficiency of steam generation in the expeller plants was extremely low ranging from 25 to 40%. The small boilers and furnaces commonly employed in the expeller units were of inefficient design. No effort was made to prevent heat losses through insulation of the steampipes. This is probably explained by the fact that adequate quantities of residues were available, particularly during groundnut milling season, to meet the solid fuel requirements of expeller units in spite of low efficiencies. The residues, particularly groundnut shell, are used by small and medium industries as furnace fuel and have a commercial value. It would, therefore, be advantageous to the expeller units to improve the furnaces, boilers and the steam distribution system to save on the residues which could be marketed. In any case, inefficient use of these fuels results in excessive pollution and has to be discouraged. Further, preheating of oil seeds with hot water seems to offer a distinct advantage over preheating with steam as practised now. The advantages will be a simpler equipment and higher efficiency. Hot water preheating should be tried on pilot scale.

It was noticed that in the larger units like refining and solvent extraction plants, where coal was used to generate process steam, no thought had been given to co-generation. The new solvent extraction and oil refining units should be designed to incorporate co-generation so that a part of the mechanical power requirement of these plants is met internally.

Hydrogenation of edible oils does not offer any advantage in terms of nutritional value or quality. It is a highly energy-consuming process. Further expansion of the installed capacity for the manufacture of "vanaspati" should be discouraged.

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A Wood Chip-fired Residential Boiler

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Abstract

The performance of a wood chip-fired residential boilder is discussed. A combustion efficiency of 81% and a maximum overall thermal appliance efficiency of 34% with 24.5% wood chips moisture content, 160% excess air and a stack temperature, heat exchange surface cleanliness, wood moisture content and firing rate have measurable effects on the overall thermal appliance efficiency.

Introduction

There is a great interest in using wood chips as fuel for residential boilers these days. Many home-owners are heating by wood chips for their residential boilers to reduce the high cost and rapidly escalating prices for natural gas and petroleum products. Wood chips can be made from residues, and can be fed any time at the rate needed. They can also be produced from wood waste and low quality wood and easy in handling. As fuel, the wood chips-fired residential boiler, structural features should be understood and its performance characteristics examined. The objectives of this paper are to determine the steady state of combustion efficiency and overall thermal appliance efficiency of a residential wood chip-fired boiler.

Material and Methods

The stoker hopper was ensured full before the starting test was done. All values were set correctly to circulate pure water through the boiler. The flow diagram of the boiler performance test is shown in **Fig. 1**.

Three tests were run in a series at three fuel feed rates, 2:1, 1:1 and 1:8 at an ambient temperature of 15.5°C and 40% relative humidity. Comparisons were made for each different speeds and each test at any one speed was run for 1 h at 10 min interval. Chip fuel samples were heated and marked in air-tight bags for moisture determination. The combustion efficiency from percentage CO_2 and stack gas temperature was calculated using combustion curves.

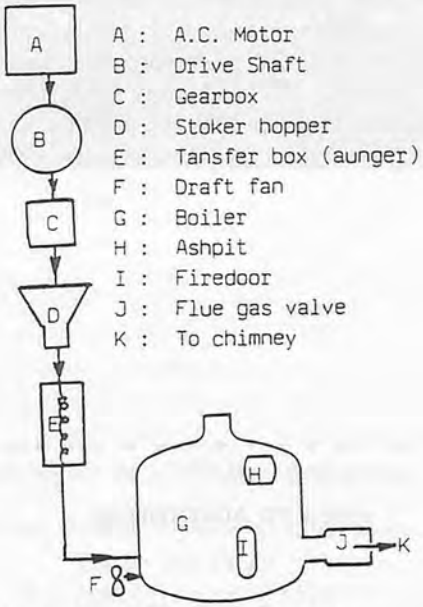

Fig. 1 Flow diagram of a wood chip -fuelled residential boiler test.

Results

The combustion and overall thermal efficiency for the three tests are shown in **Table 1**. A combustion efficiency of 81% is found on stack temperature of 122.2°C with 25.8% moisture content of fuel. With a stack temperature of 121.6°C and fuel moisture content of 24.5%, the boiler gave an overall thermal efficiency of 34%. Excess air amounting to 99% with a stack temperature of 121.1°C reduced the combination efficiency to below 60% and overall thermal efficiency to 18%.

Discussion

The results indicate that this particular wood chip-fired residential boiler is giving a low overall thermal appliance efficiency

Table 1 Combustion and Overall Thermal Efficiency of a Wood Chip Residential Boiler

Item	Test number			Item	Test number		
	1	2	3		1	2	3
CO_2 (%)	7.3	9.7	2.3	Energy supply to boiler (kJ)	104 748	193 242	16 071
Excess air (%)	160.0	99.0	>300.0	Wt. bone dry fuel (kJ)	12.2	22.5	6.3
Moisture content (%)	24.5	25.8	23.5	Combustion efficiency (%)	80.0	81.0	<60.0
Stack temperature (°C)	121.6	122.2	130.9	Overall thermal efficiency (%)	34.0	18.0	30.0
Energy supply to water (kJ)	35 423	29 846	16 071				

compared to reports of ASHVE, where solid fuel boilers have 50-75% efficiencies.

Complete combustion occurs when all the carbon and hydrogen and their compounds convert to carbon dioxide and water. To facilitate this, excess air (above theoretical) was added to the boiler. With 160% excess air added to the boiler, the efficiency was maximum. However, the efficiency decreased when more excess air was added (above 300%). This shows that there was still a portion of the carbon that has been converted to carbon monoxide instead of carbon dioxide which resulted in incomplete combustion and heat loss. Higher than necessary levels of excess air result in additional discharge of energy out of the stack, since large volume of nitrogen must be heated to the flame temperature. These large volume of nitrogen must be heated to the flame temperature. These large volumes of nitrogen primarily made up the volume of air besides 20.9% oxygen.

Some smoke is always formed during the test due to sudden shift to a high temperature to too small grate area for the quantity of varying size wood chips which has to be burned on it in a given time. Thus, combustion is not complete.

Heat transfer system in the boiler was probably reduced due to slag deposits on boiler wall tube. More complete combustion occurs in performance test 2 than in test 1 or 3, because of the high CO_2 percent found in the gas. This percentage of CO_2 shows that more C and H compounds are being converted in the process.

The fact that the overall thermal efficiency of this wood chip-fuelled boiler is very low implies that some or most of the potential heat of the fuel is dissipated in the form of radiation, heat loss by moisture in the fuel and air supply, heat loss due to CO in chimney gases and heat loss from "Unaccounted for".

Generally, in order to increase the overall thermal efficiency of the boiler, complete combustion should be maintained with lowest possible excess air level. The boiler should be operated below the atmospheric particulate emission limit and fire-side corrosion and deposit build-up should be minimized.

Conclusions

The maximum combustion efficiency attained by a wood chip-fired boiler is 81% with a stack temperature of 122.2°C and 24.5% moisture content. The amount of excess air required to be added to the boiler is 99%. Incomplete combustion will occur if too much excess air (above 300%) is added to the boiler.

Highest overall efficiency of the wood chip-fuelled boiler can be obtained at a stack temperature of 121.7°C with 160% excess air and 24.5% moisture content. ■■

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Alcohol as Tractor Fuel— Is There Any Future?

