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EDITORIAL

Land Productivity

After entering in the 21st century, the argument especially involving Iraq and Palestine with the unstable world and confusion are likely to continue for the time being.

A nature is also becoming unstable not only like a social phenomenon but like climate of Japan.

It continues without only population's continuing increasing steadily in it, and environmental destruction by human activities also loosening the pitch.

The most important thing is raising land productivity and resources productivity with the agricultural technology searched for in the 21st century.

In order to raise these productivity, progress of agricultural mechanization is indispensable to search for quicker and timely agricultural work and to enable it to perform it.

Also in an advanced nation, it is required also in a developing country to raise land productivity according to more exact agricultural work.

A keyword called environment has affected agricultural mechanization.

Although eco-friendly agricultural technology and mechanization technology are searched for, the required technology is technology which raises the land productivity mentioned above.

It does not swerve, and it cannot carry out and human beings cannot get food sufficient on the earth for the 21st century. There is still room in improvement in productivity, and expectation has started efforts of us and the agricultural machinery persons concerned.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
August 2004

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On-farm Evaluation of Current Wheat Tillage Systems on Irrigated Vertisols in New Halfa Scheme, Sudan

by
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Abstract

Farmers in the irrigated area of Sudan are of the opinion that deep ploughing increases wheat yield, and there is a high demand for introduction of heavy tillage tools for crop establishment. Therefore, the current tillage systems in farmers' fields were evaluated in 1992/93 to 1994/95 seasons through surveying and experimental work to reflect the trend and adoption level by farmers and to compare their effect on wheat yield, seedbed conditions and operational cost.

Three categories of tillage types, which were shallow ridging systems of 15cm depth, shallow harrowing with 15cm depth and deep tillage systems (harrowing and disc ploughing) of 20cm ploughing depth were identified from 10 tillage systems that practiced by the farmers over the three seasons of the study. These were combination of ridging, harrowing, disc ploughing and leveling.

Results indicated an increase in adoption level of shallow ridging systems with the lower cost of 6 and 9 US\$ ha^{-1}, with sharing percent of 18, 83 and 76% of wheat cultivated area in 1992/93, 1993/94 and 1994/95 seasons respectively. While the sharing of shallow harrowing systems was 31, 17 and 20% for the respective seasons, and their operational cost ranged from 5 to 16 US\$ ha^{-1}. But there was a decrease in deep tillage systems sharing percent from 51% in 1992/93 season to only 4% in 1994/95 season and their operational cost ranged from 18 to 22 US\$ ha^{-1}. The results of the experimental work in 1994/95 season, before the first irrigation of wheat crop, indicated no significant differences in soil aggregate size distribution percent for >3cm and <1cm. They were amounted to less than 7.4 and more than 71.3%, respectively. Also, there was no significant difference in soil bulk density for 10 – 20cm depths before the second irrigation with all tillage systems.

No differences in wheat yields for each of the three seasons, which indicated the suitable and favorable wheat seedbed with all tillage systems. Therefore, the more economic shallow tillage system could be used for wheat production in the New Halfa Vertisols.

Acknowledgement

Thanks are due to the soil scientist Dr. Ibrahim, B.A. and his staff for preparation of soil samples before the second irrigation of wheat.

Introduction

Wheat (*Triticum aestivum* L.) is a strategic commodity in the Sudan. It is exclusively produced under irrigation. Traditionally, wheat has been produced on small areas along the Nile in the north of Sudan, using animal-drawn implements and hand tools. For national self-sufficiency, wheat production has been introduced in central clay plain in irrigated governmental schemes of Gezira (168 000 ha), New Halfa (25 200 ha) and Rahad (18 900 ha). More than 80% of the national production comes from Vertisols of Gezira and New Halfa schemes (Dawelbeit and Babiker, 1997). It is grown in the winter season during the period November to March. The winter season is shorter and warmer than the traditional wheat producing areas in the world, and has frequent hot spells.

The New Halfa scheme was established for the settlement of people who transferred from the Halfa area in the north part of Sudan to mitigate the stored water flooding of the Aswan Dam in Egypt. Wheat is their main diet. Therefore, the scheme administrators have placed more emphasis on wheat production. The climate is semi-arid. The range of maximum and minimum daily air temperatures during the growing season (November-March) is 45 – 35°C and 10 – 21°C, respectively, while the range of maximum and minimum relative humidity is 100 – 40% and 18 – 51%, respectively. Only wheat varieties with high rust resistance are grown in the New Halfa scheme. The crop is fully mechanized. Combine harvesting starts in the last week of March.

On Vertisols in Rahad, higher grain yields of wheat were obtained by using the disc harrow than the disc plough, and ridging after seed broadcasting resulted in significantly greater yields than broadcasting alone (Dawelbeit and Babiker, 1997). Although heavy machines for deep tillage operation are not available in the scheme, farmers are demanding for the introduction of heavy tillage tools. They are of the opinion that deep ploughing increases wheat yield. Moreover, there is lack of information between the seedbed properties of different tillage systems and wheat yield. This necessitated an evaluation of the current tillage systems in farmers' fields.

The objectives of the study were:

Table 1. Average physical properties of soil at the New Halfa scheme, Sudan

Item	Weight
Coarse sand (g kg^{-1})	63
Fine sand (g kg^{-1})	63
Silt (g kg^{-1})	327
Clay (g kg^{-1})	547
pH paste	8.6
Organic C (g kg^{-1})	6.1

To identify and compare the different tillage systems practiced by the farmers for the reflection of the development trend and the adoption level, and

To compare and evaluate the effect of tillage system on wheat yields, seedbed properties and cost in Vertisols of the New Halfa scheme.

Materials and Methods

1. Experimental Location and Soil Properties:

The study was carried out for three seasons in 1992/93 to 1994/95 in the New Halfa scheme, which is between latitudes 15° 05_ S (approx.) and 15° 30_ N. The River Atbara forms the eastern boundary. According to US Soil Taxonomy, the soil of the scheme is Sodic Haplusterts, Very fine, Smectitic and Isohyperthemic. The average physical properties of the soil to a depth of 0 – 25cm are shown in **Table 1** (Dahab and Ali, 2000).

2. Surveys of Tillage Systems _

The surveying for identification of wheat tillage systems in farmers' fields with the use of available tillage tools in the scheme was carried out covering all the annual wheat cultivated area, which is of about 25 200 ha. The collected data included different tillage system operations, sharing percentage of each tillage system, cost and wheat yields.

All the executed tillage systems by farmers during the three seasons and their types are described in **Table 2. Table 3** shows tillage operational cost ha^{-1} according to the New Halfa price list for 1994/95 season. In this study, the primary tillage operation with 15cm average ploughing depth was considered as a shallow tillage system, while that with 20cm ploughing depth was described as a deep tillage one.

In the first two seasons (1992/93 and 1993/94) the following tillage systems were compared:

First season (1991/92): Shallow ridging (R_1 and R_2), shallow harrowing (H_1) and deep harrowing (H_5 and H_6).

Second season (1992/93): Shallow ridging (R_1, R_2 and R_3), shallow harrowing (H_2 and H_3).

Experimental Work on Tillage Systems

In the third season (1994/95), in addition to wheat tillage survey, a site in the Fourth Block in the scheme was chosen for evaluating

Table 2. Characteristics of Wheat Tillage Systems and Primary Ploughing Depths *

Tillage type	Tillage system	Characteristics
Shallow ridging	R_1	Ridging to 15 cm depth + wide level disc harrowing.
	R_2	Ridging to 15 cm depth + split ridging + wide level disc harrowing.
	R_3	Ridging to 15 cm depth + harrowing + leveling.
Shallow harrowing	H_1	Only harrowing to 15cm depth with offset disc harrow of 250cm width of cut.
	H_2	Only harrowing to 15cm depth with offset disc harrow of 660cm width of cut.
	H_3	Harrowing to 15 cm depth with offset disc harrow of 250cm width of cut + wide level disc harrowing.
	H_4	Harrowing to 15 cm depth with offset disc harrow of 660cm width of cut + ridging + wide level disc harrowing.
Deep harrowing	H_5	Harrowing to 20 cm depth with offset disc harrow of 360cm width of cut + leveling.
	H_6	Harrowing to 20 cm depth with offset disc harrow of 360cm width of cut + harrowing.
Deep ploughing	D	Disc ploughing to 20 cm depth + harrowing + ridging + wide level disc harrowing.

* Practiced by farmers in the new Halfa Scheme during the three-season study in 1992/96, 1993/94 and 1994/95 seasons

Table 3. Cost ha-1 for Tillage Operation *

Tillage operation	Cost (US$ ha^{-1})
Ridging.	3
Split ridging.	3
Primary harrowing with offset disc harrow of 250cm width of cut.	5
Secondary harrowing with offset disc harrow of 250cm width of cut.	4
Leveling.	2
Wide level disc harrowing.	3
Primary harrowing with offset disc harrow of 660-cm width of cut.	10
Deep harrowing.	18
Disc ploughing.	9

* New Halfa Scheme (1994 / 95 season).

of the used tillage systems that covered the three categories of tillage types. These were shallow ridging (R_2 and R_3), shallow harrowing (H_4) and deep ploughing (D) as shown in **Table 2**.

The experimental work was undertaken to confirm the obtained results of the previous two seasons of wheat yields. Also, to asses the effects of tillage systems on seedbed properties such as soil particles size distribution and soil bulk density at depths of 0 – 10 and 10 – 20cm with the corresponding soil moisture content.

The experiment was a randomized complete block design with four replications. Plot size of tillage treatment was 75 x 280m, which is the area of the farmer's field (2.1 ha). The experiment was a farmer-managed trial.

The primary deep ploughing operation of discing in system D was carried in the summer months (May and June) with an average ploughing depth of 20 cm. On the other hand, the primary tillage operations of shallow ridging (R_2 and R_3) and shallow harrowing (H_4) were performed in September at an average depth of 15cm. Secondary operations in all tillage systems were done in October.

All tillage system treatments were pre-watered after ridging and before the first harrowing operation, a traditional method for stimulating weed growth that can be eradicated by subsequent harrowing, which also created a favorable tilth for the wheat seed. A wide level disc harrow equipped with a seeder box was used for sowing. It is the only device for sowing wheat in the New Halfa scheme, in addition to its harrowing effects. The wheat crop in all treatments was sown in the last week of November with a seed rate of 143kg ha^{-1}. After crop sowing, a four-body ridger was used again to set up ridges 80 cm apart at 15cm high in all plots to facilitate irrigation, to mitigate water logging with heavy clay soils and for allowing the growth of wheat plants on top of the ridges. This is the traditional method for wheat crop establishment under surface irrigation system. The crop was given six irrigations at intervals of two weeks. Water was applied just below the surface of the top of the ridges. Each irrigation equals about $1000m^3$ ha^{-1}. Before the second irrigation, nitrogen at the rate of 143kg N ha^{-1}, was applied.

The used implements were: a) 4-body ridger; b) offset deep harrow; c) leveler; d) wide-level disc harrow with a seeder box; e) and disc plow.

The 4-body ridger. A 4-body ridger with ridger bodies placed 80 cm apart which was used in ridging as primary tillage operation. Then it was used in all fields for the final seedbed preparation.

Offset disc harrow. Three types of trailed offset disc harrows were used. For both types, the front discs were notched, while the rear ones were plain. The differences between them were the width of work and source of power used in harrowing operation. One type of harrow, with 660 cm working width, consisting of four gangs each with seven discs attached to the front and similar number attached to the rear with the discs placed 25 cm apart. It was used in the primary harrowing operation and drawn by 175 H.P. track-laying tractor. The second type with 360 cm working width, with two gangs in the front and two gangs in the rear, with five disc plates in each gang placed at 36 cm apart, the disc plate diameter of 80cm. It was used in the deep harrowing and drawn by 175 H.P. track-laying tractor also. The third type, with 250 cm working width, consisted of two gangs in the front and other two in the rear, with six disc plates in each gang placed at 22 cm apart, was used in secondary harrowing and drawn by 78 H.P. wheeled tractor.

Leveler. This was a heavy-drawn tool bar with 400 cm working width. It was used to crush soil clods as well as for field surface leveling.

Wide level disc harrow with a seeder box. This was used in the secondary harrowing as well as in sowing the wheat. The width of work was 450 cm.

Disc plough. This was a three-furrow disc plough, with discs of 65 cm in diameter. The width of work was 80 cm.

a) Soil particles size distribution and soil moisture content before the first irrigation. Two random samples were taken from each field before the first irrigation using a metal frame with dimensions of 50x50x20cm. The frame was pressed manually in the disturbed soil of the ridge till it reached the surface of the hard layer underneath. The soil within the frame was collected and sieved us-

Table 4. Tillage System Sharing Percent, Effect on Wheat Yield and Operational Cost *

Tillage system	1992/93 season			1993/94 season		
	Sharing (%)	Yield (kg ha^{-1})	Cost (US$ ha^{-1})	Sharing (%)	Yield (kg ha^{-1})	Cost (US$ ha^{-1})
R1	17	1121	6	70	846	6
R2	01	1214	9	08	831	9
R3	/	/	/	05	818	9
H1	31	1243	5	/	/	/
H2	/	/	/	11	658	10
H3	/	/	/	06	813	8
H5	22	1245	21	/	/	/
H6	29	1230	22	/	/	/
Means	-	1211	-	-	793	-

* New Halfa Scheme, 1992 / 93 and 1993 / 94 seasons.

ing two sieves with square openings of 3x3 cm and 1x1 cm into >3cm, <3 >1 cm and <1 cm soil aggregate size. Each category of aggregate size was weighed and determined as a percent of total sample weight. From each of the soil samples, after proper mixing, two sub-samples were taken i

n oven cans for soil moisture content determination using electric oven adjusted to 105°C for 24 hours.

b) Soil bulk density and the corresponding soil moisture before the second irrigation. Before the second irrigation of the wheat crop, soil bulk density and the corresponding soil moisture content were determined. Two random soil samples were taken from each field using a core of known volume at depth of 0 – 10 and 10 – 20 cm. Soil moisture content was determined by drying the soil sample in electric oven at 105°C for 24 hours. Then the soil bulk density was determined by dividing the dry sample weight by the core volume. The gravimetric soil moisture content by weight for each corresponding bulk density was calculated.

c) Wheat yields and tillage operational cost. The crop yields were compared and the operational cost for each tillage system was determined, which is the sum of the cost of all tillage operations according to the New Halfa scheme price list for 1994/95 season (**Table 3**). However, the cost of sowing with wide level disc and the final ridges setting in all tillage treatments were not considered.

d) Analysis of collected data. The Data were analyzed using the analysis of variance technique. When the F-test indicated statistical significance, Duncan's multiple range test or least significant difference (LSD) test at 5% significance level (LeClerg et al., 1962) was used to indicate which differences were significant.

Results and Discussion

Surveys of Tillage Systems

The sharing percent of tillage system in wheat land preparation according to the availability of tillage tools, wheat yields and cost for 1992/93 and 1993/94 seasons are shown in **Table 4**.

In 1992/93 season, the share of shallow ridging systems (R_1, R_2 and R_3) was 18% of the total wheat cultivated area in the scheme (25 200 ha), while the share of shallow harrowing system (H_1) was 31% and deep harrowing system (H_5 and H_6) was 51%. No differences in wheat yields could be detected with the use of the five tillage systems. However, shallow ridging systems and shallow harrowing system, which had been executed with the use of wheeled tractors, had the least operational cost of less than 9 US$ ha^{-1}. While the deep harrowing systems, that had been executed by track-laying tractors, had the highest operational cost of more than 21 US$ ha^{-1}.

Because of the defaults of the available track-laying tractors, and the scarcity of spare parts in the local market, the deep harrowing systems were not practiced in 1993/94 season (**Table 4**). In this season, 83% of wheat land was prepared using the least expensive tillage systems of shallow ridging (R_1, R_2 and R_3), while 17% of the land was prepared using shallow harrowing systems (H_2 an H_3). The primary tillage tool of 660 cm width of cut that used in system H_2 was to replace the primary deep tillage implement of 360 cm cut width which was used in systems H_5 and H_6 (**Table 2**). Also in this season (1993/94) there were no apparent differences in wheat yields with the use of the five tillage systems. The low wheat yields was due to the high temperature during the growing season.

Experimental Work on Tillage Systems

a) Soil particles size distribution and soil moisture before the first irrigation. The secondary tillage operations for fine seedbed which seeks to maintain good soil seed contact, were carried out at dry soil condition after the pre-watering, to avoid the stickiness of mud to the implement metal surface. The traditional method in the scheme is to sow the crop on dry soil. The quantities of available soil moisture content at a time of seedbed preparation affects the outcome of tillage system such as soil particles size distribution.

The comparison of soil moisture percent indicated significant differences (*P=0.05*) between tillage systems. Higher moisture per-

Table 5. Effects of Tillage on Wheat Seedbed Before the First Irrigation(1994/95 Season)

Tillage system	Soil moisture	Soil aggregate size distribution (%)		
		>3 cm	<3 >1 cm	<1 cm
R_2	8.3 a	5.7	19.4 a	73.2
R_3	7.5 b	7.4	17.8 b	76.5
H_4	7.0 a	6.4	22.3 b	71.3
D	9.0 b	7.2	14.9 a	78.0
Means [a]	8.0	6.7	18.6	74.8
$LSD_{(P=0.05)}$	1.08	NS [b]	3.98	NS [b]

[a] Means with the same letter within column are not significantly different at P=0.05 according to Duncan's multiple range test.
[b] Not significant.

cent was available with deep ploughing system (D) and shallow ridging system (R_3). This was probably due to the presence of big soil clods within the soil aggregate of >3 cm (**Table 5**) that acted as a shed and protected the underneath soil particles from sunrays, and hence, reduced the rate of soil moisture evaporation.

Comparing soil aggregate size distribution percent, the significant differences (*P=0.05*) between tillage systems were found only for <3> 1 cm. The systems H_4 and R_3 resulted in significantly higher percentage in comparison with the systems R_2 and D. However, all tillage systems resulted in less than 7.4% and in more than 71.3% of soil aggregates of >3 cm and <1cm, respectively. Generally, it could be stated that all tillage systems resulted in a suitable fine seedbed.

b) Soil bulk density and the corresponding soil moisture before the second irrigation. Bulk density is a measure of pore space in the soil. Table 6 shows the means of soil bulk density and the corresponding soil moisture percent for 0 – 10 and 10 – 20 cm depth before the second irrigation for wheat.

Very high significant differences (*P=0.001*) were evident between tillage systems for soil bulk density and the corresponding soil moisture percent for 0 – 10 cm depth. No significant difference in the bulk density was detected with the systems R_2 ad H_4. Deep tillage system D resulted in significantly lowest bulk density with significantly highest soil moisture percent compared to the other three tillage systems. However, there was no significant difference in the soil moisture percent between shallow tillage systems R_2 and R_3.

At 10 – 20 cm depth, the soil bulk density with deep ploughing system (D) was expected to be the lowest compared to the shallow ridging systems (R_2 and R_3) and shallow harrowing system (H_4), but no significant differences were evident over all four tillage systems. This was probably due to the soil consolidation after pre-watering and changes in the soil with time as the result of swelling and shrinking phenomena that occurs in the soils of high clay content. Moreover, deep ploughing was performed in the summer months before the rainy season. Therefore, the rainfall could participate in more consolidation of the soil. The bulk density ranged between 1.09 and 1.19 g cm^{-3}. These results agree with Unger (1984) who reported that those deep tillage effects on heavy clay soils are usually temporary. However, the corresponding soil moisture percent was highly significantly different (*P=0.01*) with tillage systems. But no differences in the soil moisture percent between shallow tillage systems (R_2 and R_3), and shallow harrowing and deep ploughing systems (H_4 and D), but the latter two tillage systems resulted in significantly higher soil moisture percent compared to the former ones. Hence, at 10 –20 cm depths the range of soil moisture percent between 23.0 to 29.7% was not attributed to the differences in bulk density under heavy clay soils (**Table 6**). These results agree with Hammad and Dawelbeit (2001) who reported that the soils of equal total porosity and bulk density could still differ in their water holding capacity due to the differences in pore sizes.

c) Sharing percent of tillage system, wheat yield and tillage operational cost: The Tillage system sharing percent in land preparation, wheat yields and tillage system cost for 1994/95 season are shown in **Table 7**.

The survey of wheat tillage systems in the scheme indicated that shallow ridging systems (R_2 and R_3) covered 76% of wheat cultivated land. While shallow har-

Table 6. Effects of Tillage System on Wheat Seedbed Before the Second Irrigation(1994/95 Season)

Tillage system	0 – 10 cm depth		10 – 20 cm depth	
	Soil bulk density (g cm^{-3})	Soil moisture content (%)	Soil bulk density (g cm^{-3})	Soil moisture content (%)
R_2	1.12 b	18.1 a	1.18	25.8 a
R_3	1.20 c	17.9 a	1.19	23.0 a
H_4	1.07 b	23.1 b	1.09	27.5 b
D	0.98 a	28.9 c	1.11	29.7 b
Means [a]	1.09 b	22.0 a	1.14	26.5 a
$LSD_{(P=0.05)}$	0.074	4.21	NS [b]	3.37

[a] Means with the same letter within column are not significantly different at P=0.05 according to Duncan's multiple range test.
[b] Not significant.

Table 7. Tillage System Sharing Percent.

Tillage system	R_2	R_3	H_4	D	Mean	$LSD_{(P=0.05)}$
Sharing (%)	13	63	20	04		
Yield (kg ha^{-1})	1725	1536	1799	1506	1642	NS [b]
Cost (US$ ha^{-1})	9	9	16	18		

[b] Not significant.

* Effect on wheat yield (SE±205.4) and operational cost in the New Halfa scheme (1994/95 season).

rowing (H_4) with the use of offset disc harrow with 660-cm width of cut covered 20% and the deep ploughing covered the rest of 4%.

Here also, although there were some differences in the measured seedbed parameters (**Table 6**), there were no significant differences in wheat yields with the use of shallow and cheap ridging systems (R_2 and R_3), shallow and expensive harrowing (H_4) and deep and expensive ploughing system (D). However, any soil with bulk density less than or equal to 1.3g cm^{-3} was considered as non-limiting to plant growth (Hammad and Dawlbeit, 2001). Therefore, the obtained results indicated that all tillage systems resulted in a suitable and favorable seedbed tilth for wheat growth. These results are in line with other experiments on Vertisols in the Sudan. Mohamed (1993) found that the use of disc harrow at different soil moisture content in the Rahad scheme Vertisols resulted in no differences in wheat yield, although there were significant differences in soil aggregate size distribution. Dawelbeit (1993) found no differences in wheat yields with disc harrowing at different depths in the range of 5 to 25 cm in the Gezira scheme Vertisols. And Dawelbeit (1994) also found no significant differences in wheat yields with different tillage systems on Gezira Vertisols.

The highest cost with shallow harrowing tillage systems H_2 and H_4 (**Tables 4** and **7**) was due to the use of D6 track-laying tractor for dragging the wide offset disc harrow with 660-cm width of cut in the primary tillage operation. To achieve less cost, this implement could be replaced by the narrower offset disc harrow, which can be drawn by a smaller-wheeled tractor.

Conclusion

1. According to the availability of tillage tools, the field surveys indicated the popularity of shallow and cheap ridging systems and a decrease in the use of the expensive deep tillage systems.

2. No differences between shallow and deep tillage systems for seedbed soil aggregate size distribution of >3 cm and <1 cm before the first wheat irrigation and the soil bulk density at 10 – 20 cm depth before the second irrigation.

3. No differences in wheat crop yields were detected with various tillage systems of shallow ridging, shallow harrowing and deep tillage systems. This indicated a suitable and favorable wheat seedbed with all tillage systems. Therefore, the more economic shallow tillage system, based on the available shallow implement, could be used for wheat production in Vertisols of the New Halfa scheme.

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Thanks are due to the soil scientist Dr. Ibrahim, B.A. and his staff for preparation of soil samples before the second irrigation of wheat.

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Development and Testing of a Seed-cum-Fertilizer Drilling Attachment to Tractor-Driven Cultivator

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Abstract

A seed-cum-fertilizer drilling attachment was developed at Research, Testing and Training Centre, Gujarat Agricultural University, Junagadh in order to do furrow opening, seed and fertilizer drilling and covering of seed simultaneously in a single operation. The trials for machine distribution of seeds and fertilizer were conducted under laboratory conditions. During the field testing of the machine, observations such as depth of seed and fertilizer placement, vertical distance between seed and fertilizer, effective field capacity, field efficiency, plant stand, seed and fertilizer rates were recorded. The machine could be used for sowing a variety of crops commonly grown by farmers in the region which could result in 20 to 30 percent savings of precious seeds and fertilizers. Uniform seed placement without clusters was achieved. The machine was useful for sowing groundnut, black gram, green gram, sorghum, pearl millet, pigeon pea, gram, wheat fertilizer application, uniform seed placement and controlled seed and fertilizer rates.

Introduction

The importance of seed-cum-fertilizer drills in timely sowing, accurate and uniform placement of seed and fertilizer needs hardly be emphasized. Experiments conducted at various centres of the country have shown that an increase of 10 % to 12 % in the yield of wheat and maize can be achieved with the use of seed-cum-fertilizer drills and planters (Anon. 1964-65). Better seed germination resulting in optimum plant population per unit area and the placement of fertilizer at desired locations in relation to the seed, are the dominating factors that contribute to yield increase.

Planting machines are basically meant for placing seeds at required depth and distance in order to maintain proper plant population. Most of the drills/planters developed use cell type (vertical/horizontal/inclined plates), fluted rollers and stationary opening with agitator. The cell type mechanisms are required to be changed depending upon the crops to be sown. Hence, farmers have shown reluctance to its adoption (Tondon et. al. 1987). The cost of seeding is also important in order to minimize the cost of production; various agricultural machines need to be designed so that they can be used for more than one job simultaneously with slight changes or adjustments.

In Saurashtra, large numbers of farmers owning tractors use tractor-drawn locally available manually-metered seed drills for sowing of groundnut and other crops. Two persons sit on the frame to meter the seeds. This operation results in 20-30 kg high seed requirement per hectare, uneven seed placement and many times clusters too (G. Singh, 2000). Moreover, there is no provision for fertilizer drilling. Previously, farmers used to apply the fertilizer 15 to 20 days in advance, but now due to change in weather conditions and uncertainty of rains, they prefer to apply the fertilizer along with the sowing operation with the onset of monsoon which is a very tedious and labour intensive operation. As the fertilizer is ex-

Table 1. Physical Properties of Grains and Their Effects on the Design of Various Components of Drills and Planters

Physical characteristic	Components
Size and shape of seed	Flutes of fluted rollers and cells of metering mechanism
Bulk density of seed	Hoper size and mechanical strength of hopper and supporting frame
Angle of repose	Hopper side slope or hopper shape
Static and sliding friction coefficient	Hopper side slope and mechanical strength
Surface smoothness	Hooper bottom opening and size

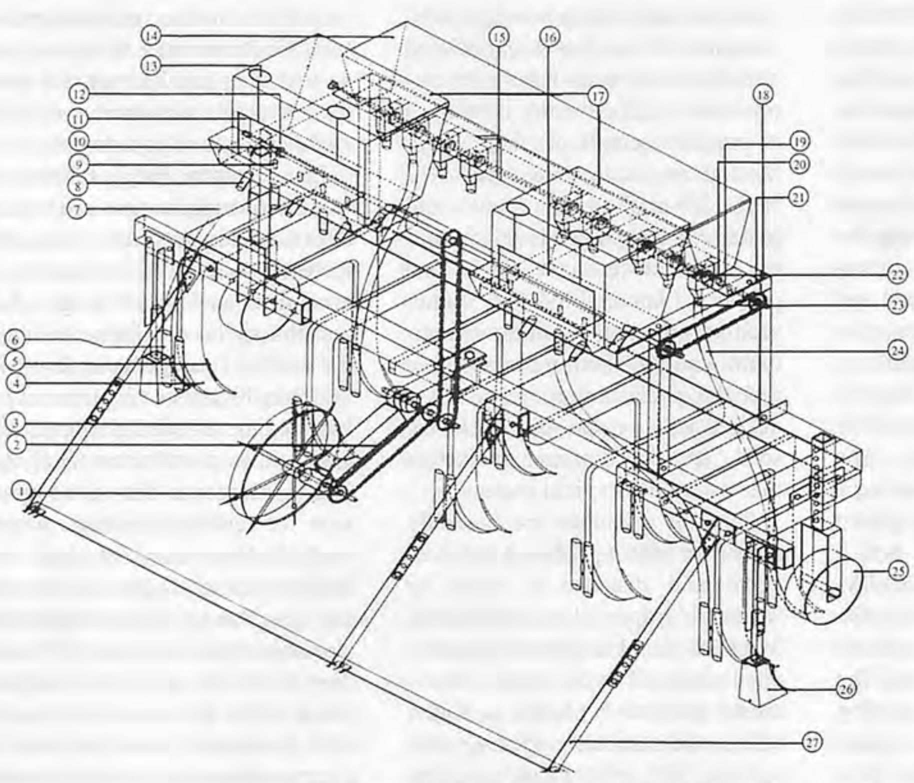
Table 2. Spatial Dimension, Size and Sphericity of Groundnut

Groundnut variety	Length (mm)	Width (mm)	Thickness (mm)	Size (mm)	Sphericity	Weight of 1000 grains (g)	Bulk density (g/cc)	Angle of repose (Degree)
JL – 24	13.31	8.02	7.41	9.24	0.694	507	0.7116	31.00
	13.60	8.57	7.32	9.48	0.697	436	0.721	31.40
	12.94	7.86	7.03	8.94	0.690	424	0.719	32.20
Average	13.28	8.15	7.25	9.56	0.693	455	0.718	31.53
GAU-G-1	11.45	8.09	7.28	8.97	0.783	333	0.708	32.20
	11.36	8.77	7.83	9.20	0.809	359	0.700	32.70
	11.71	8.37	7.28	8.93	0.762	433	0.702	33.00
Average	11.50	8.41	7.46	9.13	0.784	375	0.703	33.30
GAU-G-20	17.25	9.45	7.80	10.83	0.579	636	0.625	22.78
	14.25	9.60	9.35	10.85	0.761	617	0.623	22.88
	13.95	10.40	8.90	10.88	0.779	649	0.620	22.00
Average	15.15	9.81	8.68	10.85	0.706	634	0.622	22.55

Source: Alam A. et. al., 1980. Engineering properties of food materials, CIAE, Bhopal.
* Size = (length × width × thickness) 1/3, Sphericity = size / largest dimension

posed to the atmosphere, there may be losses of nitrogenous fertilizer. The fertilizer can be most effectively utilized if placed in the plant root zone and can increase yield of the crops by 15% (Pangotra, 1980). In Saurashtra, a few private manufacturers have started fabrication of tractor driven seed drills using PVC rotor with cells for metering seeds. These machines are very high expensive (Rs. 30,000 to 45,000). Moreover, these machines cannot meet sowing requirements of small seeds such as mustard and sesame.

Keeping the above facts in mind, a multi crop-tractor-driven seed-cum fertilizer drilling attachment



SR NO	COMPONENT
27	COVERING BLADE
26	MARKER
25	DEPTH CONTROL WHEEL
24	FERTILIZER TUBE
23	FERTILIZER SHOUT
22	FERTILIZER SHAFT
21	FERTILIZER SLIDING GATE
20	PEDESTAL
19	BUSHING
18	SEED DRILL FRAME
17	SEED BOX
16	SLIDING GATE WITH KNOB
15	FERTILIZER METERING LEVER
14	FERTILIZER BOX
13	KNOB
12	SEED BRUSH
11	SEED SHAFT
10	SPOUT LID
9	HOLE (OPENING)
8	SEED SPOUT
7	PVC TUBES
6	BOOT
5	SHOVEL
4	TYNE
3	GROUND WHEEL
2	CHAIN
1	SPROCKET

Fig.1 Tractor driven seed-cum-fertilizer drilling attachment.

Table 3. Test Results for Seed Distribution under Laboratory Conditions

Crop	Rate setting (Divi) *	Row spacing (m)	Weight of seed (gm) dropped from each furrow opener (F.O.) in 25 revolutions of the ground wheel									Total wt.Of seed from all F.O. (g)	Seed rate achieved (kg/ha)
			No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8	No.9		
Wheat	7.5	0.225	125	117	118	134	134	127	118	130	112	1111	127
Sorghum	5.5	0.45	64	-	56	-	65	-	66	-	53	304	31
Green gram	5.5	0.45	54	-	47	-	55	-	44	-	45	245	25
Gram	9.0	0.45	122	-	119	-	129	-	113	-	114	597	61
Pearl millet	2.5	0.60	-	13	-	11	-	12	-	11	-	47	05
Pigeon pea	6.0	0.90	-	62	-	-	57	-	-	68	-	187	16
Groundnut	14.5	0.45	232	-	225	-	230	-	236	-	234	1157	119

Note: Seed damage in all the crops was nil.
*1 Divi. = 1.56 mm.

Table 4. Test Results for Fertilizer(DAP+UREA) Distribution under Laboratory Conditions

Rate setting (Divi) *	Row spacing (m)	Weight of fertilizer dropped from each furrow opener (F.O.) in 25 revolutions of the ground wheel (g)									Total wt. Of fertilizer from all F.O. (g)	Fertilizer rate achieved (kg/ha)
		No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8	No.9		
4	0.225	46	71	76	68	80	42	72	68	69	592	68
5	0.225	106	152	148	144	155	128	147	132	140	1252	143
6	0.225	221	259	262	250	253	255	264	233	263	2261	259
7	0.225	345	369	355	355	369	386	380	340	363	3261	373
4	0.45	46	-	76	-	80	-	72	-	69	343	35
5	0.45	106	-	148	-	155	-	147	-	140	695	72
6	0.45	221	-	262	-	253	-	264	-	263	1263	130
7	0.45	345	-	355	-	369	-	380	-	363	1811	186
4	0.60	-	71	-	68	-	42	-	68	-	248	24
5	0.60	-	152	-	144	-	128	-	132	-	556	54
6	0.60	-	259	-	250	-	255	-	233	-	998	96
7	0.60	-	359	-	355	-	386	-	340	-	1440	188
4	0.90	-	46	-	-	86	-	-	80	-	202	17
5	0.90	-	106	-	-	148	-	-	155	-	409	35
6	0.90	-	221	-	-	262	-	-	253	-	736	63
7	0.90	-	345	-	-	355	-	-	369	-	1069	92

*1Divi.=2.5mm.

was developed and tested for a variety of seeds.

Materials and Methods

Prior to the design of the machine, some of the factors such as a versatile metering device which can be used to sow different crops and fertilizers and can meet recommended seed and fertilizers rate, suitable size of the machine matching with the power source and capability of the machine for sowing small and large seed without dismantling other parts of the machine. In addition, the physical characteristics of seeds (size, uniformity of shape, density, 1000 grains weight and frictional coefficient), which affect the design of various components of the seed drill/planters were studied and presented in **Tables 1** and **2**. Knowing the physical characteristics of seeds to be sown and agronomic requirements of these crops were also given due attention in designing the machine.

The machine consists of a frame, two seed boxes, one fertilizer box, metering mechanism (adjustable hole with agitators), a ground wheel and drive mechanism as shown in **Fig. 1**. Seed boxes fabricated from galvanized iron sheet are mounted on the frame through nuts and bolts. A common shaft made of mild steel round bar is mounted on the pedestal, which gets the drive from ground wheel through chain and sprockets. Nylon brushes are fitted on the shaft to pick up the seeds and push them out of the adjustable holes made on the vertical side of the boxes against each brush. The size of the holes can be adjusted by shifting the sliding gate operated by rotating knobs thus, varying the seed rate. A fertilizer box of appropriate size and shape is fabricated from wood. 9 diamond-shaped holes of (10 × 20 mm) size are made on its bottom. On the lower side of the bottom a slider with 9 diamond-shaped holes of the same size is provided. To vary the fertilizer rate the size of the holes can be changed by shifting the slider horizontally operating a handle provided on the rear side of the box. To agitate the

Table 5. Tests Results of Seed-cum-Fertilizer drill under Field Conditions

	Particulars	Black gram	Wheat	Groundnut
		(A) Test Conditions		
1.	Place of test	Engineering College Demonstration Farm	Cotton Research Farm	Engineering College Demonstration Farm
2.	Name and variety of seed	Black gram (T-9)	Wheat (GW-496)	Groundnut (G-2)
3.	Weight of 1000 grains (g)	25.00	45.00	25.00
4.	Name of fertilizer	DAP	DAP	DAP
5.	Condition of fertilizer	Granular	Granular	Granular
6.	Soil type	Medium black	Medium black	Medium black
7.	Soil moisture (%)	27.32	16.83	16.26
8.	Row-to-row spacing (cm)	60.00	22.50	45.00
9.	Recommended seed rate (kg/ha)	20 - 25	100 - 125	100 - 120
	Recommended fertilizer rate (kg/ha)	87.00	130.00	120.00
		(B) Field Performance		
1.	Duration of test (h)	3.00	2.50	0.58
2.	Actual area covered (ha)	2.00	1.00	0.23
3.	Effective working width (m)	0.60 x 4	0.225 x 9	0.45 x 5
4.	Travel speed of tractor (m/s)	1.00 (3.6 km/hr)	0.83 (3.0 km/hr)	0.73 (2.6 km/hr)
5.	Effective field capacity (ha/h)	0.67	0.40	0.396
6.	Theoretical field capacity (ha/h)	0.864	0.60	0.59
7.	Field efficiency (%)	77.55	67.60	67.00
8.	Depth of seed placement (cm)	6.50	7.25	6.52
9.	Depth of fertilizer placement (cm)	8.50	8.25	7.74
10.	Vertical distance between seed and fertilizer (cm)	2.00	1.00	1.22
11.	Plant population (No./m^2)	58.00	225.00	39.00
12.	Germination (%)	72.50	81.00	81.00
13.	Seed rate achieved (kg/ha)	20.00	125.00	110.00
14.	Fertilizer rate achieved (kg/ha)	88.00	136.00	120.00
15.	Cost of seeding (Rs./ha)*	307	516	520

*Hiring charge of the tractor with operator, Rs. 200/hr
Labour charge Rs. 50 / day.

fertilizer in the box 9 metallic agitators, one over each hole, are mounted on a common shaft, which receives its drive from the seed box shaft through chain and sprockets. Seed and fertilizer drilled through the holes are received by a spout provided below each hole. Spouts are connected to the boots of the furrow openers through PVC pipes to carry the drilled seed and fertilizer to the bottom of the furrows.