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Introduction

The present unpredictable nature of oil supply and price makes agriculture an expensive enterprise. Agriculture in the Third World countries still depends heavily on animal and human labour. Thus, the effect of high energy prices are not very greatly felt in the food production activities. However, progress in agriculture is going to be considerably hampered since much effort is put into modernizing and mechanizing it. Mechanization is inevitable if high efficiency is desired in order to produce more food. As farming gets more and more mechanized, the dependence on mechanical power to operate bigger and heavier mechineries increases. Tractors, the prime movers of modern agriculture, consume a great deal of energy. To take advantage of the higher efficiency of the compression-ignition engines, these tractors were designed to run on diesel. In fact, heavy-duty engines running on petrol are almost unheard of today. In the U.S., for instance, where the level of agricultural mechanization is high, 80% of the new tractors and combines were fueled by diesel by 1976 (Buffington and Zar, 1977). Of the total energy used on U.S. farms, two-thirds are being consumed by tractors, combines and other self-propelled machineries and is expected to reach 20.4 billion litres of diesel (5 377 million U.S. gallons) by 1985 (Dvoskin and Heady, 1976). This situation will soon be faced also by the developing countries as the status of mechanization increases. A long term solution in the form of an alternative engine fuel is needed. This will not only help save foreign exchange from oil imports but also reduce, if not eliminate, the scramble for oil in times of shortages.

Alcohol Fuel Performance

Already, a lot of studies have been done on alternative fuels, foremost among which is alcohol. Alcohol, especially ethanol, could be produced easily and the raw materials, being agricultural matter, are renewable. Ethanol also has been singled out as the most prospective alcohol fuel. Its suitability in spark-ignition as well as compression-ignition engines was, and still is, being studied. For farm power, the suitability of ethanol in compression-ignition engines is of paramount importance. Initially, alcohols were thought to be suitable only in spark-ignition engines, and impossible in the compression-ignition engines without major modifications. Extensive research has enabled diesel engines to run on alcohol, but like their petrol counterparts, with a lower power output and efficiency. The main issue evolving around alcohols as engine fuels is whether there really is any future in alcohols. So much research involving so much time, money and energy have been carried out. But a satisfactory alcohol engine has yet to be found. Various approaches have been tried which include direct substitution, fuel modification, dual fuelling and spark-ignition of alcohols. Performance are all still lesser than that of pure diesel. Common major features of each of these approaches are now examined in this paper.

A major obstacle in the utilization of alcohols as engine fuels is their high heat of vapourization. This factor results in excessive cylinder cooling, improper air-fuel mixing, long ignition delay and misfiring. High intensity knocking also is seldom absent which is due to this high heat of vapourization that makes direct substitution of alcohols quite impossible. Modification to the fuels includes using diesel-alcohol blends, cetane enhancers, emulsions and alcohol derivatives such as esters. For blends, ethanol can be mixed with diesel by up to about 20% volume for practical purposes. The resulting cetane number and energy content is, however, reduced which results in difficult ignition and

low efficiency due to long delay. Hydrocarbon (HC) emission tends to increase as the percentage of ethanol in the blend increases. Phase separation poses another major problem in utilizing alcohol-diesel blends, especially at low temperatures, prompting research into emulsions. Though able, to a certain extent, to overcome the problem of phase separation, the emulsions themselves are difficult to stabilize. They are also more costly and increase HC and nitrogen oxide (NO_X) emissions. Ignition in engines running on alcohol alone can be improved by adding fuel additives to increase the cetane rating. But these cetane improvers are very expensive, and being basically a nitrogen-based compound, increase the NO_X emission significantly. One researcher also reported a three-times higher wear rate on piston rings and liners of a methanol-fueled engine with cetane improving additive compared to a diesel fueled one (Holmer et al, 1980). Examples of cetane enhancers are amyl nitrate and triethylene glycol dinitrate (TEGDN). Fuel modification through the use of alcohol derivatives has so far been confined to methyl esters. In this option, methyl esters of vegetable fuels like soybean oil (Einfalt and Goering, 1985), sunflower oil (Kaufman and Ziejewski, 1984; Zubik et al, 1984) and palm oil (Ong et al, 1984) have been tried. Except for the palm oil methyl ester which were reported to have better thermal efficiency, comparable fuel consumption and little fuel deposits, the soya and sunflower methyl esters resulted in carbon deposits, lubrication oil dilution, difficult starting and high cylinder pressures and rates of pressure rise. Being a relatively simpler substitute, vegetable oils are fast getting attention as the next alternative fuel. But high viscosity and tendency to leave deposits in injectors and cylinders affect their suitability.

Dual fuelling, in which both alcohol and diesel are simultaneously used to power the engine is, by far, the most promising and popular approach. Two procedures are employed: 1) direct injection of diesel and alcohol and 2) injection of diesel with fumigation of alcohol. Some amount of modifications are required for both procedures. However, the first one possesses some major disadvantages such as two injectors required per cylinder (one each for diesel and alcohol), two injection pumps (one each for diesel and alcohol), lubrication problems in pumps and injectors used for alcohol due to its lower visocosity, and possible reduction in pressure-holding capacity of the cylinders due to the head being bored to accomodate the alcohol injectors. Alcohol fumigation is the introduction of the alcohol fuel spray into the intake air stream by means of a nozzle or a carburetor. This method improves alcohol-air mixing. Unfortunately, intake manifold design greatly influences the uniform distribution of the alcohol. Present diesel engines do not have intake manifolds suited for alcohol fumigation posing a serious limitation to high fumigation rates. Engine performance via fumigation are generally slightly better at full load, lesser at medium load and a complete disaster at low loads. Fumigation at low loads is limited by quenching, resulting in cylinder cooling and misfires. At high loads, fumigation tends to result in high intensity knocking. The demand for cetane number was reported to be low at high loads (Holmer et al, 1980).

The high octane number of ethanol means that it is a good spark-ignition fuel and able to burn at high compression ratios without knock. Nagalingam et al (1980) took advantage of these properties and introduced a hot spot in the cylinder in order to run the engine on 100% ethanol. Efficiency decreased at high speeds due to increased ignition delay resulting in lower peak pressures. Apparently the hot spot could not cope with the heat demand at high speeds. Spark plugs could also be introduced for spark-ignition of alcohols. This requires some space in the cylinder head and accurate placement and orientation of the plugs.

Current Situation on Alcohol Fuels Issue

Encouraging findings on alcohol as engine fuels have been obtained but more research need to be done to produce more concrete and conclusive results. The problem now is to get an acceptable and reliable fuel-engine combination. Presently, the world is still hesitant to objectively claim that THE fuel and/or THE engine has been found amid the multitude of reports on progress made on alcohol fuels. And this is rightfully so. Performance of alcohol in diesel engines, though differs in different research, generally gives a somewhat similar picture – lower efficiency at part loads, higher fuel consumption and varying degree of engine durability and materials compatibility. Howver, lower exhaust smoke is a good point for alcohol and can be used to increase power output where maximum power is limited by smoke. If engine durability and materials compatibility are not significantly affected, then perhaps we can say that, given the incentive to propose alcohol usage by the governments, the present level of performance achieved is acceptable.

Alcohol-powered motorcars (spark-ignition engines), though widely-used in Brazil, are atill being looked upon with doubt by the rest of the world. The effect of alcohol and alcohol combustion on engine parts is still at best,

taken with some reservations. In diesel engines, alcohol combustions produce very high peak pressures and rates of pressure rise. Cylinder strength will in no time be undermined under prolonged use. This is very unfortunate as the combustion chamber is a very important and expensive part. Changing it has to be done along with the cylinder head, and in some cases, also the piston. If the cylinder walls too are affected, then the change may amount to changing the whole engine block!

Better or comparable performance at full load only is another setback for alcohols. Though tractors are quite usually operated in the higher load range, it is still unwise to force them up to the maximum level. Also, the frequency at which they are operated at the lower and medium range loads on the farm is not insignificant. The need for ways of improving alcohol performance at part loads is thus greatly felt. In motorcars and other high speed engines, high load operation is seldom used.