In order to maintain the depth of the seed and fertilizer placement in the furrow during sowing operation, two depth control wheels, one on either side of the cultivator frame, are provided. The depth of seed and fertilizer placement can be adjusted depending upon the soil moisture condition of the field at the time of operation. To avoid furrow-opening operation, which is urrently performed as a separate operation, two markers, one on either side of the cultivator frame, are provided. Depending on the crop spacing, the marker can be adjusted. For covering of the seed and fertilizer with soil a blade can be attached to the cultivator frame. After completion of the operation the blade can be detached.

Testing of machine distribution of seeds and fertilizer through furrow openers was conducted under lab conditions as per ISI and RNAM test codes. These tests were conducted for seeds such as

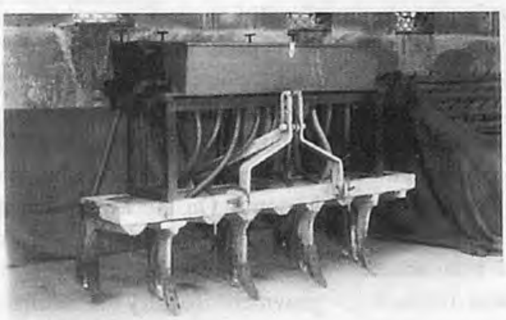


Fig. 2 Seed-cum-fertilizer drilling attachment to tractor driven cultivator (Front view).

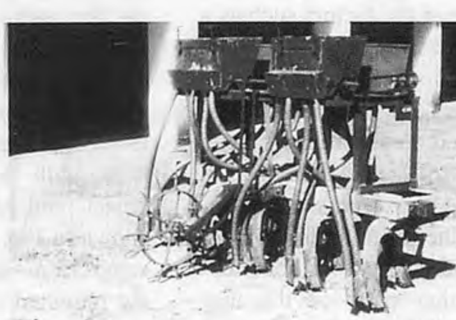


Fig. 3 Seed-cum-fertilizer drilling attachment to tractor driven cultivator (Rear view).

Fif. 4 Spouts receiving drilled seeds.

groundnut, sorghum, pearl millet, green gram, black gram, pigeon pea, wheat and gram and for fertilizer such as DAP mixed with urea. Three tests for each crop seed were conducted. The quantity of seeds dropped from each furrow opener was collected and weighed. The quantity of seeds achieved per hectare was determined and presented in the **Table 3**. Fertilizer distribution tests were conducted for DAP mixed with urea which is generally applied as basal dose by the farmers in the region. Tests were conducted for four rates/setting i.e., 4, 5, 6 and 7 divisions on the arc scale. The results were replicated thrice and the quantity of fertilizer per hectare was determined and shown in **Table 4**.

The performance of the machine was evaluated in the field for groundnut, black gram and wheat. The selection of seeds was made on the basis of size. The soil parameters such as soil type, moisture content and bulk density of soil: seed and fertilizer parameters, namely; seed variety, row spacing, type of fertilizer and condition of fertilizer were recorded during the study. Before operating the machine in the field it was calibrated to get the recommended seed and fertilizer rates. During operations, observations, viz., depth of seed and fertilizer placement, effective working width, vertical distance between seed and fertilizer, travel speed of the tractor, area covered, duration of test, plant population, quantity of seed and fertilizer sown were recorded. Using the above parameters field capacity (ha/h), field efficiency (%), plant population (No/m2), germination (%), seed and fertilizer rate (kg/ha), number of man and tractor hours used per hectare and cost of operation, (Rs / ha) were determined.

Results and Discussion

Table 3 shows that for wheat, sorghum, green gram, gram, pearl millet, pigeon pea and groundnut, the achieved seed rate was 127, 31, 25, 61, 4.5, 16 and 119 kg/ha against the recommended seed rate of 125, 30, 25, 60, 4, 15 and 120 kg/ha, respectively, which is almost equal. The results also indicated that seed damage was almost nil for each crop. From the laboratory tests it was observed that the appropriate size of hole for wheat, sorghum, green gram, gram, pearl millet, pigeon pea and groundnut was 7.5, 5.5, 5.5, 9.0, 2.5, 6.0 and 14.5 division, respectively, on the scale to obtain the recommended seed rate. For fertilizer distribution, results presented in the **Table 4**, indicate that wheat crop which is normally sown at 0.225 m row spacing using nine furrow openers at a time, fertilizer rate varied from 68 to 372 kg/ha for various rate settings while the required fertilizer rate is 130 kg/ha. The recommended fertilizer rate can be obtained at a rate setting of 4.5 division on the scale. Sorghum, pearl millet, green gram, black gram, groundnut and gram are sown at 0.45m row spacing and fertilizer doze for these crops varies from 87 to 100 kg/ha. This rate of fertilizer can be obtained at of 5.5 divisions on the scale. Groundnut (spreading type) is sown at 0.60 m row spacing covering four rows at a time. The results indicate that fertilizer rate varied from 24 to 138 kg/ha for various rate settings while the recommended rate is 55 kg/ha. This quantity of fertilizer can be achieved at a rate setting of 5 divisions on the scale.

Field observations recorded for black gram, wheat and summer groundnut show that vertical distance between seed and fertilizer varied from 1 to 2 cm thus there was no contact of seed and fertilizer in the furrows. Depending upon the soil conditions, 3.16 to 5.63 ha area can be covered in a day of 8 hours. Field efficiency results indicate that efficiency from 66.67 to 77.85 percent could be achieved. Germination percentage for black gram, wheat and groundnut was re-

Fig. 5 Agitators for fertilizer metering.

Fig. 6 Nylon brush for seed metering.

corded as 72.50, 81.00 and 81.00 percent, respectively, **(Table 5)**. From seed rate point of view results indicate that the recommended seed rates, i.e., 20 and 125 kg/ha could be achieved for black gram and wheat crops, respectively, while it was achieved at 110 kg/ha against the recommended seed rate of 120 kg/ha for groundnut. For fertilizer rate, it was recorded as 88,136 and 120 kg/ha for black gram, wheat and groundnut against the recommended rates of 87, 130 and 100 kg/ha, respectively. The costs of operation were 307, 516 and 520 Rs/ha for black gram, wheat and groundnut, respectively.

Conclusions

The following conclusions are drawn:

1.The machine can be used for sowing most of crops such as sorghum, pearl millet, green gram, black gram, pigeon pea, gram, wheat and groundnut which are commonly grown by farmers in the region.

2.The recommended seed and fertilizer rates can be achieved using the developed machine which results in 20 to 30 percent savings on precious seeds and fertilizers.

3.More uniform seed placement without clusters can be achieved.

4.Operations such as furrow opening, fertilizer drilling, seed drilling and covering of seed can be performed in a single operation at an economic rate.

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Development and Evaluation of Weeding Cum Earthing up Equipment for Cotton

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Abstract

The arduous operation of weeding is usually performed manually with the use of traditional hand tools in upright bending posture, inducing back pain for majority of the weeder-laborers. This situation necessitates the introduction of a suitable machine for weeding operations. The unit developed consists of an inter-cultivator-cum earthing up equipment fitted to a standard tractor-drawn ridger. Three sweep type blades of 45 cm width are affixed to the ridger frame with 120° approach angle and 15° lift angle for accomplishing the weeding operation in between standing rows of crops. Three ridger bottoms, which were fitted behind the sweep blade, work on the loosened soil mass and aid in earthing up by forming ridges and furrows. The unit was evaluated for its performance with the available weeders and the conventional method of weeding. Manual weeding using hand hoe registered the maximum efficiency of 82.56% (wet basis) and 82.4% (dry basis). The weeding efficiency of the tractor-drawn weeding-cum earthing up implement was 60.24 (wet basis) and 61.62 (dry basis). The savings in cost of weeding operation with bullock drawn junior hoe, self-propelled power weeder and tractor-drawn weeding-cum earthing up implement when compared to the manual weeding were 78.7, 79.8 and 68.7 per cent respectively. The savings in time of weeding operation using the with bullock-drawn junior hoe, self-propelled power weeder and tractor-drawn weeding-cum earthing up implement when compared to the manual weeding was 96.5, 96.6 and 98.9 per cent, respectively.

Introduction

Crop intensification, timeliness in farm operations and efficient use of production resources will be critical inputs in increasing the productivity of agriculture sector. A decrease in the availability of farm labor is a direct consequence of migration of farm laborers to the industrial sector due to development of the market economy and rural industries. One-third of the cost of cultivation is spent on weeding alone when carried out with manual labour. The arduous operation of weeding is usually performed manually with the use of traditional hand tools in upright bending posture, inducing back pain for majority of the laborers. This situation necessitates the introduction of a suitable machine for weeding operations in cotton production.

Review of Literature

The yield of cotton was reduced by 41.46% when the weeds were allowed to grow unchecked. The treatments of weeding alone, interculture and weeding together however, did not differ significantly. In the row crops of the cotton crop after the 50^{th} day of sowing without or with application of weedicide, the bullock-drawn junior hoe is used for inter-cultivation. After 2 or 3 inter-cultivations using the junior hoe, urea or nitrogen application was done to the crop with the help

Table 1. Comparative Performance of Weeders

Name of the weeder	Weeding efficiency (%)	Plant damage (%)	Man-hrs/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

Table 2. Specification of Weeding Cum Earthing up Implement

Particulars	Value
Over all dimensions (L x B x W), mm	2100 x 630 x 1500
Weight, kg	242
Number of rows	3
Number of weeding blades	3
Number of ridger bottoms	3
Shape of the weeding blade	V shaped sweep bottom
Width of sweep blade, mm	450
Approach angle, deg	120
Lift angle	15
Row spacing, cm	Adjustable(60,75,90 cm)
Source of power	35-45 hp tractor
Depth of operation, cm	15

Fig.1 Tractor drawn weeding cum earthing up implement.

of a ridger. The bullock-drawn blade harrow gave better performance when compared to the bullock-drawn three-tyne cultivator as seen from **Table 1**. The tractor-drawn high clearance cultivator using full and a half sweeps has given good results. The bullock-drawn lister plough may be used during the later stages of plant growth (Bahl *et al.* 1988).

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

Materials and Methods

Development of Tractor-drawn Weeding-cum Earthing up Equipment

The unit developed consisted of an inter-cultivator-cum earthing up equipment fitted to a standard tractor-drawn ridger. Three sweep type blades of 45 cm width were affixed to the ridger frame with 120° approach angle and 15° lift angle for accomplishing the weeding operation in between standing rows of cotton crop. The operational view of the unit in between the rows of cotton crop as shown in **Fig. 1**. Three ridger bottoms which were fitted behind the sweep blade, work on the loosened soil mass and aid in earthing up by forming ridges and furrows. The specifications of the unit are shown in **Table 2**.

The salient features of the unit are: the weeding and earthing up operations were simultaneously performed in a single pass; row to row distance between the sweep blades and the ridger bottoms which were adjustable (60, 75 and 90 cm); the cost of the unit was Rs.12,000; and the capacity was 1.6 ha per day.

Existing Models of Weeders for Cotton Crop

The available models of weeders which can be used for weeding in a cotton crop were:

Self-propelled power weeder (TNAU model) and b. Bullock-drawn junior hoe the descriptions of which follow:

The description of the above mentioned implements and their specification are furnished below.

Self-propelled Power Weeder (TNAU model)

The weeder was operated by a 3-hp petrol start kerosene-run engine. The engine power was transmitted to the ground wheels through a V belt-pulley and sprocket - chain mechanism. At the back of the machine was a fixed replaceable sweep blade (**Fig. 2**). Sweep blades of different widths can be fitted to the machine depending on the row-to-row spacing of the crop. A tail wheel was provided at the rear to maintain the operating depth. The sweep blade could be raised or lowered so as to have the desired operating depth. A rotary weeding attachment to the power weeder was developed. The rotary tiller consisted of three rows of discs mounted with 6 curved blades in opposite directions alternatively in each disc. These blades when rotating enabled cutting off and applying mulch to the soil. The width of coverage of the rotary tiller was 350 mm and the depth of operation could be adjusted to weed and apply mulch to the soil in the cropped field. In addition to the rotary tiller and sweep type blades, the ridger or cultivator could be fitted to the unit, in the place of rotary tiller easily by the operator of the weeder. The cost of the machine was Rs. 53,000 (Rs. 35,000/- excluding the prime mover). The capacity was 0.75 ha per day. The salient features of the unit are; useful for weeding between rows of crops like tapioca, cotton, sugarcane, maize, tomato and pulses whose rows spacing is

Fig.2 Self propelled power weeder.

Fig.3 Bullock drawn junior hoe.

more than 45 cm. The specifications of the power weeder are shown in **Table 3**.

Bullock-drawn junior hoe

This intercultural implement is used primarily for weeding in between the rows of standing crops. It consists of reversible shovels with curved tynes attached to framework with hinge arrangement. A handle and beam are fixed to the framework for guiding and attaching the unit to the yoke (**Fig. 3**). The spacing between the shovel could be adjusted according to the row spacing of the crop. The cost of the unit was Rs.1500.

Conventional Method of Weeding

In the conventional method of weeding a cotton crop the operation is performed by women laborers using a hand hoe (**Fig. 4**). The hand hoe consists of a triangular shaped mild steel-weeding blade of 75 mm width that is attached to a short wooden handle of 450 mm long. The weeding operation is carried out in an upright bending posture.

Treatments Selected for the investigation

The treatments selected for the investigation were:

T_1-Operation with junior hoe

T_2-Operation with self-propelled power weeder (TNAU model)

T_3-Operation with tractor-drawn inter-cultivator

T_4-Control(Manual using hand hoe)

The developed tractor-drawn weeding-cum earthing up implement was evaluated for its performance in terms of weeding efficiency (wet and dry bases), depth of operation and per cent breakage of the cotton plant. The moisture content of the soil during evaluation was 14.48 per cent on dry basis.

Weeding Efficiency and Per Cent Breakage

The weeding efficiency (wet basis) was computed by using the following expression:

$$\eta_{ww}\,\% = \frac{Wr}{Wr + Wu} \times 100$$

Where,

η_{ww}-Weeding efficiency (wet basis), per cent

Wr-Wet weight of weeds removed by the implement/m^2

Wu -Weight of weeds left in the field after the weeding operation/m^2

The weeding efficiency (dry basis) was computed by using the following expression:

Where,

$$\eta_{wd}\,\% = \frac{Wr}{Wr + Wu} \times 100$$

η_{wd}-Weeding efficiency (dry basis), per cent

Wr-Weight of oven dried weeds removed by the implement/m^2

Wu-Weight of oven dried weeds left in the field after the weeding/m^2

The percent breakage of cotton stalks was computed by using the following expression:

$$\eta_{b},\,\% = \frac{P_b}{P_t} \times 100$$

Where,

P_b-Number of plants broken in the row

P_t - Total number of plants in the row

The cost of weeding using the tractor-drawn weeding-cum earthing up implement was compared with the weeding using the power weeder, junior hoe and manual method of weeding. The cost and time saved by the tractor-drawn weeding cum earthing up implement against other methods were compared.

Results and Discussion

During the field trials, it was observed that the power weeder (TNAU model) could not be operated in between the standing rows of cotton crop. One of the ground wheels had to be necessarily run on the ridge, resulting in overturning of the unit. As a result the plant was damaged. Hence the power weeder was used in the plot sown by pneumatic planter and cultivator seeder where there was no ridge between the rows of cotton crop and the performance was com-

Table 3. Specification of Power Weeder (TNAU model)

Particulars	Value
Over all dimensions (L x B x H), mm	2400 x 1750 x 1100
Weight, kg	300
Source of Power	3.5hp petrol start kerosene engine
Number of blades	Sweep blade-1; Shovel-5
Nominal working width, mm	2250 (Adjustable depending on row spacing)
Depth of operation, mm	30 (adjustable)

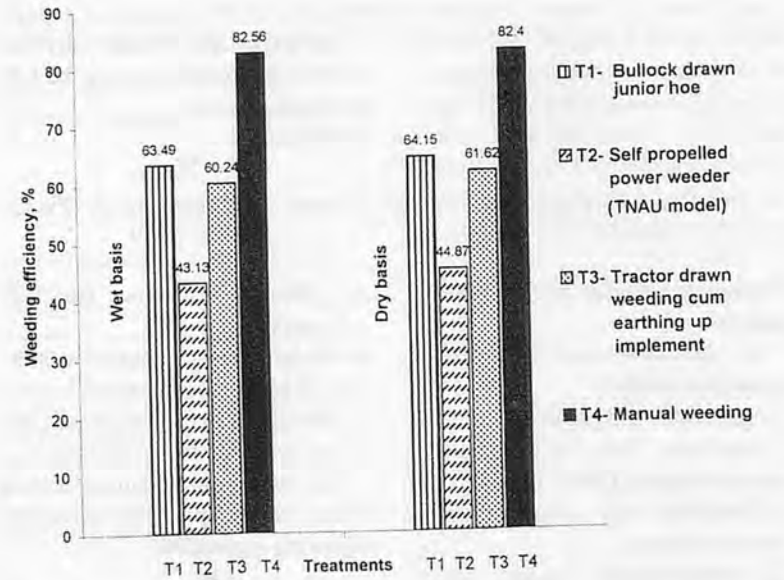


Fig.4 Efficiency of weeders evaluated in cotton crop.

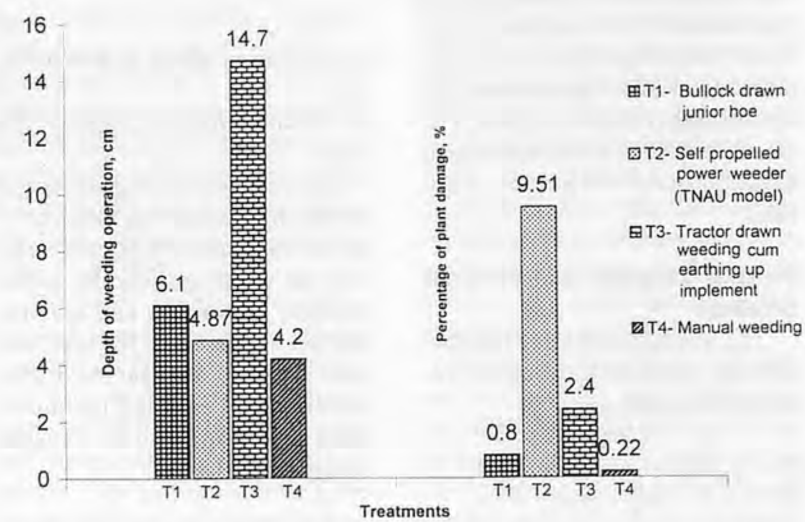


Fig.5 Depth of operation of weeders and percentage of plant damage in cotton fielg.

pared.

The performance evaluation of the weeders in the cotton crop is shown in **Table 4**. It is noticed that the weight of the weeds collected in the treatment T_3 was maximum when compared with those T_1, T_2 and T_4. The high weight of weeds collected was due to the complete up rooting of the weeds with roots by the tractor-drawn weeding-cum earthing up implement.