Of the different options anticipated for research, only major engine modification and redesigning have not been tried and would most probably not in the near future. These approaches are going to continue to stay in the background unless and until petroleum fuel supplies have come to a very critical stage. It has been recognized that both, especially redesigning, are a very expensive, time-consuming and difficult approach. But after all the years spent on alcohol fuel research, one could not help wondering if it would have been better or at least helpful if these approaches had been carried out earlier. This remains as a challenge to researchers as to whether the time now is ripe to venture into it. Money would be the biggest stumbling block. Among others, the engine would have to be able to accommodate a longer delay, operate at a higher compression ratio, promote better fuel vapourization and withstand higher temperatures.

Summary and Conclusions

Both the developing and developed countries of the world have to overcome the inevitable limited supplies and high prices of petroleum fuel in the future. Therefore, an alternative fuel for the internal combustion engines is greatly needed. In agriculture, where heavy-duty engines are widely used, the alternative fuel should be able to perform satisfactorily in the compression-ignition system. Whether this fuel can replace or just as an extender of diesel oil, it is desirable that the procedure involved be as simple as possible. If major modification is needed, then it should be worth the engine performance and durability as well as fuel cost. Research using different options will increase the knowledge on alcohol and other alternative fuels. Research in present approaches should be intensified and new ones conducted.

Although extensive studies have been carried out on alcohol fuels, a really satisfactory engine or method has yet to be devised. In this respect, major engine modification could be the next approach. Different parts or systems of the engine could be modified to suit alcohol. It is recognized that this approach is more difficult, time-consuming and expensive. Complete engine redesigning, however, can still remain in the background at this stage.

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ABSTRACTS

The ABSTRACT pages is to introduce the abstracts of the article which cannot be published in whole contents owing to the limited publication space and so many contributions to AMA. The readers who wish to know the contents of the article more in detail are kindly requested to contact the authors. The requests from the readers for publishing the whole contents among the articles introduced here may also be sent to editorial staff. Regarding the article of many requests, the publication of whole contents will be reconsidered.

Effect of Secondary Tillage Practices on Wheat Production: Abdul Razzaq, Senior Subject Matter Specialist (Engg.), Adaptive Research Farm, Sheikhupura, Pakistan.

It is essential to select and use proper implements for the preparation of suitable seedbed in order to provide an ideal environment for the growth of plants. The use of improper implements is a mere wastage of fuel and machine time and harms soil structure which ultimately results in low yield.

In this investigation, comparative performance of three tillage implements, i.e., cultivator, rotary cultivator and disc harrow was studied. It was established that disc harrow was better than other implements in secondary tillage operations as tilling and yield of wheat crop was increased with its use. The economic analysis indicate that the disc harrow was also economically beneficial for seedbed preparation in wheat production.

Status and Future Projections of Agricultural Engineering Manpower in India: B.G. Yadav, Senior Scientist, Central Institute of Agricultural Engineering, Bhopal, India.

In this paper efforts are made to assess the present technical manpower in agricultural engineering in the country and to project the demand for the year 2000. Suggestions are made to meet the technical manpower needs in the country by increasing the in-take capacity in the existing institutions, by adding agricultural engineering faculties in various institutions of higher learning, and providing facilities for agricultural engineering graduates to complete their post-graduate programme in other engineering disciplines.

Optimum Allocation of Land under Different Crops According to Water Requirement: Vilas Salokhe and Sarath Illangantileke, Visiting Faculty Member and Associate Professor, respectively, Agric. and Food Engg. Div., Asian Institute of Technology, Bangkok, Thailand.

An optimum allocation of land under different crops was carried out for a 150 ha command area according to the crop water requirements. A linear programming technique was used to optimize the available water and land resources. The results of the analysis reveal that in order to maximize the benefits from the area, 80.46 ha of wheat, 50.71 ha of gram and 1.48 ha of potato should be grown. Due to this optimum allocation the net benefits from the land area increased in comparison to the present benefits.

Design and Development of a Water Hyacinth Harvester: Pratap Singh, Prof., Dept. of Farm Machinery and Power, College of Technology and Agric. Engg., Udaipur, India; K.N. Nag, Vice-Chanceller, Rajasthn Agriculture Univ., Bikaner, India.

Water hyacinth is an aquatic plant which grows on all types of water bodies like lakes, canals, rivers, etc. The presence of water hyacinth is very harmful for water. It causes oxygen depletion in water and reduces its natural ability to absorb organic pollution. The loss of water due to evapotranspiration from water hyacinth is also very high. Three basic methods of control of water hyacinth are, chemical, biological and mechanical. The safest method to control water hyacinth is mechanical control. A water hyacinth harvester was designed and developed at the College of Technology and Agricultural Engineering, Udaipur, India. The harvester utilized a picker conveyor mechanism for removing the plants from the water. Different sizes of pickers were tested to achieve a high picking efficiency with low energy requirement. A highest picking efficiency of about 98% was achieved with the harvester. Energy requirement for harvesting 100 kg of plants was about 4.2 Wh.

Tractive Performance of Drawbar Power Tiller: N.P.S. Sirohi and J.S. Panwar, Scientist S-2 and Professor, respectively, Div. of Agric. Engg., I.A.R.I., New Delhi, India.

The use of power tillers, even after their existence for over two decades now, has been minimal in India. While no systemic study has been done to evaluate the performance and adequacy of design of these tillers for drawbar operations, it does seem that inadequate tractive capacity is the main reason for this unpopularity of power tillers.

(Continued on page 84)

Development of Agricultural Mechanization in China

Status of Agricultural Mechanization

The area of China's territory totals 9.6 million km^2. The population in China's mainland was to 1 045 million in 1985, among which rural population accounted for 663 million or 63.4% of the total population. The gross output value of agriculture amounted to 458 billion yuan, making up 34.3% of the gross output value of industry and agriculture. The grain per capita averaged 365 kg, and the gross national product per capita averaged 753 yuan. China is one of the developing countries with a large population and backward economy. Agricultural productivity needs to be improved.

China has persistently devoted much attention to the development of agriculture, particularly the means of improving agricultural production. In the 1950s, the stress on development was put on animal-drawn farm implements but at the same the government ran a pilot scheme for agricultural mechanization. In the 1970s, agricultural mechanization in the country forged rapidly ahead. By 1980 farm machinery and electrical power for farm use amounted to 146 million kW, constituting 80% of the total power in rural areas. As China has enough labour in rural areas, and animal force has also been developed steadily, farm machineries are mainly used for increasing agricultural production and enhancing the capabilities to cope with natural disasters, tasks which labour and animal forces find difficult to accomplish as they need high energy consumption and great efficiency, e.g., irrigation and drainage, deep tillage, crop protection, harvesting, etc.

Table 1 Development in Main Farm Power

Item		1970	1975	1980	1985	1986
Rural labour	mil.	281	299.4	313.7	370	NA
Farm working animal	mil.	49.4	51.2	50.9	66.5	NA
Mechanical power in farm in which:	mil.kW	21.7	74.8	146	208	228
Tillage power	mil.kW	4.3	26.4	40	61.5	68.1
Irrigation power	mil.kW	13.4	35.8	54.8	57.5	60.2

Table 2 Mechanization Level of Main Operations

Item	1975	1980	1985	1986
Tractor-ploughing (%)	33.3	42.4	38.9	40.8
T.P. area (mil.ha.)	33.2	42.1	37.3	39.3
Mechanical planting (%)	5.2	10.9	9.4	9.1
M.P. area (mil.ha.)	7.9	15.6	13.6	13.1
Mechanical harvesting (%)	1.5	3.1	3.5	3.4
M.H. area (mil.ha.)	2.3	4.35	5.09	4.9
Mechanical irrigation (%)	52.9	56.6	56	58.9
M.I. area (mil.ha.)	22.8	25.3	24.6	26.1

Prior to 1970, agriculture in China developed on the basis of agricultural cooperatives. Machinery and electrical power for rural use increased rapidly. A large proportion of farm machinery power was used for tillage, irrigation and drainage (**Table 1**).