The weeding efficiency for all the selected treatments is shown in **Fig. 5**. It is observed that there was no significant variation between the weeding efficiency on wet basis and weeding efficiency on dry basis in all the treatments. Among the treatments, the T_4 registered the maximum efficiency of 82.56% (wet basis) and 82.4% (dry basis). The efficiency of T_1 and T_3 are comparable. T_2 had the lowest efficiency of 43.13% (wet basis) and 44.5% (dry basis) among the treatments.

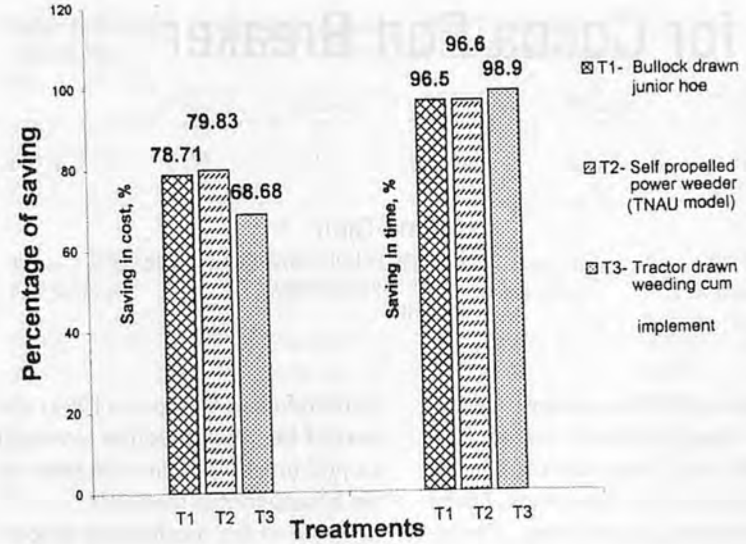
The depths of operation in weeding for all the treatments are shown in **Fig. 5**. It was inferred that the depth of operation was highest in T_3. Owing to this maximum depth of operation the weeds were completely uprooted and the weight of the weeds collected per unit area was also maximum in T_3 as seen from the observations recorded in **Table 4**.

The depth of operation was the minimum in T_4. But the weight of weeds collected per m^2 area was more when compared to T_1 and T_2. This was due to the fact that some of the weeds were pulled out by hand during the manual weeding. The depth of operation was low in T_1 and T_2, which necessitated additional passes in these two treatments.

The percentage of plant damaged in the trial field during the operation of the weeders is shown in **Fig. 6**. The percentage of plant damaged was greater in T_2 followed by T_3. This is due to the fact that the wheels and the blade caused damage to the plants while passing the irrigation channels and while turning of the weeder at headland. With sufficient head land and training in the operation of the units in between the rows of cotton crop the percent of plant damage can be minimized.

The results of the trial for weeding operation in cotton crop with the selected treatments are presented in **Table 5**.

The savings in cost and time of weeding operation using the bullock-drawn junior hoe, self-propelled power weeder and tractor-drawn weeding cum earthing up implement are shown in **Fig 6**. It is clearly reflected from the figure that all the treatments T_1, T_2 and T_3 were positive except T_4. Among the T_1, T_2 and T_3, T_2 recorded the highest percent saving in cost, followed by T_1 and T_3. The high initial cost of the tractor and weeding unit increased the cost of weeding operation in T_3 and hence the lowest. There was not much difference in savings in time among the treatments T_1, T_2 and T_3.



Fig, 6 Saving in cost and time when compared to conventional method.

Table 4. Results of the Performance Evaluation of the Weeder in Cotton Crop

Particulars	T_1	T_2	T_3	T_4
Wet weight of weeds collected after weeding operation, gm/m^2	139.3	160.0	324.9	429.9
Wet weight of weeds left in the field after weeding operation, gm/m^2	80.09	211.02	214.4	91.02
Total wet weight of weeds , gm/m^2	219.39	371.02	539.4	520.9
Weeding efficiency, %	63.49	43.13	60.24	82.56
Dry weight of weeds collected after weeding operation, gm/m^2	72.12	68.15	148.7	245.4
Dry weight of weeds left in the field after weeding operation, gm/m^2	40.31	83.73	91.99	51.86
Total dry weight of weeds , gm/m^2	112.3	151.88	240.7	297.2
Weeding efficiency, %	64.15	44.87	61.62	82.40
No. of plants for 30 m long	162.6	150	167	155.3
No. of damaged plants	1.33	14	4	0.33
Percentage of damage	0.80	9.51	2.40	0.22
Depth of operation, cm	6.1	4.87	14.7	-

Table 5. Results of the Evaluation Trail for Weeding Operation in Cotton Crop

particulars	T_1	T_2	T_3	T_4
Width of operation,m	0.45	0.75	2.25	-
Length of the field,m	46	46	46.0	-
Time taken to travel,sec	65.6	60.54	100.3	-
Forward speed of operation,kph	2.53	2.75	1.66	-
Theoretical field capacity,ha/hr	0.114	0.207	0.373	-
size of the field,m^2			46x11.5=1890m^2-	
Time taken, in 1st pass, min	27.9	29.7	16.0	-
Time taken, in 2nd pass, min	27.0	24.6	-	-
Total time taken, min	54.9	51.4	16.0	450 women hrs/ha
Actual field capacity, ha/hr	0.058	0.06	0.198	-
Field efficiency, %	50.9	50.0	52.6	-
Cost of operation, Rs/hr	50	55	250	9.0
Cost of weeding, Rs/ha	862.07	887.1	1268.63	4050.00
Saving in cost when compared to conventional method, %	78.71	79.3	68.68	-
Saving in time when compared to conventional method, %	96.5	96.6	98.9	-

Conclusions

Based on the analysis of the results the following conclusions are drawn:

1. An inter-cultivator cum-earthing up implement fitted to a standard-tractor drawn ridger was developed.
2. The developed unit was evaluated for its performance in comparison with the existing models of weeders and conventional method of weeding.
3. Manual weeding using the hand hoe registered the maximum efficiency of 82.56% (wet basis) and 82.4% (dry basis). The weeding efficiency of the tractor-drawn weeding-cum earthing up implement was 60.24 (wet basis) and 61.62 (dry basis).
4. The savings in cost for weeding operation using the bullock-drawn junior hoe, self-propelled power weeder and tractor-drawn weeding-cum earthing up implement when compared to manual weeding was 78.7, 79.8 and 68.7 per cent, respectively.
5. The savings in time for weeding operation using the bullock-drawn junior hoe, self-propelled power weeder and tractor-drawn weeding-cum earthing up implement when compared to manual weeding was 96.5, 96.6 and 98.9 per cent, respectively.

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Design Parameters for Cocoa Pod Breaker

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Abstract

This work centered on the fracture characteristics of whole cocoa pods under dynamic loading that are relevant to the development of machinery for primary processing. The moisture content and some physical properties of cocoa bean were determined. The impact and uni-axial compression tests were carried out on F_3 Amazon (hybrid) whole cocoa pods in lateral and longitudinal axes.

The mean values of the minimum impact load and rupture energy were 2.27kN and 5.14kJ for loading in the lateral axis, and 2.42kN and 8.01kJ in the longitudinal axis. The mean values of maximum compression rupture load and toughness are 1.38kN and 5.44J for compression in the lateral axis and 1.95kN and 24.23 J in the longitudinal axis. The average stiffness modulus was 124.5kN/m.

The average moisture content of the fresh cocoa pods used was 77.9% wet basis, with an average length and diameter of 15.37cm and 7.60cm, respectively. The average thickness at the furrow was 0.92cm and ridge, 1.22cm.

Introduction

Cocoa (Theobroma cacao L) is strictly a tropical tree crop which is cultivated in the tropical forests of West Africa, Latin America and South East Asia (Opeke, 1987). In Nigeria, it is commonly grown in the western part of the country especially in Osun and Ondo States. Processed cocoa beans are used in the manufacture of chocolate-based products and cocoa butter. The residual cocoa powder is used in cakes, biscuits, cocoa food, soft drinks, ice-cream, baking, and other confectioneries such as bournvita, cacao, pronto etc. The dry pod husk can be utilized as a livestock feed constituent (Adeyanju et. al., 1975a, Opeke, 1987; Atuahene et. al. 1984). Locally, crude spirit known as illicit liquor can be made from its liquid.

The economic importance of cocoa notwithstanding, its processing has been restricted to manual operations. Breaking of the cocoa pod has been one of the most difficult tasks during its processing. There is, therefore, need to consider ways of breaking the pods mechanically.

In view of this, a detailed knowledge of mechanical characteristics of cocoa pod will lead to the understanding of the characteristics of materials and general behavior under applied loads. A study of these properties is very fundamental in relation to research work on the design and development of machines for handling and processing of agricultural products. The structure of the pod is believed to be important in relation to the pod breaking behaviour (Maduako and Faborode, 1990). Therefore, it is necessary to first characterize the pods breaking behaviour by carrying out impact and compression tests (ASAE, 1990). This is with a view to reducing the pod into small particles. Faborode and Oladosu, (1991) observed that the reduction involved in pod breaking is not the same as for homogeneous materials.

Some of the mechanical properties affecting the breaking behaviour of agricultural materials are defined as hardness, toughness, elasticity or rigidity of the material (Sitkei, 1986).

There has been some work on mechanical pod breaker, though none of the machines is in the market today. Few examples of such machines are the Zinke breaker and cocoa pod processor.

Materials and Methods

Cocoa pods of a commercially grown variety of Nigerian cocoa, F_3 Amazon, were harvested from the Cocoa Research Institute of Nigeria (CRIN), Idi-Ayunre, Ibadan. The moisture content was determined using the oven method at 3, 24, 48, 72, 96, 120 hours after harvest.

The parameters for the physical characteristics were measured before the pods were subjected to tests for mechanical failure. The experimental tests on all cocoa pods were carried out within five days after harvest using only ripe healthy pods.

The length, diameter and thickness of (20) whole cocoa pods were measured using vernier calipers.

Ten whole cocoa pods of different sizes were used for the uni-axial compression tests in both lateral and longitudinal directions of the pod, using a tensiometer. By prop-

Table 1. Moisture Content of F_3 Amazon Whole Cocoa PodS

Sample Number	Weight of sample at the given time (g)					Weight of water removed in 72 hours (g)	M.C at 72 hours (%w.b)
	0 hours	12 hours	24 hours	48 hours	72 hours		
Pod 1	322	131	89	77	75	247	76.7
Pod 2	294	92	62	57.5	54	240	81.6
Pod 3	312.5	177	128	84	76.5	236	75.5

Table 2. Size and Thickness of F_3 Amazon Whole Cocoa Pods

Pod Number	Length (cm)	Diameter (cm)	Thickness	
			t_f (cm)	t_r (cm)
1	16.69	7.85	1.32	1.50
2	15.16	8.03	0.97	1.16
3	15.78	8.74	0.90	1.19
4	12.62	6.47	0.74	1.00
5	13.80	3.84	0.80	1.25
6	13.19	7.51	1.08	1.32
7	15.12	9.12	1.20	1.73
8	15.10	8.55	0.65	0.97
9	18.60	9.00	1.32	1.50
10	15.75	7.13	0.76	1.20
11	19.17	9.25	1.52	1.82
12	17.34	8.68	1.10	1.42
13	17.14	8.40	0.99	1.15
14	17.62	7.35	0.92	1.28
15	16.80	7.15	0.72	0.99
16	13.15	6.94	0.55	0.97
17	12.22	6.20	0.52	0.76
18	13.64	7.91	0.63	1.00
19	14.90	6.65	0.90	1.00
20	13.65	7.28	0.83	1.10
Average values	l = 15.37	d = 7.60	t_f = 0.92	t_r = 1.22
Std. Deviation	e = 0.05	e = 0.04	e= 0.01	e=0.01

erly aligning the specimens with respect to the compressing unit, it was ensured that a truly concentric or axial load was applied so that bending stresses were not set up. Each pod was compressed between two parallel plates; noting the force at which deformation took place. This was replicated five times, respectively, for both lateral and longitudinal section of the pods. An impact drop test was carried out, using 16 cocoa pods. 8 pods were used each for both lateral and longitudinal drop tests. The cocoa pods were dropped from different heights to a flat (metal) galvanized steel surface to determine the height from which the pods would crack when dropped in both lateral and longitudinal axes.

The stiffness modulus for a pod was determined in accordance with the procedure of Reece and Lott (1976). Twenty samples of cocoa pods of various sizes were selected and the weight of each pod in air was measured with a weighing balance. The mass density of each pod was determined by using Archimedes' water displacement technique. The pods were completely immersed in water, displacing a known volume of water. The volume of water displaced was measured, using a measuring beaker.

Table 3. Bulk Density of F_3 Amazon Whole Cocoa Pods

Sample Number	Weight of Pods in the Box (Kg)	Bulk Density Y_b(Kg/m^3)
1	5.35	428.0
2	5.60	448.0
3	5.87	469.6
4	5.98	478.4
5	5.74	459.2

Y_b = 456.6; e=1.8 Internal Volume of the Box = 0.0125m^3

Discussion of Results

The results of the physical properties for F_3 Amazon whole cocoa pods measured are as shown in **Tables 1- 4**. The average moisture content of fresh whole cocoa pod at harvest was 77.9% wet basis that is comparable to a value of 84.9% wet basis reported for cocoa pod husk by Maduako and Faborode (1990). It was observed that there was much shrinkage in the thickness of the pod husk after each test. The weights of the samples became almost constant from about 48 hours upwards in the oven. This perhaps implies that a duration of 48 hours is adequate for the moisture content tests at an oven temperature of 102^o C for whole cocoa pods.

The average length and diameter of F_3 Amazon whole cocoa pods were 15.37cm and 7.60cm, respectively. The mean thickness of pod husk was found to be 0.92cm at the furrow and 1.22cm at the ridge (**Table 2**). It is expected that during pod breaking, the breaking edge will most of the time hit the pod at the ridge. So, for machine design, the husk breaking at the ridge is probably more important than that at the furrow. The husk thickness affected many of the mechanical properties of whole cocoa pods.

From **Table 3**, the average bulk density of whole cocoa pods was 456.6 kg/m^3. This parameter is important in choosing the size of the

Table 4. Weight, Volume and Mass Density of F_3 Amazon Whole Cocoa Pods

Pod Number	Weight (g)	Volume (ml)	Mass Density, (Kg/m^3)
1	460	680	676.5
2	396	495	800.0
3	495	650	761.5
4	230	310	741.9
5	364	480	758.3
6	337	425	792.9
7	535.5	710	754.2
8	395	500	790.0
9	656.5	840	781.5
10	306.5	405	756.8
11	781.5	895	873.2
12	604.0	670	901.5
13	525	780	673.1
14	322	400	805
15	294	370	794.6
16	257	345	744.9
17	312.5	410	762.2
18	201	205	980.5
19	355	465	763.4
20	291.5	305	955.7
Average values	W = 406	V = 517	P = 793.4
Standard deviation	e = 3.9	e = 4.9	e = 2.0

hopper for pod breaker. The hopper must be able to accommodate enough pods to achieve the required throughput capacity and efficiency of operation. In addition, the stability or balance of a pod breaker during operation will also be affected by the weight of pods in the hopper and hence, the bulk density of the pods.

As seen in **Table 4**, the average mass density for F_3 Amazon whole cocoa pods was 793.4kg/m^3 which was about 1.74 times the bulk density. The average weight of the sampled pods was 406g, while the average volume was 517cm^3. These values together with the bulk density are important in determining the capacity of any pod breaking machine.

The minimum impact rupture load for the whole cocoa pods across its lateral axis was 2.37kN,while the impact rupture energy was 5.14kJ as shown in **Table 5**. These values are less than 2.42kN and 8.10kJ impact rupture force and impact rupture energy for longitudinal breaking of pods (**Table 6**). Comparatively the impact rupture energy for oranges has been reported to be about 21.3x10^{-3} KJ (Chuma et. al., 1978). Cocoa is obviously a much tougher material than orange. The machine designer should exploit the lateral axis when determining the suitable orientation of the pod before reaching the hammer. Also, since the load and energy values obtained are the minimum below which the pod cannot be cracked, the machine designer may need to use a safety factor above unity when estimating the impact load required to break the pod completely so as to release the wet beans.

The result of the uni-axial compression tests for all the cocoa pods showed that for compression in the lateral axis, the force-deformation curve was essentially linear, terminating at the maximum rupture load, while the curve for compression in the longitudinal axis was irregular in shape. Sample force-deformation in both lateral and longitudinal axes are shown in **Fig. 1**. The pattern of deformation has similarly been observed for pods by Maduako and Faborode (1994), Faborode and Dinrifo (1994); and for other agricultural products, especially grains and egg shell (Mohsenin, 1980; Reece and Lott, 1976).

It is observed from **Table 7** that the compression load required to rupture a pod in lateral axis is less than that required for the longitudinal compression, implying that the central portion of a pod (**Fig. 1**) contains the weaker axis. This is partly because the (bottle) neck of a pod possesses considerable resistance to breakage in longitudinal compression. None of the force-deformation curves the entire cocoa pods in the lateral axis featured a bioyield point, where deformation increases without an increase in load. This implies that the pod husk is rigid as can be noticed from

Table 5. Impact Drop Tests on F_3 Amazon Whole Cocoa Pods in Lateral Axis Rupture height, h = 2.17m; Acceleration due to gravity, g = 9.81 m/s2

Pod No.	Weight of Pod (kg)	Time of drop (s)	Velocity of drop (m/s)	Potential Energy (KJ)	kinetic energy (KJ)	Rupture energy (KJ)	Rupture load (KN)
1	0.304	0.80	2.71	6.47	1.12	5.35	2.47
2	0.417	0.50	4.34	8.88	3.93	4.95	2.28
3	0.248	0.90	2.41	5.28	0.72	4.56	2.10
4	0.349	0.90	2.41	7.43	1.01	6.42	2.96
5	0.307	0.70	3.10	6.54	1.48	5.06	2.33
6	0.330	0.90	3.10	7.02	1.59	5.43	2.50
27	0.357	0.60	3.62	7.60	2.34	5.26	2.42
28	0.234	0.80	2.71	4.98	0.86	4.12	1.90
Average values			V_f=3.05			RE = 5.14	I_f = 2.37
Standard deviation			e = 0.04			e = 0.04	e = 0.02

Table 6. Impact Drop Test on F_3 Amazon Whole Cocoa Pods in Ongitudinal Axis Rupture height, h = 3.31m; Acceleration due to gravity, g = 9.81m/s2

Pod No.	Weight of Pod (kg)	Time of drop (s)	Velocity of drop (m/s)	Potential Energy (KJ)	kinetic energy (KJ)	Rupture energy (KJ)	Rupture load (KN)
1	0.323	1.00	3.31	10.49	1.77	8.72	2.63
2	0.412	1.20	2.76	13.38	1.57	11.81	3.57
3	0.347	0.85	3.89	11.28	2.63	8.64	2.6 1
4	0.211	1.00	3.31	6.85	1.16	5.69	1.72
5	0.272	1.00	3.31	8.83	1.49	7.34	2.22
6	0.326	1.45	2.28	10.59	0.85	9.74	2.94
7	0.250	0.90	3.68	8.11	1.69	6.42	1.94
8	0.212	1.00	3.31	6.88	1.16	5.72	1.73
Average values			V_f =3.23			RE = 8.01	I_f = 2.42
Standard Deviation			e = 0.03			e = 0.14	e = 0.04

Table 7. Compression Tests on F_3 Amazon Whole Cocoa Pods in Lateral and Longitudinal Axes

Pod Number	Pod weight (Kg)		Maximum compressive rupture load, F_c, (KN)	
	lateral	Longitudinal	lateral	Longitudinal
1	0.536	0.337	1.94	
2	0.364	0.495	1.26	2.06
3	0.321	0.230	1.31	1.56
4	0.307	0.283	1.21	2.07
5	0.396	0.657	1.20	2.15
	F_c = 1.3 8 ;	e = 0.03		F_c = 1.95e = 0.03

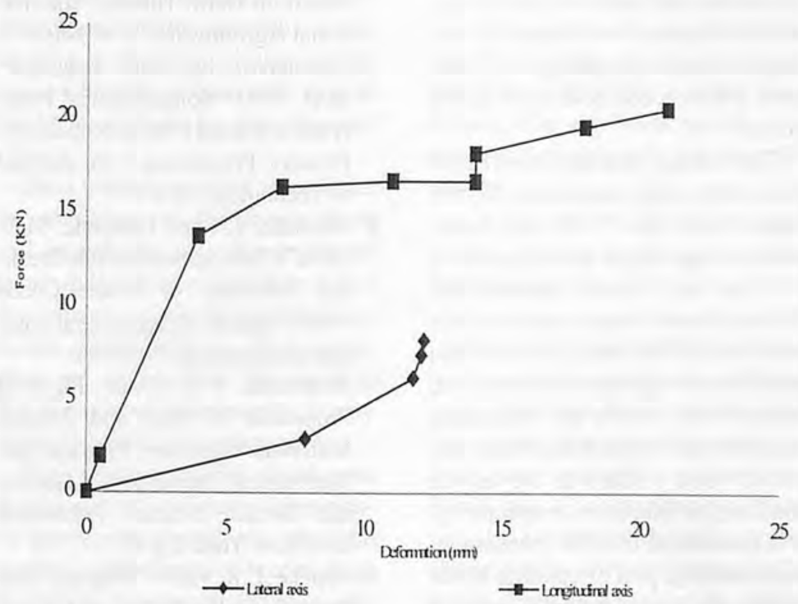

Fig.1 Typical force-deformation curves for F_3 Amazon (hybrid) whole cocoa pods in lateral and longitudinal axial compression.

Table 8. Evaluation of The Toughness of F_3 Amazon Whole Cocoa Pod

Pod Number	Lateral Axis Toughness (J)	Longitudinal Axis Toughness (J)
1	7.38	16.14
2	4.80	26.21
3	4.01	34.98
4	4.99	18.53
5	6.04	25.31
Average values	Tlat. = 5.44	Tlong. = 24.23
Standard deviation	e = 0.14	e = 0.78

the values of stiffness modulus shown in **Table 8** where the average stiffness modulus was 184.5kN/m for lateral compression. The absence of a bioyield point is not unexpected because in breaking a cocoa pod, rupture is achieved essentially by cracking and a crack in the pod husk is more likely to occur without any prior yield in the structure of the pod in view of the partial hollowness (Maduako and Faborode, 1990) of the whole cocoa pod.

Unlike in the lateral axis, the deformation in the longitudinal axis featured yielding of the pod husk tissue before the eventual fracture of the pod. For this reason, a stiffness modulus cannot be evaluated in this axis on the same assumption as for lateral axis. Maduako and Faborode (1994) obtained similar results for three varieties of cocoa pods. The maximum compressive rupture load were 1.38kN and 1.95kN, respectively, for compression in lateral and longitudinal axes as shown in **Table 7**. The values of the lateral and longitudinal compressive rupture loads of 1.38kN and 1.95kN are greater than the range of 440N to 670 N and 520N to 870N, respectively, reported by Maduako and Faborode (1994) who worked on three varieties of cocoa pods.

From **Table 9**, the average toughness of the entire cocoa pods was 5.44J and 24.23J under lateral and longitudinal compression loading, respectively. These findings provide scientific support for the prac-

Table 9. Evaluation of The Stiffness Modulus of F_3 Amazon Whole Cocoa Pods in Lateral Axis

Pod Number	Force of rupture	Deformation at Failure (mm)	Stiffness Modulus (KN/m)
1	1.940	7.6	255.5
2	1.260	7.6	184.4
3	1.315	6.1	215.6
4	1.216	8.2	148.3
5	1.197	10.1	118.5
			SM = 184.5
			E = 5.7

Fig. 2 A ripe matured cocoa pod.

tice of local farmers who break cocoa pods with blunt objects along the lateral axis, the weaker of the two axes. The values were higher than 1.92 to 3.26 J (lateral axis) and 2.58 to 3.92 J (longitudinal axis) reported by Maduako and Faborode (1994). The wide disparity observed in these values may be due to the nature of the cocoa pod used, showing that the cocoa pods used in this work is tougher than that of the ones used by other researchers. This can be seen in the moisture content obtained in this work being lower than the moisture content obtained by Maduako and Faborode.

During the laboratory experiment, when the cocoa pod was under impact or compression testing, failure was observed to occur only across the pod husk while the wet bean mass remained generally intact inside the pod. This suggests that the pod husk contributes almost one hundred percent (100%) of the maximum compressive breaking force and minimum impact breaking force in a safe cocoa pod breaking process. This also supports the observation of Maduako and Faborode (1994) that a partial hollowness exists between the pod wall and the wet bean mass.

Conclusions

Some physical and mechanical properties necessary in the design and development of machinery for the post-harvest handling of F_3 Amazon whole cocoa pods were determined.

The average moisture content of fresh cocoa pods considered for this experiment was 77.9% wet basis, with average length and diameter of 15.37cm and 7.60cm respectively. The minimum impact rupture loads were are 2.37kN and 2.42kN in the lateral and longitudinal directions, respectively, while the maximum compressive rupture and loads are 1.38kN and 1.95kN in the lateral and longitudinal axes, respectively. It is concluded that for mechanical pod breaking, pod orientation in the lateral axis should be preferred as it utilizes less amount of energy.

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A Solar Tunnel Dryer for Natural Convection Drying of Vegetables and Other Commodities in Cameroon

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Summary

A natural convection solar dryer was constructed adapted and at the Agricultural Engineering Department of the University of Dschang. The dryer was mounted as a simple and dis-mountable structure made up of a collector, a drying tunnel and a chimney whose role was to facilitate airflow by the chimney effect.

Tests were carried out to evaluate the efficiency of the empty dryer and its efficiency in the drying of some indigenous vegetables and a few other agricultural commodities in the raining season when conditions are unfavorable for sun-drying because of permanently cloudy skies and intermittent downpours.

The produce to be dried was spread out in trays made from plastic gauze and placed one after the other in a manner as to receive heat both from direct solar radiation and from the collector. This dryer could hold up to 17 kg of fresh leafy vegetables per drying batch. The average maximum temperature within the drying tunnel was 61.9 ºC and the minimal airflow was estimated at 9.65 m^3 / h. The dryer enabled a reduction in exposure time in the open-air of about 50 % in addition to a net amelioration of the quality of the dried products.

The dryer is of simple construction and can be used in rural areas that do not have electricity supply and with unfavorable weather conditions. The pay back period was estimated using green pepper at 18 months.

Acknowledgement

The author is grateful to Dr. Tangka Julius and Weka-Fotso Guy Michel of the Department of Agricultural Engineering, Faculty of Agronomy and Agricultural Sciences of the University of Dschang for their contribution to this work.

Introduction

This work was motivated by the need to have a low-cost working solar dryer that can be used to dry high value commodities such as fruits and vegetables with a reduced risk of contamination. This was also because of the difficulty to obtain locally the components of a tunnel dryer as described by Mühlbauer et al., (1996). It was not only difficult to import these components, but importing them would also add tremendously to the cost of the dryer, thereby making it too expensive for small farmers.

Sun-drying is the common way of conserving agricultural products in Cameroon. Producers spread cereals, legumes, fruits and vegetables on the ground to dry. During this operation, dust, rain and animals can contaminate the produce. The final commodity is, therefore, poor in quality and of low market value. More efficient and affordable means of drying are, therefore, necessary to guarantee a quality product and a good revenue to the farmer.

Dryers have been developed and used to dry agricultural products in order to improve shelf life (Esper and Mühlbauer, 1996; Igbeka, 1980; Mühlbauer *et al.*, 1996). Most of these either use an expensive source of energy such as electricity (El-Shiatry, 1991, Berinyuy, 2000) or a combination of solar energy and some other form of energy (Sesay and Stenning, 1996). Most projects of these nature have not been adopted by the small farmers, either because the final design and data collection procedures are frequently inappropriate or the cost has remained inaccessible and the subsequent transfer of technology from researcher to the end user has been anything but effective.

The production of fruits and vegetables in Africa increased from 112 million tonnes in 1970 to 203 million tonnes in 1994 (Wills *et al.*, 1998). However, this increase in production has not necessarily met the requirements of the population because of several reasons. Vegetables and fruits are perishable commodities which are usually

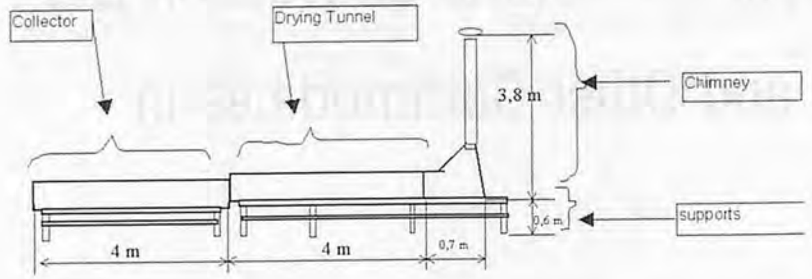


Fig. 1 Solar tunnel dryer adapted for natural convection drying of vegetables and other comnnmodities.

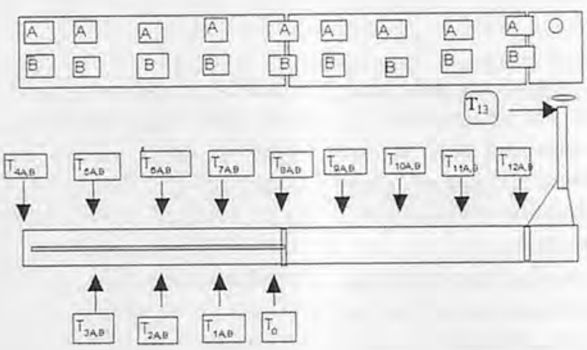


Fig. 2 Positions of temperature sensors in the dryer.

harvested at high moisture content. When harvested, a large portion is lost because marketing and handling conditions are poor. In addition, very few post-harvest technologies exist and where they do, they are too complex or unaffordable to the farmer (Berinyuy *et al.*, 1997). Proper drying is thus a viable alternative for a small producer to prolong the shelf life of the harvested fresh produce.

Because of this lack of adequate post-harvest systems, there is seasonal wastage and off seasonal shortages. Post-harvest food loss reduction has not received sufficient attention on a global scale and the situation is even more serious in the humid tropics where the conditions of high temperature and humidity coupled with high incidence of pests and diseases aggravate these losses (Oluranda, 1985). There are seasonal fluctuations in supply characterized by very low prices during the rainy season and short supply and higher prices during the dry season. Post-harvest losses are high due to the lack of proper conservation methods. This situation tends to drive more people away from farming thereby perpetrating rural exodus and poverty.

The aim of this work was to adapt technologies which allow the use of solar energy to improve the food situation and hence the livelihood of resource-poor rural families in Cameroon. The study addressed specifically the following:

Modifying and testing a solar tunnel dryer for use under humid tropical conditions.

i. Designing an easy-to assemble low cost solar dryer based on locally available materials.

ii. Evaluating the quality of dried products with respect to colour, taste and contamination by foreign materials.

Materials and Methods

a) The Dryer

A natural convection tunnel dryer (**Fig. 1**) was adapted from Esper and Mühlbauer, (1996), constructed and mounted on a simple wooden structure that could be dismantled. It consisted of a collector, a drying tunnel and a chimney whose role was to facilitate airflow by the "chimney effect". The collector and the drying chamber were both 1 m wide and 4 m long and mounted on wooden columns 60 cm high. The base of the chimney, the collector and dryer supports were made from hard wood (*T. scleroxylan and E. escelsa*) which are locally available and do not pick up water easily. The collector floor was made of corrugated aluminium, painted black to improve on heat absorption. To minimize heat losses to the surrounding, the dryer and collector had composite walls made of two 15 mm plywood sheets that sandwiched a layer of compacted wood shavings 5 mm thick. Two layers of transparent polyethylene sheets were used to cover the two compartments. Heat storage was provided below the floors of both the collector and dryer by crushed basalt rocks. Air intake for the collector follows a double pass (first below the heat store and then above it) to increase the chances of obtaining an appreciable temperature rise. A deflector made of aluminium was provided between the two passes to

$$V = 0{,}0008\left(\frac{0{,}00308 \cdot \Delta T \cdot g \cdot H}{h}\right)^{0{,}87}$$

Equation a

Table 1. Dryer Characteristics

Evaluated parameter	Value
Solar radiation on collector	12126.3 J m^{-2} day^{-1}
Air speed through the dryer	9.6 m^3 hr^{-1}
Global efficiency of the system	18.0 %
Efficiency of drying	79.2 %

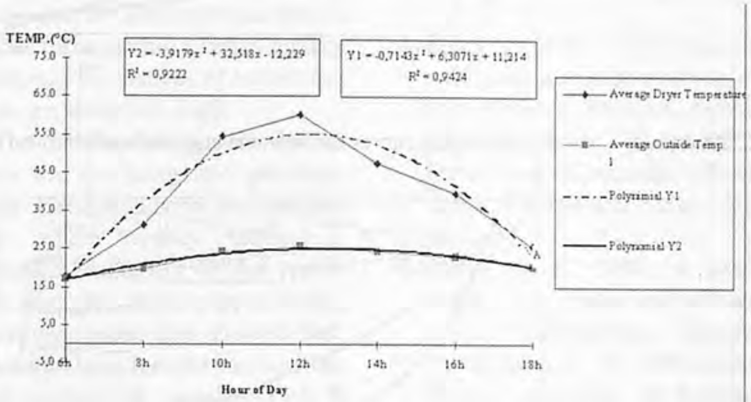


Fig. 3 Average air temperatures in the drying chamber.

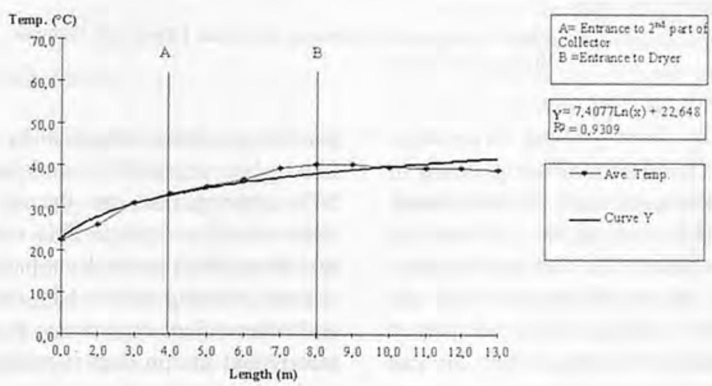


Fig. 4 Temperature profile along the dtyer.

reduce the angle of turn and reduce energy losses due to eddies.

During operation, air from the collector moved into the drying chamber where it passed over and below the product suspended on perforated drying trays. Exhaust air then moved through the chimney after heat and moisture exchange with the product. The chimney base measured 1 m by 0.7 m by 0.9 m high and was constructed from aluminium sheets. This base box was connected to a 12-cm diameter PVC pipe, 3.8 m high. The whole chimney was painted black to enhance heating by solar radiation, causing the warm air to rise thereby ensuring natural draft through the system.

b) Instrumentation

Temperature measurements inside the dryer were taken at two hourly intervals using gauge 30 copper-constantan thermocouples. This was monitored at 26 points (**Fig. 2**). The temperature at any particular point, T_1, along the dryer was taken as the average between the values on opposite points on each wall based on this equation:

$$T_1 = \frac{T_{1A} + T_{1B}}{2}$$

where T_1 was the temperature at the first one meter of air traveling along the dryer. T_{1A} and T_{1B} are, respectively, the temperatures at points B and A of the same section (**Fig. 2**). The relative humidity of the air inside the dryer was determined using the wet bulb depression technique.

The airflow rate and the efficiency of the dryer were evaluated using the empirical methods as described by Brenndorfer *et al.*, (1985). For our system, this airflow could be calculated from the **equation a:**

V is the flow rate in m/s; Δt is the difference between the average temperature in the drying cabinet and the ambient; g, the acceleration due to gravity and H the vertical height of the heating system (including the chimney).

c) Test Materials

We placed the samples on trays in the drying chamber. We periodically removed and weighed the trays until the decrease in weight was less than 10 g. We determined the moisture contents of these commodities using the oven drying technique.

Results and Discussions

The dryer was first tested empty and then when filled with various fruits and vegetables. The results reported here are for trials carried out during the months of July and August in 1999 and 2000 at the Department of Agricultural Engineering, University of Dschang. During these months in Dschang, intermittent downpours are common, the relative humidity of the air is above 90%, and the average ambient temperature is around 15° C.

Table 1 shows the characteristics of the dryer and Table 2 the results of drying some vegetables using the dryer. The complete dryer cost 290,000 FCFA and can dry 17 kg of

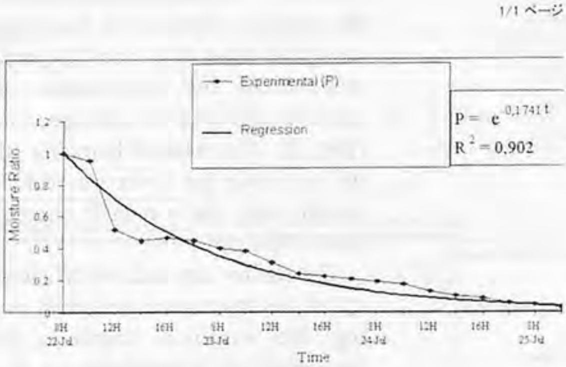
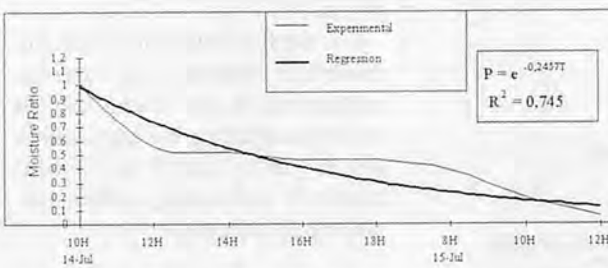


Fig. 5 Drying curves for Red pepper.



Fig,7 Drying curves for Amaranth.

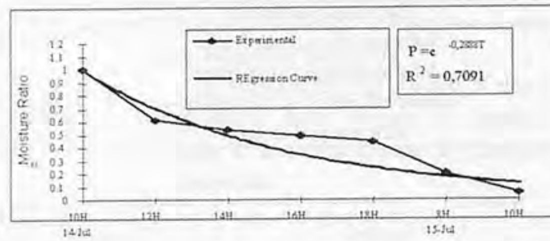


Fig. 6 Deying curves for Vemonia amygdalina(Bitter leaf).