From 1979 onwards, agriculture in China was carried out on a contract system of responsibility linked to production, hence agricultural production was based on farm households. Agricultural production developed rapidly and the monoculture structure in grain production has charged into diversified economy. Since then, the peasant handled farm machinery on their own independent management. Though farm power in use increased considerably, production scale became smaller hence, small-sized farm machinery became the main necessity. The activities in farm operations greatly increased in limited plots of land. And this has resulted in the decrease of the extent of field mechanization (**Table 2**).

Production and Development of Agricultural Machinery

The varieties and production of agricultural machinery increased according to the needs in China's development of agricultural mechanization. At the beginning of the founding of New China, farm power was mainly introduced from abroad. The agricultural machinery industry began to develop only in the mid-1950s. Since then agricultural machineries have gradually been designed and manufactured indigenously. The agricultural machinery industry had established itself as an industrial system with comparatively rational distribution and complete in category, which produced different sizes of agricultural machineries and implements.

Since 1979 the reforms in the rural economy brought about changes in the need for agricultural machinery, i.e., peasants need more small-sized agricultural machinery; more livestock machinery, farm products processing machinery and transportation machinery, and less crop cultivation machinery. This change has resulted in a situation

where the former agricultural machineries were incapable of adapting themselves to the new needs arising from a new situation. The total output value of agricultural machinery industry in 1980 and 1981 were reduced by a big margin. The output value in 1981 decreased by 28.8% compared with that in 1979. After a readjustment in agricultural machinery product structure and diversification of the agricultural machineries the total output value of agricultural machinery picked up again in 1982. The total output value of agricultural machinery in 1984 exceeded that of 1979 and the total output value in 1985 increased by 46% over that of 1979 (**Table 3**).

By the end of 1986, agricultural machinery manufacturing enterprises in China numbered 2 266, with a total staff workers of 1 164 thousand. The number of agricultural machinery research institutes above the prefecture level totalled 260 employing scientific and technical staff of about 6 000; the number of agricultural machinery and types of implements that can be produced in the country was estimated at 3 100, including 75-120 hp crawlers, 12-65 hp wheeled tractors, 3-15 hp. walking tractors and their attachment, pumps and sprinklers, farm and farm product processing equipment, feed processing and animal raising equipment and transportation vehicles for farm use, etc..

The overwhelming majority, over 98%, of the present agricultural machinery used in agricultural production is now made indigenously.

Table 3 Output of Selected Agricultural Machinery

Item	1980		1986	
	Factory	Output (1 000)	Factory	Output (1 000)
Tractor (>20hp.)	40	97.2	20	32
Small tractor (<20 hp.)	62	217.9	79	747
Tractor-carried tillage implement	110	259	108	49
Power sprayer	11	64	9	32.6
Grain harvesting combine	13	0.8	11	2

Problems of the Agricultural Machinery Industry

The following are the main problems of the agricultural machinery industry in China:

1. *Inadequate Makes or Models* – Some models of agricultural machinery such as large-sized tractors and rice transplanters, and other specific makes/models are not necessarily the needs of small-scale production in China.

2. *Unbalanced Production* – There is currently a surplus capability in the production of medium-sized tractors and their attachments, but in producing small-sized machinery the factories are less benefited due to their small-scale hence, require appropriate readjustment to enable the production of a wider variety of models and raise their production capability.

3. *Low Production Level* – The current models of units manufactured by the farm machinery industry in the country are rather backward in performance and low in reliability. Among the 3 000 or so agricultural machinery products, more than 90% was designed in the 1960s and early 1970s (**Table 4**).

4. *Low Price of Agricultural Machinery* – From 1961 to 1978, the prices of agricultural machinery were reduced 10 times. Since 1978 the price structure hardly charged, while the prices of raw materials and other charges have increased considerably. The withdrawal of state subsidiary has resulted in a low profit or even loss on the part of factories. This condition has adbersely affected the production and development of new farm machinery models (**Table 5**).

Table 4 Analysis of Product Level of Existing Agricultural Machinery

Level	Agricultural machinery (%)	In which tractor (%)
Fairly advanced	2	33
Equal to 60's	90	–
Equal to 50's	8	–

Table 5 Domestic Prices of Selected Agricultural Machineries

Item	Price (yuan*/unit)
Crawler tractor (Dongfanghong-75)	21 400
Wheeled tractor (Shanghai-50)	15 000
Wheeled tractor (25 hp.)	8 700
Small tractor (15 hp.)	4 500
Walking tractor (12 hp.)	2 800
Mounted 4-furrow plough	900
Mounted 16-row drill	1 340
Knapsack sprayer (3 hp.)	400
Combine (model-1075)	98 000

*1$ = 3.72 yuan (RMB).

Tasks and Measures for Development of Agricultural Mechanization

By the year 2 000, the total grain output of China is expected to increase from 400 million mt at present to 500 million mt, reaching 400-kg per capita consumption. At the same time, the income of peasant households is expected to increase greatly. Some 100 million agricultural labour is predicted to transfer from crop planting to the

Table 6 Projected Trends in Mechanization Level of Main Operations

(Percent)

Item	1986	2000
Tractor-ploughing	40.8	60-70
Mechanical planting	9.1	35-40
Mechanical harvesting	3.4	25-30
Mechanical irrigation	58.9	65-75

developing of town and village enterprises and other business ventures. Thus the mechanization in crop planting trade will have to be developed, especially in economically-developed areas, state farms, commodity grain producing areas and where there are favourable factors for developing agricultural mechanization are anticipated to be achieved. Priority for the development of agricultural mechanization will no doubt be given. So the level of field mechanization is expected to be raised on time (**Table 6**). Additionally, 40-45% of the present agricultural machineries in use will be obsolete and will have to be replaced gradually by more advanced types.

The general trend in the requirement of China's agricultural mechanization is as follows:

1) The requirement for small-sized agricultural machinery will continue for years to come, medium-sized tractor requirement is expected to meet soon; and after three and five years the stress on agricultural machinery production will shift to large- and medium-sized units;

2) The development of new agricultural machinery and implements and small-sized tractors and attachments for tractors over 100 hp will continue. Thus agricultural will result in higher output in farm production. The implements will be stalk crusher, combining soil preparation equipment; precision drill; film-laying drill; rice transplanter; and various grain combines.

3) The replacement of the present types with new ones is aimed at improving the agricultural machinery industry in order to achieve an energy-saving, high efficiency and high reliability system.

The measures to accomplish the above-mentioned tasks are:

1) Increase in agricultural input: funding, fuel, etc;

2) Strengthen the development of the agricultural machinery industry by increasing the models and raising product level;

3) Improve operation conditions for machinery; to expand production scale and improve utilization of agricultural machinery;

4) Import small quantity of implements (which can not be made in China) according to projects' needs; and

5) To import production technology on the premise of balance of foreign exchange; to buy products licences from abroad whenever possible.

by Hua Guozhu (Director, Chinese Academy of Agricultural Mechanization Sciences and Vice President, Chinese Society of Agricultural Machinery, No. 1 Beishatan Deshengmenwai, Beijing, China)

New Groundwater Quality Report Released

Amana, Iowa – A major report of engineering implications for groundwater quality has been released by the American Society of Agricultural Engineers (ASAE). The study results from three years of review by leading engineers involved in agricultural water management.

The report, "Engineering Approaches in Solving Groundwater Quality Problems," Looks at the situation today in six areas which affect groundwater: irrigation, nutrients, wells, pesticides, on-site sewage disposal, and organic wastes. According to Richard K. White, a Clemson University agricultural engieer and leader of the study group, corrective actions are suggested for each contaminant situation.

Single copies of the issues briefing are available free of charge from ASAE at 2950 Niles Road, St. Joseph, Michigan 49085. The complete report with full bibliography is available for a small handling charge.

Recommendations on Agricultural Hand Tools Research by the Group Meeting Held at Central Institute of Agricultural Engineering, Bhopal, India, on Sept. 21, 1987

General:

1) Agricultural hand tools should be included in the implement census which is carried out alongwith livestock census.

2) It is necessary to prepare a status document covering research work carried out so far in the country on agricultural hand tools.

3) Information regarding existing designs of hand tools should be compiled and documented. It will be worth-while to collect and keep one piece of each type of hand tool traditional as well as improved at one place. It will help the research workers and manufacturers in their work.

4) It was suggested that starting an All India Coordinated Research Project on Ergonomics will be very helpful in the development of improved hand tools.

5) There is a need to have a co-

operative tie-up of the various institutions involved in research, manufacture and extension to promote the commercialization of improved hand tools.

Research:

1) Agricultural hand tools may have some variations due to prevailing functional use and varying anthropometric characteristics from region to region. Therefore, necessary improvement, if feasible, may be made in the existing hand tools and new hand tools for specific/multiple functions may be developed. To increase the work output, manually-operated equipment may also be developed which should be ergonomically better and functionally more efficient.

2) While designing the hand tools use of principles of soil dynamics and force analysis must be made. The blade design of soil working hand tools should be based on soil dynamic studies. It is also necessary to specify the sharpness of blade and hardness required in various soil working tools.

3) It is necessary to base the design of handle, i.e., shape, size and cross section on anthropometric considerations. Therefore, anthropometric data of farm workers needs to be collected and data bank be maintained at one place.

4) In selection of material for handles, mechanical as well as ergonomic aspects should be considered.

5) Tool-handle joint is very important in the performance of a tool. The joint should be firm. 'D' shaped eyes for fixing handles for some equipment like spade have given good results. Therefore trials may be carried out on these aspects to finalize the recommendations for large scale adoption.

6) Ergonomical studies on different modes of operations may be carried out. This information will be useful for designing of hand tools.

7) While reporting the test data of hand tools and manually-operated equipment, alongwith tool performance, i.e., work done/hour, data regarding operator-tool performance, i.e., work done per day should also be reported. This data should be based on day long tests.

8) Improved hand tools may be compared with traditional ones at different centres and efforts should be made for popularization of promising ones.

9) Traumatic injuries are on increase due to the use of improper design of hand tools, therefore, it is very necessary to give due consideration to various ergonomic aspects in design and testing of hand tools and manually operated equipment.

10) There is a need to introduce metallurgical improvement in most of the hand tools being marketed in India.

11) It was suggested to develop a improved sugarcane harvesting knife combining good design features of the existing knives and using proper material.

12) There is a need to carry out ergonomic studies on manually operated sprayers and dusters.

13) At present there is hardly any work being carried out on horticultural tools. Therefore, it is necessary to evaluate the existing tools for their performance and to develop manufacturing technology for production of quality hand tools. There is also a need to design and develop tools for operation which are at present being done by hand.

Standardization:

1) It is necessary to have a standard method for testing of hand tools and manually-operated equipment.

2) There is a need to develop ISI standards for various hand tools so as to maintain the quality.

3) The ISI standards available on some hand tools are more than 10 years old and need to be reviewed by a panel of experts for suggesting modifications in material, handle design, tool design and other aspects.

Manufacturing and Popularization:

1) It is necessary to have centralized manufacturing of hand tools so as to maintain quality and to reduce cost.

2) State Agro-Industrial Development Corporation should take up industrial design aspects. Once the prototype is finalized by research organizations, the corporations may tailor the product for commercial manufacturing. While doing this care should be taken to see that the critical dimensions and aspects are maintained.

3) Village artisans must be involved in manufacture, Sales, service and custom hiring of improved agricultural hand tools and equipment. The quality of equipment manufactured by them can be improved through upgrading of their fabrication techniques.

4) Each tool and equipment should have a operator's manual mentioning about various critical adjustments, operation, procedure and trouble shooting.

5) To encourage the manufacturers for production of quality hand tools, it is necessary to have assured demand. Central and State Governments and Agro-Industries should join hands in extension work for popularization of improved agricultural hand tools so that an assured demand is created.

6) It is necessary to start pilot projects for finding ways to reduce cost of production of hand tools.

7) Cheap and quick testing facilities should be made available to hand tool manufacturers to enable them to maintain quality of their

products.

Graeme R. Quick Named Head of IRRI Agricultural Engineering Department in August 1988

Dr. Quick, 52, has worked as a professonal engineer in industry, teaching, consulting, and governmental agencies. He has 10 years experience as an engineer outside his native Australia. Dr. Quick has authored more than 70 publications, including the book *The Grain Harvesters* He has edited the journal *Agricultural Engineering Australia* for 10 years. Quick holds patents on products manufactured by several companies. Prior to joining IRRI he was Director of Agricultural Engineering for the Department of Agriculture in NSW, Australia.

International Society for Terrain Vehichle Systems
2nd Asia-Pacific Conference
December 6-10, 1988 at Asian Institute of Technology Bangkok, Thailand

This conference is sponsored by AIT and the Japanese Society for Terramechanics. The primary objective of the 2nd Asia-Pacific Conference is to provide opportunities for engineers and others active in terramechanics to exchange their experiences, ideas and to promote advancement of terramechanics.

Conference theme: Agricultural, military and civil engineering aspects of offroad vehicles with particular reference to the Asia-Pacific region. The major topics covered will be, measurement of soil properties, agricultural operation in dryland conditions including tillage, agricultural operation in wetland conditions including tillage, military applications, construction applications, soil compaction, steering, vehicle and component design and ride dynamics.

Registration: The registration fee is inclusive of conference fee, cost of conference materials, city tour, attendance to social functions, official reception and a copy of conference proceedings. Registration fees are as follows:

Delegate/Participant US$230
Accompanying Person US$120

Correspondence: All correspondence relating to the conference should be addressed to

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A Short Course in Agricultural Machinery and Management
January – March, 1989 at Division of Agricultural and Food Engineering, Asian Institute of Technology Bangkok, Thailand

Details of the Short Course: To cope with the ever increasing food demand of a continuously increasing population in Asia, food supply has to be doubled in Asian countries by the year 2000. This is possible either by increasing crop yields or by increasing cropping intensity as with very few exceptions, no more opening up of new land is possible. To cultivate more than one crop a year, the farm operations have to be speeded up and carried out in time, which is only possible by the use of farm machines. Thus in the near future farm machines are going to play a very important role. It is therefore essential to have a broad knowledge of the functional requirements and principles of operation of field machines, machinery selection and management. With this view in mind a short course of about 12 weeks duration in agricultural machinery and management will be held from January to March 1989.

Admission: Any person holding a bachelor's degree from an institution of recognized standing is eligible for admission. He should possess an acceptable level of English proficiency.