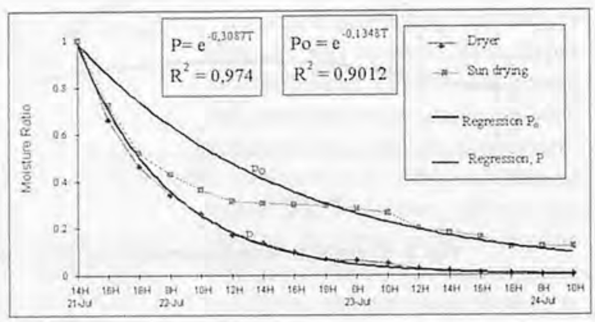


Fig.8 Comparison between the Solar Dryer and Natural drying for Cabage.

sliced cabbage from 95.6% moisture content wet basis down to 9.0% in five days.

Tests with the dryer empty showed that morning temperatures within the dryer are comparable to those outside. They increase gradually to a maximum of 61.9° C at about noon and then fall progressively towards evening (**Fig. 3**). This figure also shows that while the temperature difference between the ambient air and the air in the dryer was close to zero at 6.00 a.m. this value rose to about 34 °C at noon. At 6.00 p.m. there was still a temperature difference of 5.2 °C between the air in the dryer and the ambient air, probably due to the heat storage provided.

The temperaure of the air through the drying system rose faster at the first pass through the collector than the second (AB) but on exit from the collector, this stabilized somewhat (**Fig. 4**). However, a regression of the data shows a progressive increase along the whole length of the dryer system. This rise in air temperature in the afternoons was uniform whereas in the mornings this rise was not very evident. The fact that by afternoon, the dryer elements had absorbed sufficient heat to permit progressive heating of the air can probably explain this.

Fig. 5 to **8** show the drying curves for some vegetables. Since the product was left in the dryer during rainfall and overnight, it picked up moisture. Drying therefore recommenced the following sunlight period. Regression of the data over the whole drying period showed that the drying followed a standard exponential decay. Although the regression coefficient, r^2 was low for bitter leaf and Amaranth, the values for red pepper and cabbage were above 0.9. Comparison of natural air drying and drying using the adapted dryer showed that the product under natural drying contained twice as much water after three days than that dried in the dryer (**Fig. 8**). These results are comparable to those obtained by El-Shiatry et al., (1991) showing a 50% improvement on the drying time over sun-drying. This means that the product in the dryer has less chance of being infested by mould and other micro-organisms. It also means that the product is ready for packaging or storage sooner.

The determined air speed of 9.68 m^3 is comparable with other natural convection systems (Weka, 1998). The overall efficiency of the system of 17.68% indicates that the percentage of energy absorbed by the collector and used to dry the product is low. This value is similar to that reported elsewhere (Brenndorfer *et al.*, 1985). The moisture extraction efficiency was 79.15%. This resulted in good drying of the vegetables within an acceptable time limit. With an initial moisture content of 80% wet basis, bitter leaf was successfully dried to a moisture ratio of less than 0.1 within three drying days (**Table 2**).

The appearance and test of the final product dried with the dryer was also better than that produced through sun-drying. Sun-dried cabbage was darker in colour and tasted sour. This together with the fact that a good quantity of the product can be dried within a short period means that the producer can have a higher turnover for a better quality product. The chances of better revenue are, therefore, high.

The main operating costs for the dryer are for labor and pre-treatment. These are low in the rural setting where family labour is abundant. Analyses on the operation of drying green pepper during the rainy season also showed that, the initial high investment can payback within 18 months. This is even shorter if other commodities are dried and the dryer is used during other periods of the year.

Conclusions

A solar dryer based on the tunnel principle was adapted and tested for the drying of vegetables and other commodities. The results from the tests are comparable to those obtained for similar systems elsewhere. It is, therefore, possible to harness solar energy using this very simple technology to dry vegetables in Cameroon. Using this technique, the drying time is considerably reduced and the quality of the final product is acceptable in appearance and quality. Although the initial cost of the dryer is high, the running cost is low and for a high value crop such as peppers. This could payback in less than two years. It is also possible to continue drying even when the environmental conditions such as rainfall and high relative humidity make it difficult for an open-air drying process to take place.

Table 2 Results of Drying Trials on Some Vegetables on the Solar Dryer

Product	M_0 (%)	M_f (%)	T (hours)
Amaranth (not sliced)	87.9	2.9	30
African red pepper (whole fruit)	80.9	10.8	96
Green cabbage (sliced)	95.6	9.8	130
Bitterleaf (sliced)	84.3	1.2	30
Ripe plantains (sliced)	75.3	20.8	100
African yellow pepper (whole fruit)	86.8	13.4	336
Fermented cassava chips	60.0	10.0	168

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Rural Vegetable Oil Processing in Kenya Status and Research Priorities

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Abstract

A review of the current status of rural vegetable oil processing techniques in various provinces of Kenya and its economic analysis is presented in this paper. A survey carried out showed that rural vegetable oil processing was going a long way to improve the nutritive and financial status of the rural people. It also has great potential if emphasis is put on improvement of oilseed quality, increased production and development of efficient and effective extractors and filters. Formulation of standards for the unrefined vegetable oil is also required so as to ensure consumers safety. It was found that farmers earned over US$ 2,800 per annum from sunflower processing alone.

Introduction

In Kenya, vegetable oils and fats are some of the largest imports of agricultural products accounting for over US$ 150 million (GoK, 2000). This is because local production meets only 18% of the national requirements. The low oil production is attributed to policy, pricing, marketing, quality of oilseeds, processing technology, positioning of processing industries and extension package currently in use (Shitanda, 1994). However, Kenya has a very high potential for oil crop production due to its diversified climatic zone and vast underutilized land, especially in the semi-arid areas. Some of the main crops with such a potential are sunflower, rapeseed, mustard seed, peanuts, soybean, coconut, safflower, castor, cashewnut, and linseed (Zulberti, 1988). The main imports at present are palm, coconut, and soybean oil.

Considering the current exponential birth rate of over 3 %, Kenya's population is expected to be over 40 million people by 2010. It is, therefore, estimated that the country will require over 400,000 tons of edible oil, 800,000 tons of industrial vegetable oils and about 300,000 tons of oilseed cake for livestock industry (Mahasi *et al.*, 1994; GoK, 2000). **Table 1** shows the per capita consumption of edible oils in Kenya over the past almost 30 years.

To be able to meet the oil needs of the rapidly growing population, there is great need for a collaborative approach to the problems by the relevant stakeholders who are the; Ministry of Agriculture, Research Institutions, and Non-Governmental Organizations (NGO's) aimed at boosting vegetable oil production. This would save foreign exchange and improve the nutritive and financial status of the rural people who heavily depend on agriculture.

Table 1. Consumption of vegetable oils in Kenya

Year	kg/capita	Total [tons]
1970	1	10,000
1986	5	105,000
1999	6	250,000
2000	8	350,000

GoK, 2000.

Vegetable Oil Processing

Rural vegetable oil processing in Kenya has been carried out in the country since the incoming of the missionaries over 200 years ago. It involves mainly three stages: a)pretreatment; b)extraction and c)post-extraction stage (Young, 1980). At the present time, processing is carried out in nearly all the eight provinces of the country, although the Ministry of Agriculture used only five provinces for the pilot Rural Oil Protein Production and Processing Project (ROPPPP) in the late 80s. The project was implemented through the national extension program and the Rural Technology Development Units and Centres. Farmers were taught about the production of high quality oilseeds, processing of the oilseeds and utilization of the products. The oilseeds that are mainly processed are sunflower, coconut and groundnut. However, sunflower is gaining more fame since it is more economical to produce and to process. A number of NGO's are also involved in the promotion of rural vegetable oil processing, especially church organizations. The depreciation of the Kenyan shilling, low income for the rural duelers and the high costs of industrially produced oils has tremendously boosted the rural vegetable oil processing in the country. At present there are over 60 individuals and NGOs carrying out small-scale vegetable oil processing in the country, especially in the Eastern and Western regions. The three stages involved in the processing of vegetable oils at the rural level in Kenya are described in greater detail below:

Pre-treatment Stage

This is the stage prior to the extraction stage which mainly involves cleaning, dehulling, scotching (cooking) or roasting of the oilseeds. Cleaning is done manually through hand-picking or by sieves to remove stones, leaves, soil, low quality seeds and other unsuitable materials. Hulling is rarely done except for coconut since extra machines are required. However, in some instances disc and roller hullers are used. Though hulling increases the processing costs, it also increases the extraction rate and reduces the rate of wear in the extraction gauge. Scotching is mainly carried out through sun-drying on some flat surfaces like rocks, concrete floors or black plastic paper so as to increase the efficiency of extraction, and reduce moisture content of the oilseeds. Although the method is effective, it is too slow, not appropriate for large quantities of oilseeds and is environmentally dependent. Low moisture content of about 10-13 % is generally preferred. Roasting of oilseeds has been tried out but has been found to affect adversely the quality of the oil and is also energy consuming (Adeeko *et al.*, 1988).

Extraction Stage

Extraction mainly involves the separation of the raw material into oil and residue (cake). Two methods are mainly used (mechanical and chemical methods), but at present only one method is used at the rural level in Kenya. The method used depends on the oil content of the oilseeds, nature of the oilseeds, scale of production and the final use of the oil or cake (China *et al.*, 1988). At the rural level, mechanical extractors are commonly used since they have low investment cost, requires no skilled labour, have high employment generation, there is no danger of explosion and no chemical contamination occurs. Initially only screw expellers were in use in the country which were mainly introduced by church organizations. However, the expellers have been found to be expensive, not easily available, difficult to run (due to limitations of power), outdated, and difficult to repair when broken down (Shitanda, 1994). However, the screw expeller has high capacity and efficiency compared to the ram press (Khan *et al.*, 1983).

The type of ram press in Kenya was originally designed by Engineer Carl Bielenberg of the Appropriate Technology International (ATI) and is thus known as "Bielenberg Ram Press" (**Fig. 1**). It mainly consists of a piston, compression cylinder, gauge, pressure control cone, hopper, oil pan and a handle. Oilseeds are first put in the hopper when the handle is down and the gauge exit is shut by the pressure control cone. The handle is then moved up and down allowing the oilseeds to enter the gauge through the compression cylinder. When the press becomes difficult to operate and oil starts oozing out of the gauge, the pressure control cone is adjusted to reduce pressure for easy operation and exit of the cake. The extracted oil is collected in the oil pan.

Fig. 1 The bielenberg ram press used at rural level.

The handle length and cone clearance are adjustable so as to vary the pressure in the gauge and the mechanical advantage of the machine. Longer handle and small clearance results in high-pressure and vice versa. Most of the farmers who own the ram press buy their oilseeds from farmers near or far from their operating zone at approximately US$ 0.2/kg for sunflower seeds and US$ 0.4/kg for peanuts. However, some farmers grow their own oilseeds, which is more economical (Shitanda, 1993). Peanuts are, however, rarely used for oil extraction since they fetch higher prices when consumed directly.

Although commonly used at the rural level, the Bielenberg ram press has a number of disadvantages which are a) high initial cost (over US$ 1,000); b) low efficiency (60-70%), heavy weight (over 200 kg) which makes it inconvenient to transport, difficulty of operation, especially for women; and c) low extraction rate of 1-1.5 lit/h. Due to the high precision required for the gauge openings, the Bielenberg ram press can not be easily manufactured by the cottage industry or informal sector. The ATI has, however, come up with a new version of the Bielenberg ram press known as ATI Ram Press(**Fig. 2**). This version is relatively cheap costing about US$ 500. It is easier to operate, lighter (about 100 kg), easy to manufacture, has a higher capacity of about 2 lit/h and efficiency of about 80% (ApproTEC, 1995). The press has greatly gained fame, especially in Western, Nyanza and

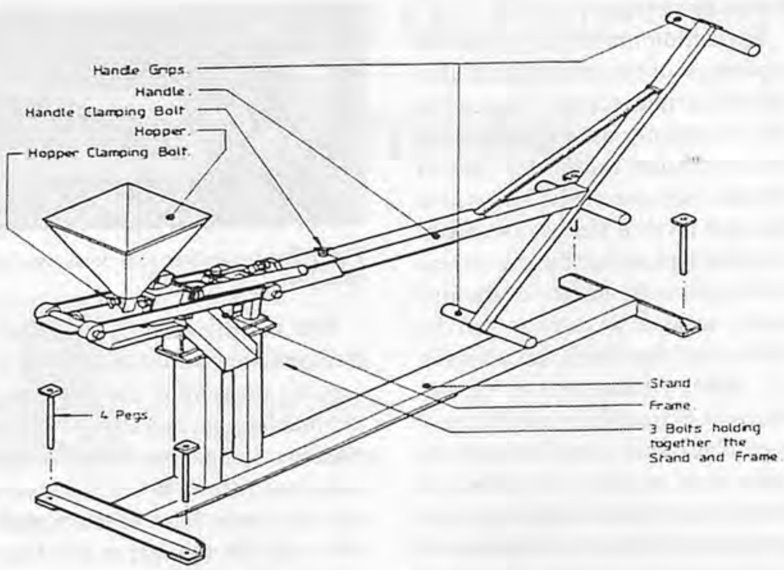

Fig. 2 ATI ram press (appro tec, 1995).

Fig. 3 Designed and fabricated multi-drive screw expeller under test.

Eastern provinces of Kenya, and is being fabricated by local manufacturers (Shitanda, 1994).

To back up the efforts by ATI in order to avail of appropriate technology for the farmers in the rural areas, we designed, fabricated and tested a multi-drive screw expeller (**Fig. 3**) with a view to minimizing drudgery for man, increase capacity and efficiency, and reduce operation costs. This was to be achieved through harnessing the high capacity and efficient mechanism of a screw expeller so as to be operated by human, animal, engine, motor or tractor PTO. The project was undertaken at Jomo Kenyatta University of Agriculture and Technology (Biomechanical and Environmental Engineering Department) with the support of the Japanese International Co-operating Agents (JICA). The expeller is still undergoing further tests but preliminary results are quite promising (Shitanda, 2000).

Post-Extraction Stage

This is the stage that follows the extraction stage in which the extracted oil is purified. Various methods have been used and new others have been proposed. Currently the extracted crude and dark coloured oil is purified either by boiling, sedimentation or filtration method. The crude oil is first sieved to remove large materials like oilseeds, cake and stones using a plastic or metallic strainer sieves. Boiling method is used but on small scale. It involves mixing water with oil in the ratio of 1:2.5 and then boiling the mixture till all the water evaporates. The oil is then allowed to stay undisturbed till all the fine particles settle down and then the clean oil at the top is decanted. Heating facilitates the settling of fine particles in the oil, but the colour of the resulting clean oil changes to brown instead of the normal pale yellow colour. Mugeto (1992) observed that heating the oil affects its storageability since it becomes rancid faster. The method is also wasteful since a lot of energy is consumed and all the oil is not separated. Heated oil is also risky to handle due to the danger of burning.

The sedimentation method mainly involves leaving the crude oil in a cylindrical container of about 0.2 m diameter and 0.5 m height for some time (about 2 days) and then decanting off the clean oil at the top. The method is rarely used since it is too slow, wasteful, and not very effective. It also exposes the oil to oxidation thus facilitating its deterioration. In order to minimize most of the above mentioned problems, the filtration method has been introduced since it is more effective, safe, and more reliable. The column filter shown in **Fig. 4** has been very useful and is commonly used by those with the ATI Ram Press. It consists of a dirty oil reservoir, a dust cover, filter element holder and a cloth filter element. The cloth, which is the main filtering material, is sewn from canvas or coat linings. It is fitted at the bottom of the filtering column in order to increase the rate of filtration through increased head.

Both horizontal and vertical filters are used, although most of them are still under test since no appropriate filtering system for rural processing is available. Although the method results in cleaner and high quality oil, it is relatively slow and the cleaning of the filters becomes difficult due to gumming. To increase the filtration rate, we have now designed and fabricated a centrifugal oil filter, which is currently under test. Preliminary tests have also been quite promising. Since the extracted oil is in constant contact with steel during extraction and purification, there is a high chance of the relatively acidic oil to reacting with the metal resulting in high percentage of iron in the oil. To avoid endangering the life of the consumers, such a possibility needs to be investigated.

Packaging, Storage and Marketing

Purified oil is packaged in 5 or 20 litres plastic Jeri cans and sold to hotels, schools or retailers at about US$ 1/lit. Retailers then sell the oil in small quantities of up to about 100 ml. Local people also come with their own containers, varying in sizes depending on their needs and financial status. People have really liked the oil since it is cheap and " sweet" compared to the industrially produced oil. Farmers have also started packaging their oil and selling it in big towns like the capital city, Nairobi. Excess oil is stored in houses under cool dry and dark conditions. Although Mugeto (1992) recommended the use of translucent containers to reduce rancidity, the containers currently being used vary in color since most farmers simply recycle containers that had other substances. This posses danger because containers which initially had things like paraffin, engine oil or detergents are used. The Kenya Bureau of Standards has also not developed standards for the crude vegetable oil giving farmers a leeway in their operation.

The cake in most cases is put in sacks and stored under cool dry conditions ready for use by the farmers as animal feed. In some cases, the cake is sold at about US$ 0.25/kg to poultry and dairy farmers. Its marketability is, however, poor due to poor extension services and low quality.

Economic Analysis

The case for an entrepreneur processing sunflower seeds using the ATI Ram Press with a useful life of 10 years is thus presented. The approximate costs involved per annum are detailed in **Table 2**. The highest expense is on oilseeds whereas revenue is mainly from the oil. The economic analysis shows that rural vegetable oil processing has high potential in the rural areas and can be a major source of income for the people in the rural areas who live on less than US$1 per day. This can therefore go a long way to alleviating poverty and improving the standards of living of the people.

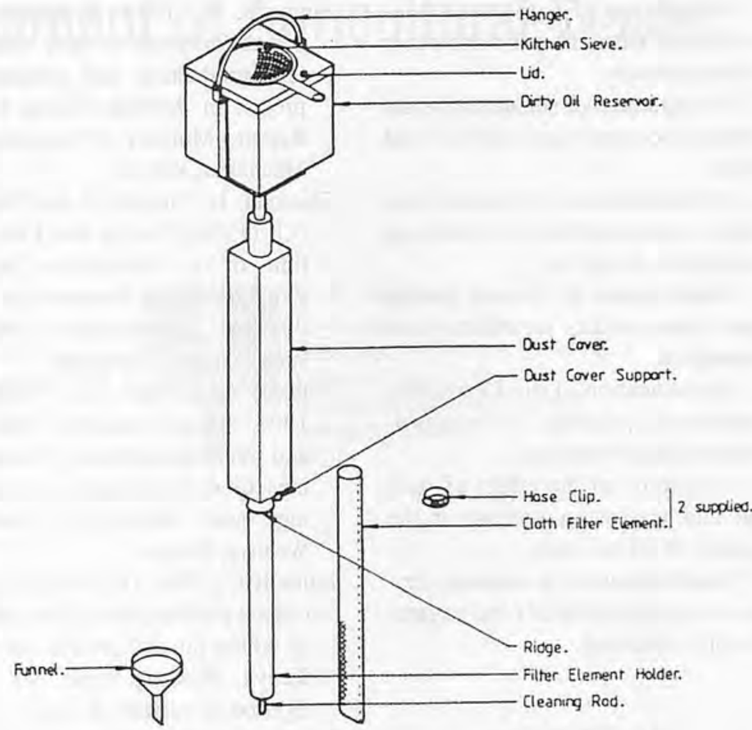

Fig. 4 Column filter (ApproTEC, 1995).