The closing date for receipt of applications for admission for this short course is 15 October 1988.

The fee for tuition is US$2 700. The total cost of accommodation is US$150. Subsistence is at the student's own expense at an estimated minimum of US$130 per month. Air fare is to be paid by the student.

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International Society for Horticultural Science
Symposium on Bedding and Pot Plant Culture
April 29 – May 4, 1989 at Michigan State University, East Lansing, Michigan, U.S.A.

Objectives: The objective is to

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The following topics will be covered:

- Breeding and Propagation
- Growth Media, Nutrition and Irrigation
- Marketing, Mechanization, Containers and Transport
- Environmental and Chemical Control of Growth and Development
- Post-Harvest Physiology

Contributed oral papers or posters are invited on these topics. The time limit for each paper will be 20 minutes including time for discussion.

Language: The official language of the symposium will be English.

Scientific program: The program will consist of contributed papers and posters. Both are regarded equally and may refer to any of the main topics listed.

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Dealer Association Adopts New Name

The National Farm & Power Equipment Dealers Association (NFPEDA) has officially changed its name to the North American Equipment Dealers Association (NAEDA).

At a vote taken during the group's annual convention in Vancouver, August 9, the decision was made to change the organization's name, to reflect and identify the new and diverse needs of the association's membership.

During the past two years, the association has formed two new equipment divisions–Industrial and Outdoor Power. These divisions were established as a direct result of the organization's changing dealer base.

More and more, dealers throughout North America are becoming involved in light industrial and outdoor power equipment sales and service, as urban expansion has crept into once predominant agricultural regions. This, coupled with ever-increasing numbers of pure outdoor power and industrial dealers joining the association, led to the need for a name change.

In changing its name, NAEDA wishes to emphasize it is not altering its direction in any way for current agricultural members. All stationery and printed materials will clearly state that it is an organization "Serving Farm, Industrial and Outdoor Power Dealers." The new name merely incorporates all these groups into one solid, and clearly identifiable association of dealers.

Address: 10877 Watson Road,
St. Louis, Missouri 63127,
U.S.A. ■■

(Continued from page 78)

ABSTRACTS

A typical drawbar power tiller was tested under different field conditions for tractive performance. The parameters of performance were evaluated to assess the potential of the power tiller as an effective and efficient alternative to two pairs of bullocks on Indian farms. The chassis weight and tyre size of the tiller were the controlling parameters of design, severely limiting the availability of engine power at the drawbar. Increase in weight caused better output of pull and drawbar horsepower. However, ballasting beyond a limit necessitated changes in chassis design for proper dynamic balancing.

Effect of Rainfall on Water Table at Balarampur, near Kharagpur, West Bengal: K.K. Mishra, Junior Scientist, R.A.K. College of Agriculture, Sehore, India; Satyanarayana, Prof. and Head, Dept. of Agric. Engg., I.I.T., Kharagpur, India.

The study was conducted at the Agricultural Engineering Department of the Indian Institute of Technology in Kharagpur to understand the influence of rainfall on water table behaviour of open wells. The analysis of the data of a sample well indicates that the water table does not rise suddenly in the beginning of the rainy season but the entire rainfall satisfies the soil moisture pores prior to bringing any change in the water table. Once the soil moisture is satisfied, the water table rises quite rapidly up to the peak but with the varying rates. The amplitude of water table decreases with the increase in the total cumulative rainfall. ■■

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BACK ISSUES

(Vol. 18 No. 1, Winter 1987~)

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 18, No. 1, Winter, 1987)

Editorial (Y. Kishida) 9
Study on Basic Knowledge of Plowing Science for Asian Lowland (Paddy Field) Farming (J. Sakai, Phongsupasamit, T. Kishimoto) . . 11
Preparation of Medium-Textured Soil for Rice Production (A. Razzaq) . . 19
Effect of Field Dimensions on Energy and Labour Consumption for Rotary Cultivating Small-Sized Plots (Md. W. Ullah, S. Kofoed) 22
Flat and Broadbed-and-Furrow Systems of Cultivation (H. Lal) 27
Energy Consumption in Rice Processing Operations in Nigeria: Selected Case Studies (G.O.I. Ezeike) 33
Stabilization of Rice Bran by conduction Heating in a Continuous Rice Bran Stabilizer (A. Chakraverty, D.S.K. Devadattam) 41
Some Physical Properties of Wheat and Paddy and their Relationships (Md. N. Islam, T.T. Pedrsen) 45
Relationship of Grain Shape and Mass to Tensile Strength of Rice (M.S.U. Choudhury) 51
Development and Field Evaluation of a Stubble Collector-Cum-Planker (N.K. Bansal, D.N. Sharma, M.L. Jain) 57
Low-Cost Peat Production and Gasification (M.E. Herbst) 60
Integrated Regional System of Thermal Utilization of Biomass Resources (H. Shimizu, T. Kimura, R. Pairintra) 65
Sugarcane Trash Management in India (A.C. Srivastava, R.D. Singh) 72
Delivery System for Farm Machinery Technology in India (G. Singh, T.P. Ojha) 75
News 83
New Products 85

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 18, No. 2, Spring, 1987)

Editorial (Y. Kishida) 9
Studies on Basic Knowledge of Plowing Science for Asian Lowland-Paddy Farming (J. Sakai, S. Phongsupasamit, T. Kishimoto) 11
Case Studies on Tractor Utilization for Two Farming Districts in Northern India (G. Singh, R.K. Tandon) 18
Effect of Vegetative Cover, Tillage and Planting System on Run-off, Soil Erosion and other Soil Physical Properties (F. Abiyo) 23
Harvesting of Acala Cotton by Machines in Rahad Scheme in the Sudan (M.H. Ahmed, B.D. Bilal, S.A. Mohamed, E.A. Simsaa) 29
Development and Evaluation of Wide-Swath, Tractor-Mounted Sprayer for Cotton Crop (L.N. Shukla, N.S. Sandhar, S. Singh, J. Singh) . . 33
Comparative Performance of Rasp-Bar and Wire-Loop Cylinders for Threshing Rice Crop (J.G. Sarwar, A.U. Khan) 37
Rice Drying, Husking and Milling (S.J. Omar, R. Yamashita) 43
Problems in Storing and Processing High-Moisture Paddy (S.A. Raj, K. Singaravadivel) 47
A Study of Mechanism for Measuring Draft of Single-Bullock Cart (D.N. Sharma, S.P. Agarwal, M.L. Jain) . . 50
Development of a Rice Parboiling Machine (A.A. Obobi, U.G.N. Anazodo) 53
Cardamom Processing in South India (R.T. Patil) 55
Ginger Peeling Machine Parameters (Y.C. Agrawal, A. Hiran, A.S. Galundia) 59
Design and Development of a High-Capacity Chopper for Water Hyacinth (M. Alam, D. Gee-Clough) . . 63
Design of FMI Sugarcane Planter (M. Khalid) 67
Mechanization of Sugarcane Farming at Komenda, Ghana (R.J. Bani) . . . 69
Methods of Determining Heat Potentials of Agricultural Biomass (K. Kumar, S. Bal, T.P. Ojha) 71
A Comparative Study on the Effects of Four Drying Methods on Germination of Paddy (Md. A.K. Milah, Md. A. Quasem, K.A. Haq) 74
Application of Network Approach in Agro-Industry in Pakistan (A.P. Chaudhary, M.A. Sargana, S.I. Ahmad) 77
Abstracts 62
News 83
New Products 85

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 18, No. 3, Summer, 1987)

Editorial (Y. Kishida) 9
Engineering Design Theories of Hand-Tractor Plows (J. Sakai, S. Phongsupasamit, T. Kishimoto) 11
Development of Improved Agricultural Implements at ICRISAT (N.K. Awadhwal, T. Takenaga, R.K. Bansal) 21
A Study on Field Performance of Small Tractors (D. Erdoğan) 26
Factors Affecting Repair and Maintenance Costs of Farm Tractors (S. Bukhari, J.M. Baloch, A.N. Merani) 29
Feasibility Study on Animal-Drawan Tool Carrier for Selected Crop Rotations (S. Singh, S. Singh, V.K. Sharma, P.K. Gupta) 33
Implications of Tractorization on Employment, Productivity and Income in an Irrigated Area of Ahmednagar District, India (A.S. Patil, A.S. Sirohi) 36
Lining Irrigation Canals with Asphaltic Materials in Bangladesh (A. Khair, S.C. Dutta) 41
Effect of Irrigation Methods on Silage Yield of Corn (I.B. Koondhar, B.A. Chandio, B.T. Devrajani) 46
Monitoring Corn Canopy and Root by Precision Planting: A Challenge on Planter Design (R.C. Yadav, U.S. Gupta) 49
Drainage Problems in Al Hasa, Saudi Arabia (A.H. Abdoun) 51
Rice Drying, Husking and Milling (S.J. Omar, R. Yamashita) 53
Development of an Axial-Flow Thresher with Multi-Crop Potential (O.P. Singhal, G.E. Thierstein) . . . 57
Development of a Bulk-Milk Vending Machine (D.V.K. Samuel, S.A.D. Prasad) 66
Bullock-Operated Dung-Cleaner (H.C. Joshi, D.N. Jana, D. Chaudhuri, A.E. Nivsarkar) 69
A Low Cost Village-Level Milk Sterilizer (S.L. Srivastava, N.G. Bhole) 71
Farm Machinery Utilization Planning (T. Konaka) 75
Abstracts 81
News 82
New Products 83
Book Review 84

◇ ◇ ◇

ARICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 18, No. 4, Autumn, 1987)

Editorial (Yoshisuke Kishida) 9
Iron Wheels for Plowing (J. Sakai, S. Phongsupasamit, T. Kishimoto) . 11
Performance Study of a Two-Wheel Tractor (Md. W. Ullah, S. S. Kofoed) 19
A New Intrac (Tractor) Generation (A. Gego, L. Fritz) 23
Specific Pull for Plowing with Different Tool Bars/Carrier over Various Moisture Regimes (H. Lal) 31
Preparation of Fine Textured Soil for Rice Production (A. Razzaq) 36
The Heat Transfer Coefficient in Grain Beds (M.H.K. Khandker, J.L. Woods) 39
Experimental Co-efficients of Power Tiller Blades (J. Md. Baloch, S.B. Bukhari, A.Q.A. Mughal, I.B. Koondhar) 45
Stochastic Design of Optimal Wind Pump Irrigation System (R.K. Panda, T.K. Sarkar, K.V. Sathe) 49
Agriculture in Haiti: With Emphasis on Irrigation (M.R. Goyal, P. Bellesive) 54
An Animal-Drawn Iron Plough as an Alternative to the Indigenous Plough (A. Tajuddin, R. Karunanithi) 57
Grain Losses at Harvesting and Threshing of Paddy in Turkey (Y. Pinar) 61
Rice Drying, Husking and Milling (S.J. Omar, R. Yamashita) 65
Fuel and Agricultural Energy Galance in Haryana, India (A.R. Rao, R.S.R. Gupta, A.P. Sharma) 69
Appropriate Technology for Nigerian Cattle Industry (K.C. Oni) 71
Effect of Weeder Design on Operating Force (V.J.F. Kumar) 75
Abstracts 38
News 80
New Products 84
Book Review 85

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA, AND LATIN AMERICA (Vol. 19, No. 1, Winter, 1988)
Editorial (Y. Kishida) 7
Farm Mechanization in West Java, Indonesia (G. Singh, H. Siswasumarto) 9
Cost of Operating Tractors on Quetta Farms, Pakistan (S.B. Bukhari, J. M. Baloch, S.H. Naqvi) 14
Mechanical Transplanting of Rice in Pakistan (A.S. Khan, W.W. Gunkel) 21
Design and Development of a 6-Row Korean Transplanter (A.S. Khan, W.W. Gunkel) 27
Field Performance of Seeding Devices in Rainfed Situation in Orissa, India (P.C. Senapati, P.K. Mohapatra, D. Satpathy) 35
The AMRI Sugarcane Planter (M. Yasin, C.A. Salam, M.A. Farooq) . . 39
Mechanization of Sugarcane Ratoon Culture in India (M.P. Sharma, K. Singh) 45
Supplemental Mechanical Weed Control for Maize-Cowpea Rotation in Mucuna Mulch (E.A. Baryeh) . . . 48
Effects of Electrostatic Charging and Vertical Air Current on Deposition of Pesticide on Cotton Plant Canopy (Y. Zeren, E. Moser) 55
Disign and Construction of a Simple Rice Parboiling Hardware for Use in Nigeria (O. Oje) 61
Operational Safety Requirements for Farm Machinery: A Case Study in Pakistan (A.I. Mufti, S.I. Ahmad, I.S. Ahmad, A.P. Chaudhary) 64
Agricultural Mechanization in Orissa, India (S.K. Dash, S.C. Pradhan) . . . 69
Field Reliability of Farm Machinery (A.P. Chaudhary, S.I. Ahmad) 73
Abstracts 44
News 79
Book Review 81

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 19, No. 2, Spring, 1988)
Editorial (Y. Kishida) 7
A Study on Engineering Design Theories of Hand-Tractor Plows II (S. Phongsupasamit, J. Sakai, T. Kishimoto) 9
Use of Conical Rotors for Multi-purpose Wetland Farming Machines (A.U. Khan, M. Diestro, R. Bautista, E. Calilung, A. Vasallo) 20
Comparative Tractive Performance of Three Tractors (J.G. Shebi, K.C. Oni, F.G. Braide) 25
Comparison of Zero-Tillage and Conventional Tillage in Wheat and Maize Production under Different Soils and Climatic Conditions in Nigeria (P.R. Maurya) 30
Working with Bangkok Clay Soil— Some Experiences (V.M. Salokhe, D. Gee-Clough) 33
Development and Fabrication Techniques of Improved Grubber (G. Singh) 42
A Small Scale, Non-Destructive Tropical Grass Seed Harvester (R.T. Peterson, I. Romero, D.B. Tinker) 47
Handling and Transportation of Vegetables in Ghana (E. Kra, R.J. Bani) 52
Using Agro-Processing Equipment in Enhancing Rural Industrialization in India-Case Studies (R.P. Kachru, P.K. Srivastava, S.D. Deshpande, T.P. Ojha) 55
Small Farmer Mechanization in Chile (E.J. Hetz) 63
Status of Farm Mechanization in Iraq (L.M. Ali, A.M. Al-Khafaf) . . 69
A Successful Model for Introducing Agricultural Machinery (P. Datt, T.P. Ojha) 74
Standardization Efforts in Agricultural Engineering (R.N. Sharma) 77
Abstracts 54
News 82
New Products 83
Book Review 85