Table 2. Annual Cost Analysis for ATI Press

Item	Expense US$
Machine cost	500
Salvage value	80
Depreciation	50
Housing	10
Interest	50
Taxes and Insurance	6
Total Fixed Costs (TFC)	
Labour	696
	1500
Repair and Maintenance	30
Oilseeds	5,000
Packaging and Storage	385
Total Variable Costs (TVC)	6,915
Oil	9,000
Cake	1,500
Total Revenue(TR)	10,500
Net Annual Return	2,889

Conclusion and Recommendations

Rural vegetable oil processing in Kenya has a very high potential and is quite economical, especially in the semi-arid areas where crop competition is low and drought resistant oil crops like sunflower and safflower can do well. However, it still faces a number of challenges and its success depends on the formulation of strategic plans by the Ministry of Agriculture, NGOs and research institutions in order to address the following recommendations urgently.

Design of high capacity, versatile, and efficient oil extractors and filters.

Formulation of high quality animal feeds from the cake and other oilseeds waste.

Development of standards for the rural processed vegetable oil and cake.

Diversification of product use like in soap and fertilizer making and as bio-diesel fuel.

Improvement of oilseeds quality and characteristics for effective oil extraction.

Intensification of rural extension services to promote oil crop production and processing.

Evaluation of the effect of storage and processing methods on the quality of oil and cake.

Establishment of a resource centre for coordination of rural vegetable oil processing.

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Design and Development of Agricultural Wastes Shredder

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Abstract

A 6-hp, 1800 rpm diesel engine-operated shredder with a capacity of 200 kg/h was designed and developed for agricultural crop wastes shredding viz. castor, cotton and pigeon pea stalks in order to utilize them as organic matter as well as in industrial applications. During testing the cutting unit, feeding unit and power transmission system, etc. worked satisfactorily for designed capacity. At the critical speed of cutter head i.e., 500 rpm, more than 80% cut stalks pieces were observed in the length group of 15 - 30 and 30 - 45 mm with capacity for all three crop stalks. The fuel consumption was 1.15, 1.26 and 1.04 l/h with the shredding capacity of 162, 156 and 179 kg/h, respectively, for castor, cotton and pigeon pea stalks. The average power consumption of the machine at critical speed was 5.23 hp. The total cost of fabrication (including engine) was Rs. 41,000 ($ 820). It was also observed that the required shredding operation period for one-ton stalks of castor, cotton and pigeon pea was 6.17, 6.41 and 5.59 hours, resulting in the respective shredding cost of Rs. 272 ($ 5.44), 282 ($ 5.64) and 246 ($ 4.92).

Introduction

It is seen that the large quantity of agricultural wastes is being unutilized annually because of handling, storage and management difficulties. The agricultural waste has generally low bulk density which ultimately requires large volume for storage. It is also observed that the agricultural waste production is seasonal, while the requirement of industries based on them is continuous which needs a safe and economical storage.

It is realized that if waste is treated in such a way that reduces its storage space, then its use for manurial purpose as well as industrial utilization becomes more viable. The shredded waste can be useful for the production of hard boards, particle boards, corrugated boards and boxes, paper-pulp and industrial application. It is also a useful source of lignin and in animal feeds. In order to utilize agricultural waste in industries as well as organic manure materials, it requires reducing the storage volume, i.e., to break into small pieces. For this purpose a shredder was designed and developed.

Design and Fabrication

The agricultural crop wastes under study, i.e., castor, cotton and pigeon pea crops were harvested in the month of March – April 1998. At the time the waste was to be stored, the moisture content, bulk density, length, top width and weight of stalks and diameter of root/ stem were determined. Such parameters were considered in designing the machine components.

The concept of disc flywheel type power operated chaff cutter was adopted to design the machine with a capacity of 200 kg/h. The maximum bending stress required for cotton plant root was 51.74 kg/ cm^2 (Colwick et al., 1971), which

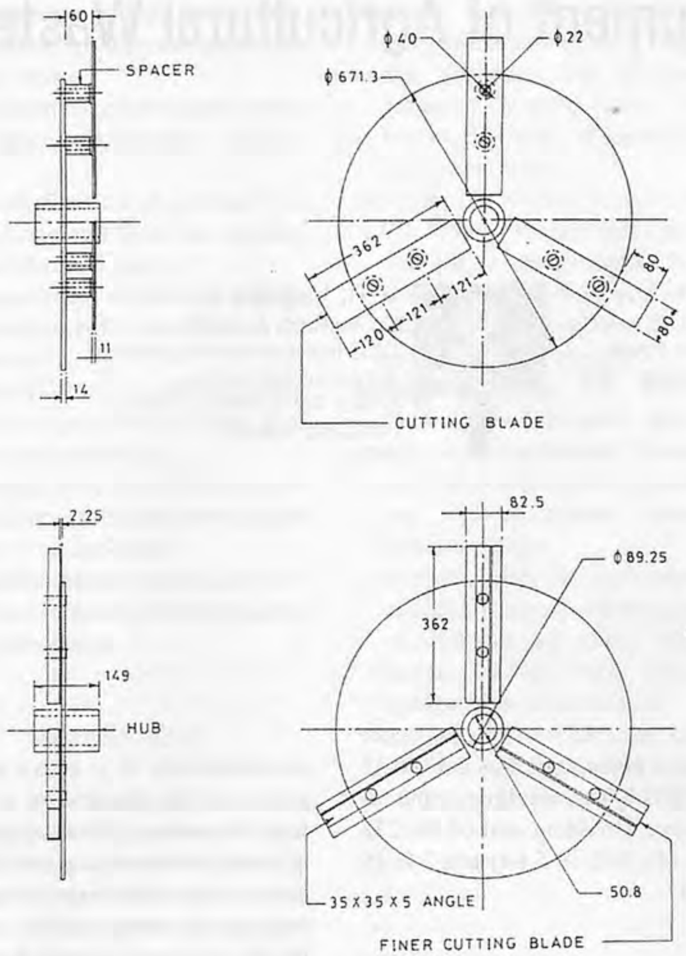

Fig.1 DETAILED DIMESIONS OF CUTTING UNIT

ALL DIMENTIONS ARE IN mm SCALE:-1:10

was considered as equivalent to dynamic shear stress. The force requirement for cutting two stalks simultaneously (25mm root/stem diameter) was calculated by using the Blevins (1954) and Bainer (1955) formula. Considering the power transmission losses, the HP requirement of engine was calculated as: HP = P x S /75

where,

P = Total work done requirement kg-m

S = Speed in rps

In order to meet the required cutter speed and torque, a 6.0-HP, 1800-rpm, air-cooled diesel engine was selected as power source.

Cutting Unit

The cutting unit (**Fig. 1**) consists of a disc-flywheel type cutter head with cutting blades, finer cutting blades, shear plate, shaft and concave.

(a) Shaft

The shaft diameter was designed on the basis of capacity of the machine (200 kg/h), torque to be transmitted (8.73 kg.m) and twisitng moment (1708.2 kg.m) of the shaft using the following formulae:

The torque to be transmitted by the cutter head pulley shaft was:

$T = (P \times 4500) / (2 \pi N)$

The cutter head pulley required an overhung and the distance of the center from the nearest bearing was 17 cm. Therefore, the bending moment on the shaft due to belt pull was:

$M = (T_1 + T_2 + 2T_c) \times 17 \times n_b$

where,

T_1 = Tension on tight side (kg)

T_2 = Tension on slack side (kg)

T_c = Centrifugal tension (kg)

n_b = Number of belts (2)

Then, the equivalent twisting moment was:

$T_e = \sqrt{(T^2 + M^2)}$

and thereby required a diameter of the shaft was:

$D_s^{\ 3} = (16 \times T_e) / (\pi \times f_s)$

where, f_s was taken as maximum permissible shear stress.

The two pedestals with bearing were used to support the cutter head shaft at both the ends.

(b) Fly wheel

The weight of the disc flywheel was calculated from kinetic energy as:

$E_f = [W_f \times (2 \pi \times K_f \times N_f)^2] / 2g$

where,

E_f = Kinetic energy developed per second (kg.m)

W_f = Weight of disc fly wheel (kg)

g = Acceleration due to gravity (m / s^2)

K_f = Radius of gyration of disc fly wheel (m)

N_f = Revolutions of disc fly wheel per second

The required weight of MS plate disc fly wheel was 40.36 kg, considering the average speed of 17.5 m/s, the outer diameter was 671.3 mm and thickness was 14 mm which resulted in the final speed of disc flywheel at 492 rpm. The outer diameter of the disc flywheel hub was determined from the diameter of shaft at 88.9 mm. The length of the hub was 149 mm so as to facilitate the fastening of the bolts on both the sides of the hub. The standard dimensions of a square key for the shaft of 50.8 mm diameter was fabricated for fastening the flywheel and cutter head pulley.

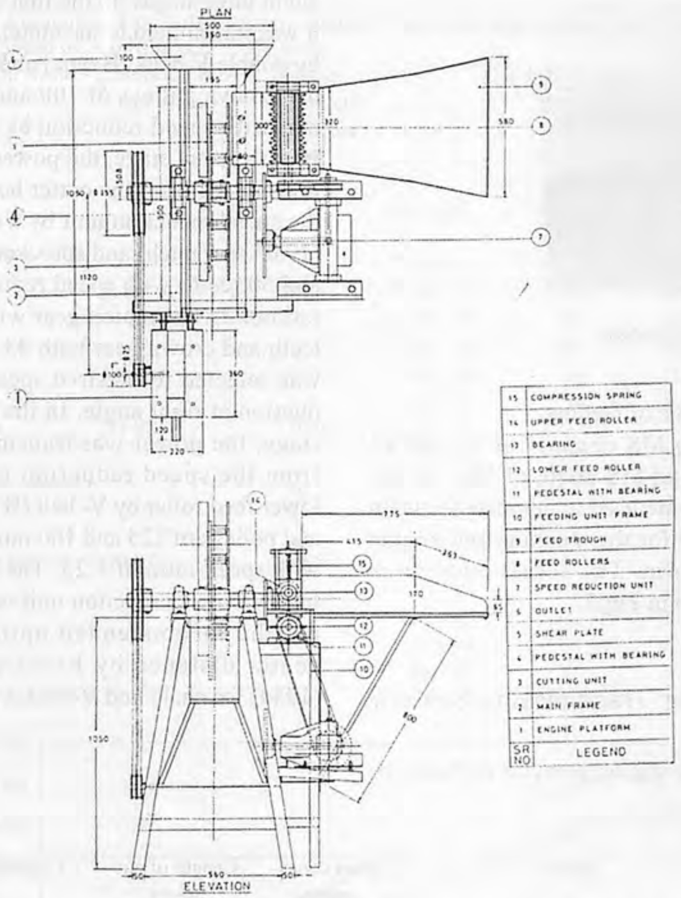

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Fig.2 Plan and front view of shredder.

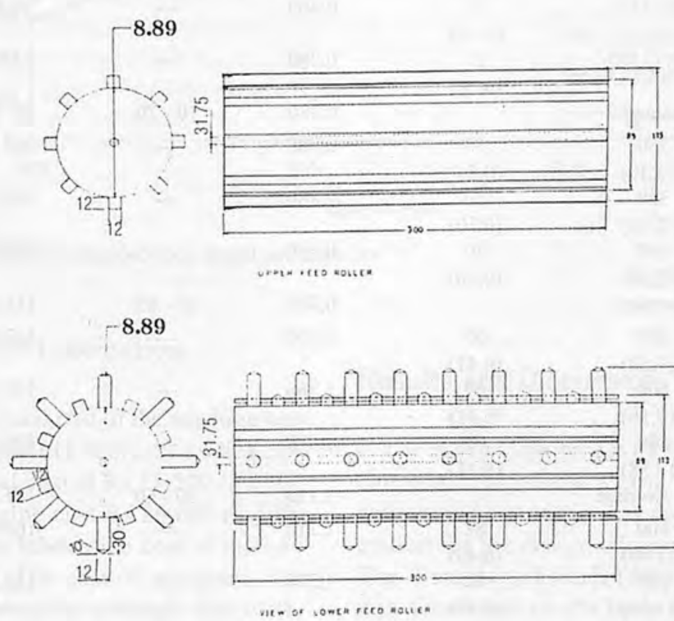

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Fig. 3 Detailed dimensions of feed rollers.

(c) Cutting blades

Considering the strength required for cutting stalks, three blades from leaf spring were fabricated. The size of the blade was 362 x 80 x 11 mm. One side of the blade was sharpened and the edge was made 30^{0} beveled for smooth cutting.

The length of the blade (362 mm) was kept more than the radius of disc flywheel (by 80 mm) in order to recut the long pieces and to prevent clogging. Three finer cutting blades fabricated from "charkha blade" (362 x 82.5 x 2.25 mm) were provided for further cutting of long pieces of waste products.

(d) Concave

The concave was fabricated from an 18-gauge (1.25 mm) GI sheet and MS angle of 25 x 25 x3 mm. The concave grate was made from MS square (9 mm) and round bars (ϕ 6 mm) in such a way that the slot size could be maintained as 25 x 45 mm. The shield was fabricated from a 20-gauge (1.00 mm) GI sheet and bolted to the main frame. The shear plate (300 x 80 x 11 mm) was made from a cutting blade material with square corners so that they could be turned to use all the four corners before being sharpened or discarded.

(e) Feeding unit

The feeding unit consisted of a feeding trough and feed rollers (**Fig. 2**). The objective of the feeding trough is to provide a passage to feed the material to be cut, while the feed rollers were functioning to catch, compress and convey the material towards the cutter head. The feeding trough was fabricated from a 20-gauge (1.00 mm) GI sheet. The trough was completely horizontal for easy feeding and easy entry of long stalks. Two feed rollers (upper and lower) were fab-

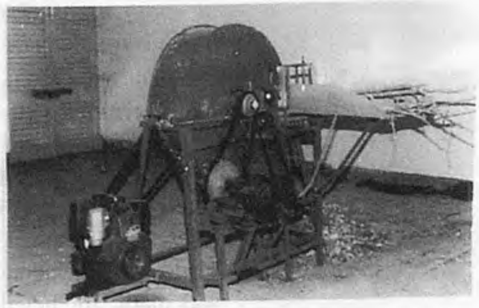

Fig. 5 Agricultural wastes shredder.

ricated from a GI pipe with a diameter of 88.9 mm. In both rollers, 8 bars of MS square of 12 x 12 mm were welded axially on the periphery (**Fig. 3**). In the case of the lower feed roller about 60 spikes (ϕ 12 x 30 mm) were welded in between square bar throughout the periphery. The upper feed roller was kept hanging by providing compression spring at both ends, which helped to compress the material to be cut at the time of feeding.

The MS channel of 75 x40 x5 mm and MS angle of 50 x 50 x 5 mm were used to fabricate the main frame for the machine and engine platform. The actual position is shown in **Fig.5**.

Power Transmission System

The engine power was transmitted in three stages. In the first stage, it was transmitted to the cutter head by double V-belts (B type) and double groove pulleys of 100 and 355 mm with speed reduction as 3.55. In the second stage, the power was transmitted from the cutter head to the speed reduction unit by a chain (19.05 mm pitch) and sprockets (25 and 50 teeth) with speed reduction ratio of 2. The pinion gear with 10 teeth and crown gear with 43 teeth was selected for desired speed reduction at right angle. In the third stage, the power was transmitted from the speed reduction to the lower feed roller by V- belt (B type) and pulleys of 125 and 100 mm size with speed ratio of 1.25. The location of speed reduction unit was as per the recommended optimum center distance by Krutz et al. (1984) for chain and V- belt drive.

Table 1 Test Performance Results of the Shredder

S. No.	Crop waste	Moisture content of stalks (%)	Speed: Cutter head rpm(mps)	Speed: Feed roller rpm(mps)	Fuel consumption (l/h)	Length of cut pieces (mm)	Capacity (Kg/h)
A-1	Castor	9.65	200 (7.03)	27 (0.16)	0.310	---	58.5
A-2	Cotton	11.05	200 (7.03)	27 (0.16)	0.400	---	56.5
A-3	Pigeon pea	10.95	200 (7.03)	27 (0.16)	0.280	---	67.0
			Average		0.330	10 - 70	60.7
B-1	Castor	9.65	350 (12.30)	50 (0.30)	0.700	---	109.5
B-2	Cotton	11.05	350 (12.30)	50 (0.30)	0.880	---	105.5
B-3	Pigeon pea	10.95	350 (12.30)	50 (0.30)	0.630	---	126.5
			Average		0.737	10 - 65	113.8
C-1	Castor	9.65	500 (17.58)	69 (0.41)	1.150	---	162.0
C-2	Cotton	11.05	500 (17.58)	69 (0.41)	1.260	---	156.0
C-3	Pigeon pea	10.95	500 (17.58)	69 (0.41)	1.040	---	178.5
			Average		1.150	10 - 60	165.5
D-1	Castor	9.65	600 (21.09)	82 (0.49)	1.210	---	168.0
D-2	Cotton	11.05	600 (21.09)	82 (0.49)	1.290	---	162.5
D-3	Pigeon pea	10.95	600 (21.09)	82 (0.49)	1.135	---	180.0
			Average		1.212	10 - 60	170.2

Table 2 Length of Cut Stalk Pieces of Castor, Cotton and Pigeon Pea at the Cutter Head Speed of 500 Rpm (i.e. 17.58 m/s)

Crop waste	Moisture content of stalks (%)	Sample weight of cut-stalk pieces (g)	Cut stalk pieces		
			Length (mm)	Number	Per cent
Castor	9.65	90.5	0 - 15	10	6.21
			15 - 30	68	42.24
			30 - 45	64	39.75
			45 - 60	18	11.18
			60 - 75	1	0.62
Cotton	11.05	70.0	0 - 15	3	2.83
			15 - 30	53	50.00
			30 - 45	41	38.68
			45 - 60	9	8.49
			60 - 75	---	---
Pigeon pea	10.95	84.5	0 - 15	5	4.07
			15 - 30	57	46.34
			30 - 45	44	35.77
			45 - 60	15	12.20
			60 - 75	2	1.63

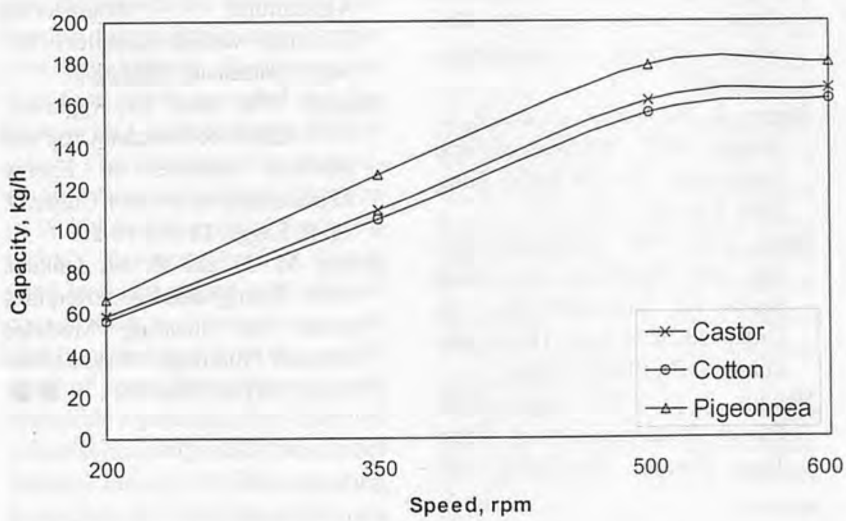

Fig. 4 Relationship between speed and capacity.