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 19, No. 3, Summer, 1988)
Editorial (Y. Kishida) 7
Modeling Flow of Irrigation Water Discharge Uniformity in Microtube Emitters (M. Gueye, J. Yonemura, A. Sasao, A.R. Shajary) 9
Power Requirements of Different Cropping Systems in Bangladesh (M.A. Hossain) 15
Computer Programme for Selecting Farm Machinery for Small Farms (H.O. Laurel) 20
Design of Extended Octagonal Ring Dynamometer for Rotary Tillage Studies (T.C. Thakur, R.J. Godwin) 23
Wet and Dry Tillage Practices in Paddy Production (A. Majid, S.I. Ahmad, M. Farooq, A.I. Mufti 29
A Compression Ignition Engine on Biogas-Diesel Fuel (T.K. Bhattacharya, B. Singh, T.N. Mishra) 32
A New Multi-crop Inverted-T Seeder for Upland Crop Establishment (M.A. Choudhary) 37
Optimum Sprout Length for Sowing Pre-Germinated Paddy Seed in Puddled Soil (A.P. Srivastava, J.S. Panwar) 43
Performance Evaluation of Mechanical Reapers in Pakistan (G. Singh, A.P. Chaudhary, D. Gee-Clough) . . 47
Cost of Using Power Reapers: Malaysian Experience (K. Aribi, I.Y. Md. Salleh) 53
Threshing Efficiency of Pulses Using Step-wise Regression Technique (S.K. Tandon, B.S. Sirohi, P.B.S. Sarma) 55
Storage of Farm Products in Rural Papua New Guinea (S.N. Misae) 58
Husk Utilized as Fuel (B.S. Pathak, A. Singh) 65
Improved Equipment for Castor Bean Crop Cultivation (A.C. Varshney) 71
Run-off Farming in Ghana: A Mathematical Approach (S.K. Agodzo) 75
Effect of Restrained and Un-Restrained Linkage on Implement Performance (J.M. Baloch, A.N. Mirani, S. Bukhari) 77
Abstracts 82
News 83
Book Review 85

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 19, No. 4, Autumn, 1988)
Editorial (Y. Kishida) 7
Performance of Selected Tillage Implements (S. Bukhari, M.A. Bhutto, J.M. Baloch, A.B. Bhutto, A.N. Mirani) 9
Effects of Load and Speed on Performance of Clod Crushers (T.C. Thakur, B.P. Varshney, A. Yadav, P. Chand) 15
Development and Testing of Bullock-drawn Land Scraper and Land Grader (S.C. Pradhan, S.K. Dash, H. Raheman) 21
An Animal-drawn Mechanical Ridge Tier for the Cereal Farming Systems of Burkina Faso (J.G. Nagy, H.W. Ohm, L.L. Ames, L.D. Schaber) 25
The Tir Seeding Method and Tir Drills: A Literature Review (M. Yilmaz, N. Yilmaz) 31
Laboratory Studies on Spray Distribution Pattern of the Wide-swath Spray Boom (H.S. Bisen, N.S.L. Srivastava) 34
Comparative Use of Self-propelled and Tractor-drawn Combines (A. Razzaq, C.B. Ahmad, C.B. Ahmad Sabir) 39
Testing and Evaluation of Improved Yaatra Ox-cart (S.D. Deshpande, T.P. Ojha) 44
Modern Food Grain Silos in Bangladesh (J.N. Samaipati, T.T. Pedersen) 49
Possibilities of Mechanizing Paddy Production in Kenya (S. Furuichi, D.K. Some) 53
Potentials for Computer-aided Farm Machinery Decisions in Pakistan (M.A. Choudhary, S.W. Brown) . . 58
Cotton Cultivation in Haryana State, India (V.P. Bahl, D.N. Sharma, M.L. Jain) 63
Performance of Oil Milling Technologies in India (B.S. Pathak, A. Singh, R.N. Verma) 68
A Wood Chip-fired Residential Boiler (K. Jusoff) 73
Alcohol as Tractor Fuel— Is There Any Future? (R. Janius) 75
Abstracts 78
News 79

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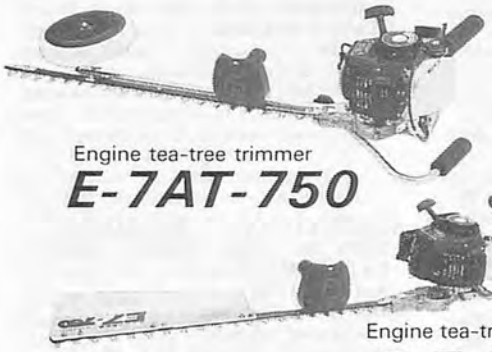


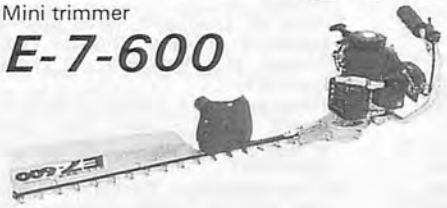
Engine tea-tree trimmer
E-7AT-750

Clipper type tea-leaf picker V8-NEWZ2

type	Clipper type tea-leaf picker V8-NEWZ2				
picking width	850mm	1,000mm	1,070mm	1,140mm	1,210mm
weight	11.4kg	11.95kg	12.15kg	12.35kg	12.6kg
engine	41.5cc(3.2PS)				

Engine tea-tree trimmer
E-7-750

Mini trimmer
E-7-600



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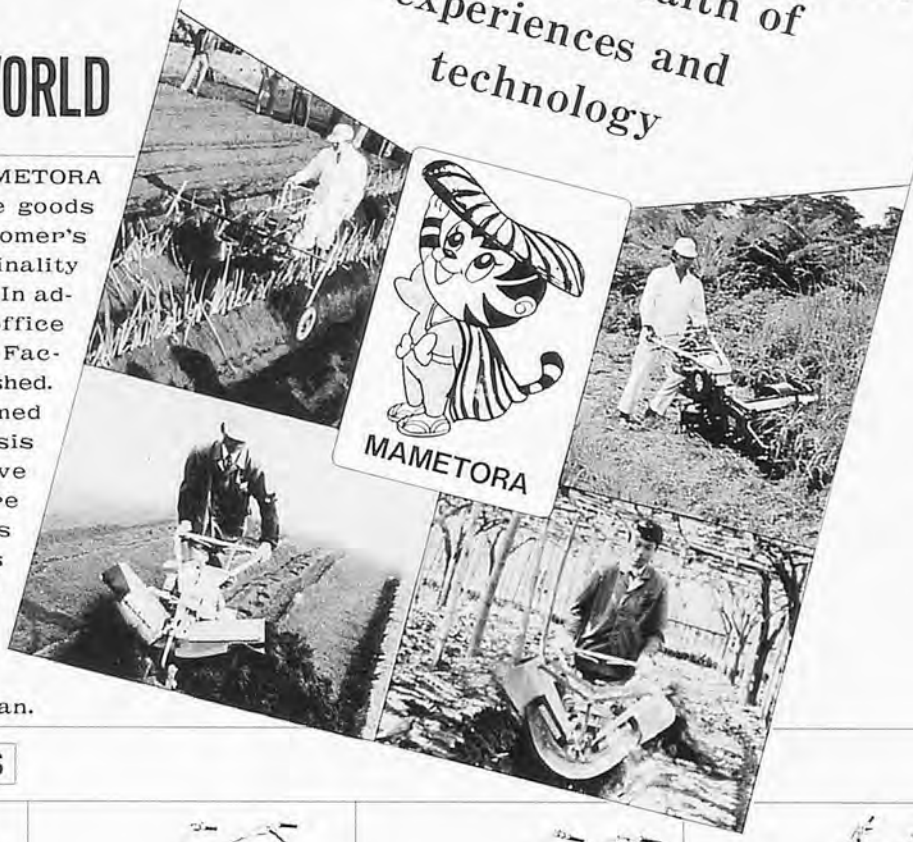

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