Cost of Fabrication

The total cost of the machine was Rs.41,000 ($ 820), including the material cost at Rs.11,500 ($ 230), the engine cost Rs.26,000 ($ 520) and the fabrication cost of Rs.3,45 ($ 69). The cost of operation was determined by a straight-line method, which was Rs.44 ($ 0.88) per hour.

Results and Discussion

The physical properties of castor, cotton and pigeon pea crop were determined and taken into consideration for the design of shredder. The diameter of shaft (50.8mm) was determined on the basis of the capacity of the machine (200 kg/h) and torque to be transmitted (8.734 kg-m). During the working of machine the shaft diameter was satisfactory from a strength point of view as no breakage or twisting of the shaft was observed. Disc flywheel, cutting blades and shear plate were also found satisfactory for their functional requirement.

The design dimensions of trough and feed rollers in feeding unit were found convenient for material feeding as per designed capacity. The size of slots (45x25 mm) and width of concave (195 mm) were suitable for designed capacity as no clogging problem felt during its testing. The power transmitted from engine to cutter head by the double V-belts (B-type) and pulleys (100 & 355 mm) helped in reducing the belt slippage during speed fluctuation. No overloading of engine was observed during the testing.

During the testing the output of the machine and fuel-consumption at varying cutter head speeds of 200, 350, 500 and 600 rpm for selected wastes are shown recorded in **Table 1**. The curve Fig. 4 shows the relationship between the capacity of the machine and the speed of cutter head. The capacity of the machine increased with an increase in the cutter head speed from 200 to 500 rpm. The cut pieces were categorized in five groups depending on their length of cut viz. 0-15, 15-30, 30-45, 45-60, and 60-75 mm. The speed of the cutter head (500 rpm) with higher percentage of finer cut pieces was considered as the critical speed of the cutter head shown in **Table 2**.

During the testing, the critical cutter head speed for fuel consumption was found as 1.15, 1.26 and 1.04 l/h, respectively, with respective capacities of 162, 156 and 179 kg/h, in the case of castor, cotton and pigeon pea stalks. The operation period and cost of shredding for one ton of material was also determined. Taking into account the market value of the shredded material at Rs. 800 ($ 16) each to 1000

($ 20) per ton, and the average cost of raw material was about Rs. 100 ($ 2) per ton. The resulting average shredding cost was Rs. 266 ($ 5.32) per ton with the benefit-cost ratio of 2.44.

Conclusions

1.During testing, the cutting unit, feeding unit and power transmission system worked satisfactorily for their functional performances at the designed capacity of machine (200 kg/h).

2. The cutting unit of the disc type flywheel with 3-cutting blades fulfilled the functional requirements and helped to increase the machine performance.

3. The rate of feeding was well controlled by the feed rollers and smooth working of the feeding unit without any breakage.

4. The functioning of the power transmission system was found satisfactory without slippage and any complication in mounting on the frame.

5. At the cutter head speed of 500 rpm more than 80 % cut pieces of stalks were observed in the length group of 15-30 and 30-45 mm in case of all selected crop stalks.

6. At critical cutter head speed (500 rpm), the fuel consumption was 1.15, 1.26 and 1.04 l/h with the shredding capacity of 162, 156 and 179 kg/h for castor, cotton and pigeon pea stalks, respectively.

7. The required operation period for one ton stalks of castor, cotton and pigeon pea stalks was 6.17, 6.41 and 5.59 hours, respectively.

8. The required cost of shredding for one-ton stalks of castor, cotton and pigeon pea was Rs. 272 ($ 5.44), 282 ($ 5.64) and 246 ($ 4.92), respectively.

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Dynamometer Design for Traction Forces Measurement on Draught Horses

by
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Abstract

The paper describes the design of an extended octagonal ring transducer. Four equal transducers were designed and each one assembled in an individual compact sensing unit to measure the horizontal and support forces acting on each foot of a draught horse. Each force, on each foot, can be recorded simultaneously and independently of each other. The dynamometer was required to measure vertical forces up to 10 kN and horizontal forces up to 5 kN. During calibration, the applied load and output volts of both channels for each transducer were highly correlated with the coefficient of correlation, R2 ≈ 1, with negligible hysteresis. The observed cross-sensitivity of a transducer was less than 2.5 %. The mounting procedure for direct measurement of vertical and horizontal forces acting on the foot at different times during walking is also described.

Introduction

Generally, the work performance of draught animals is measured by quantifying their capacity to generate power. The draught (horizontal) component of pull has been of most interest to researchers concerned with animal traction because it determines the design of animal drawn implements and sets limits on the feasibility of using them in a given condition.

Hitherto, force measurements on animals have been restricted to monitoring the force developed by all limbs combined, usually by means of a tension link dynamometer acting along the axis of the traces. In order to make a complete analysis of the mechanics of traction of an animal, it is necessary to know the forces that are produced by the legs at the point of contact with the ground, i.e., the traction forces and the support forces.

Against this background this study examined the practicability of measuring both vertical and horizontal forces at the point of contact between ground and feet of a horse during draught work and explored the implications of the results.

Special measuring devices have been designed, manufactured and tested to obtain information on how these forces change while the animal is in motion. Instruments fitted to the hooves of the horse (one per foot) should create minimum interference with the animal at work, and should not impose undue stress.

Acknowledgements

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Materials and Methods

Development of the Dynamometer

In order to carry out the research it was necessary to design compact transducers capable of measuring the supporting force at each foot of the horse and the tractive force developed.

It was decided that the best option was an extended octagonal ring strain gauge transducer. Several transducers of this type were built for use in agricultural engineering (Godwin, 1975; O'Dogherty, 1996; Thakur et al., 1988). The transducer was chosen for its convenience in use, its rigidity and high stability, and its ability to make a biaxial measurement of forces. **Fig. 1** shows the basic structure of an octagonal ring dynamometer.

Where, the dimensions are defined as:

2L = distance between ring centres
w = width of the ring
r = internal radius of the ring
t = ring thickness
g = ring gap

An important feature of the instrument is that, if possible, it should be able to be attached to and removed quickly from the animal's foot at the beginning of each working session. This makes management of the experimental work much easier. In order to achieve this a special boot was chosen. The

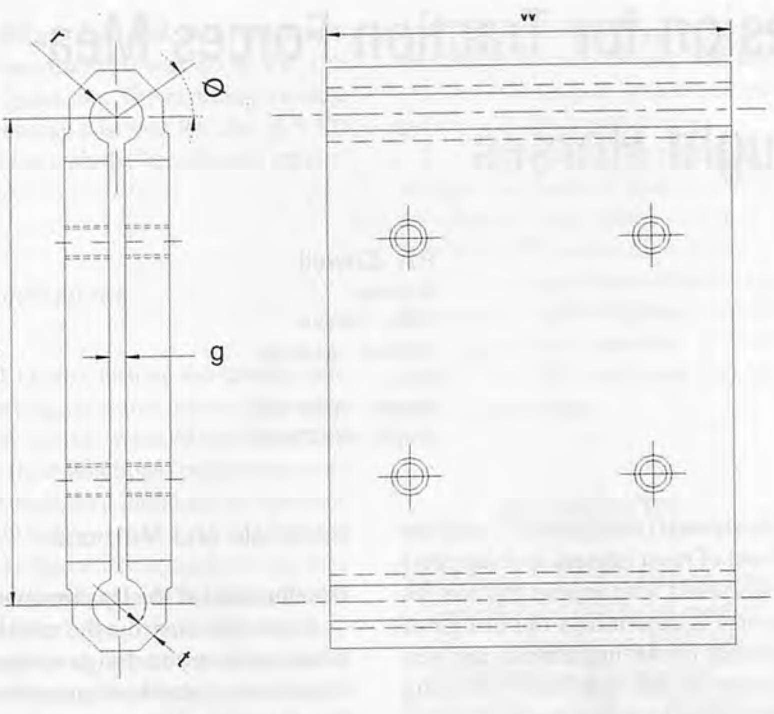

Fig. 1 Sketch of the extended octagonal ring dynamometer.

boot, called "equiboot", is slipped onto the horse's feet and secured by means of a buckle and a tension cable making the fitting tight and secure.

In order to obtain the boot size for the particular test horse, the hoof was measured across the bottom at the widest point. Two sizes were selected; size E5 (139.7mm - 146.1mm) for the forelegs and for the hind legs E4 (123.8mm - 133.4mm). The difference in size is due to the fact that the front feet are usually nearly circular while the rear ones are larger, and more elliptical in shape.

The overall assembly of the equiboot, octagonal ring transducer and horseshoe is shown in **Fig. 2**. A flat plate was placed inside the equiboot and the octagonal ring transducer was attached to the base of the boot by screws. Another flat plate was screwed in a similar manner beneath the transducer to which a mild steel horseshoe was attached.

Because the assembled unit has to be fitted underneath the existing horseshoe, the horse is raised. In order to avoid lifting the horse too much above the ground the dynamometer should be as thin as possible.

The instrument and associated parts are an extra weight added to the foot of the horse which can cause discomfort and can interfere with its standard walking pattern. In order to minimise weight, an aluminium alloy HE 15 was used. This is a light material and strong enough to resist the forces to which the dynamometer will be exposed. The dynamometer was required to measure the supporting forces up to 10 kN and tractive forces up to 5 kN. **Fig. 3** shows the final dimensions of the extended octagonal ring transducer.

The distance 2L (= 90 mm) was selected to suit the length of the existing horseshoe, w = 75 mm (active ring only) was chosen to give the maximum area consistent with the width of the horseshoe. The radius r = 5 mm was selected in order to keep the total thickness (t) of the dynamometer to a minimum. Finally, a ring gap of 3 mm was chosen to separate the two beams.

In this special case, external dimensions outside the main shape of the extended octagonal ring transducer were added to increase the bearing area, increase its stiffness, and to adapt it to the irregular shape of the hoof (Ortiz-Laurel, 1992).

Since it is uncertain whether or not a horse draws equally with the right and left legs, four sensing units were built for the test. By this means it is possible to determine the forces developed by the four limbs separately and instantaneously.

Although considerable effort was made to obtain sensing units that were as thin and light as possible, a thickness of 50 mm was required from the bottom face of the lower horseshoe to the upper plate inside the boot with a total weight of 1.8 kg.

Fig. 2 Overall assembly of a foot dynamometer.

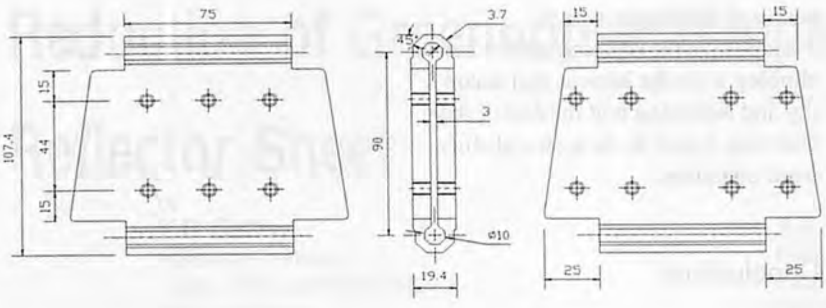

Fig. 3 Final shape and dimensions of a foot transducer.

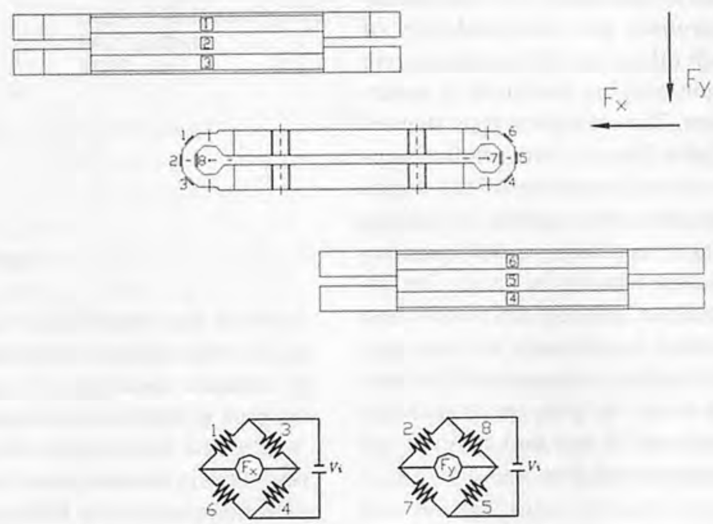

Fig. 4. Strain gauge disposition and bridge circuits.

Strain Gauges Nodes and Bridge Circuits

Cook et al., (1963) found the strain nodes at the following angular positions for octagonal rings; 50° and 90°. At the gauge position of 50°, Godwin (1975) found experimentally a cross sensitivity problem in which the Fx bridge was sensitive to Fy. He recommended a new position for the gauges for measuring the force Fx at 34°.

Strain gauges with a gauge factor of 2.085 and resistance of 120 ohm were used. The bridge supply voltage was 5 V, which was provided by a data logger.

The factors that dictated the gauge size was space available for mounting the gauges on the faces of the transducer, and also the inner ring surfaces required a short gauge length. In the latter case it was necessary to develop a careful installation procedure to bond the strain gauges inside the small holes.

In order to minimize cross sensitivity, attachment of the strain gauges on the dynamometer at the exact positions was done by following the indications given by Godwin (1975). **Fig. 4** shows the location of the strain gauges on the dynamometer.

After the gauges were installed and wired, two Wheatstone bridge circuits were employed using the eight gauges.

Table 1. Sensitivities and cross sensitivity values of the dynamometers

Extended octagonal ring transducers	Sensitivity ($\mu V\ N^{-1}\ V^{-1}$)		Cross sensitivity (%)	
	Fy	Fx	Fy in Fx	Fx in Fy
Front-right	0.142	0.129	1.82	0.922
Front-left	0.144	0.140	2.44	1.022
Rear-right	0.165	0.133	2.35	0.922
Rear-left	0.155	0.134	0.411	0.592

Calibration

The calibration of each extended octagonal ring transducer was performed by putting different known loads in the Fx and Fy directions and measuring the change of voltage in the strain gauge circuits when loading and unloading. To take into account the influence of the data logger the measurement of the resulting voltage during the calibration was made by using the same frequency as used for the experimental tests.

The choice of a data logger as the data recording system was mainly influenced by the need to be able to operate in the field and to avoid any interference with the horse during the measurement phase.

Data collected by the logger can be transferred to a portable computer for storage on a floppy disk. Subsequent analysis could then be carried out using a software package for data manipulation. The data logger also supplied the excitation voltage for all the measuring instruments.

After the main calibration test in the laboratory a simplified calibration test was devised for use before and after each set of experiments. Comparisons of the results revealed no significant changes.

Readings of both bridges were recorded while the transducers were loaded and unloaded by equal increments to compute any interaction of the forces, and to show any hysteresis. The sensitivity associated with the different bridge circuits for the forces acting on each transducer are shown in **Table 1**.

Since minor imperfections arose during the manufacture of the dynamometers and the installation of the strain gauges it is unlikely that only the corresponding bridge will record a force. Small deflections (interaction) could also be recorded on the bridge designed to register a force at right angles to the one applied on that particular situation.

Results

The interaction between the two force measurements of the four transducers was generally small. As an example, for the front-left dynamometer, when the vertical load was applied, the effect on the horizontal force bridge was 2.44 percent or less of that of an equal horizontal load. The effect of the horizontal force on the vertical force bridge was also generally small, with a mean value of 1.02 percent of that of an equal vertical load. The complete results of the maximum cross sensitivity during the calibration tests are shown in **Table 1**.

Field Test

Preliminary experiments were carried out to determine the repeatability of a series of steps taken by the horse. A study of this variation affords the basis for deciding upon the number of steps to be taken into account in the practical tests.

The animal on which the experiments were carried out was a 12-year-old gelded highland pony. The normal behaviour of the horse was not seriously restricted when using the modified equiboots.

The maximum number of complete walking cycles achieved by the horse to fill out the memory capacity of the logger was 3.

Handling the sensing unit when slipping it on the hooves and securing and removing it at the end of the trial was found to be a straightforward operation.

Conclusions

Four equal extended octagonal ring dynamometers were designed and found capable of making a biaxial measurement of forces, simultaneously and independently of each other, providing an accurate strain gauging operation is undertaken. The calibration tests showed reliable linearity between loads applied and response of the dynamometers with very low hysteresis. Interactions between the transducers were found to be small. The assembled sensor units did not interfere significantly with the normal walking behaviour of the testing horse, despite an increase in height of 50 mm and a weight of 1.8 kg on each foot.

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Reduction of Greenhouse Temperature Using Reflector Sheet

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Abstract

Solar insolation and ambient temperatures remain quite high during the summer months in Northern India. In order to keep the inside air temperature within controlled limits, summer greenhouses are required to be equipped with some cooling equipment. The installation and operation of such equipment is costlier and consumes a lot more energy. Irregular availability of electricity in the rural areas makes it more difficult to operate such equipment. Therefore, greenhouses are required to be designed or modified using some low cost and effective technology which is easy to use and saves energy required for cooling the greenhouses. Thus an aluminized polyester sheet of 24 microns thickness was used inside a 100-m^2 polyhouse at a height of 2.5 m from the ground with the reflective side facing the sky. It was observed that the total solar radiation (Kw/m^2) entering the poly-house was reduced by about 43%, thereby reducing the inside air temperature by 3-4°C as compared to the polyhouse without the reflector sheet. An increase in the inside relative humidity by about 10% was also observed. If this sheet were used in conjunction with the other conventional methods of cooling like fan and pad and evaporative cooling etc. a significant amount of energy can thus be saved. Light intensity inside the polyhouse also decreased. However, during the summer months, light intensity inside the greenhouses well exceeds the required limits of most of the plants and even if some part of it is reflected, the photosynthesis process of plants is not affected.

Introduction

In order to protect the crop (vegetables and flowers) against adverse weather conditions and to regulate better growth, protective cultivation is practiced. Under northern India conditions there are more sunshine hours all the year round. In the hot summer months of the year temperature inside the greenhouse rises too much and becomes fatal for the plants grown inside. There are a number of cooling methods by which inside air temperature can be controlled. Ventilation (natural or forced) of the greenhouse can lower the inside air temperature during autumn and spring but it becomes ineffective during the hotter months of summer. Other methods like fan and pad system and high pressure mist system have to be employed for effective cooling of greenhouses during these months. These methods are economically not feasible at the farmer's level as these involve high initial and running costs. These methods also depend upon electricity which is not regularly available in the villages of Punjab. Shading of the greenhouse roof is also practiced during hot summer months [2]. Commercial shading compounds or minutes prepared with paint pigments are used for this purpose. White compounds reflect 83% of the sunlight as against 43% by green or 25% by blue or purple. The disadvantage of shading the roof is that it becomes a permanent feature. During the cloudy days and off shine hours when light intensity inside the greenhouse is already low, it affects the photosynthesis rate of the plants. The effect of shading on the quality of tomatoes grown under plastic greenhouse was shown by Lagier [3]. A movable shading screen was used inside a polyhouse for peak summer months. It was observed that anyway not much change in the aver-

Table 1. Thermal data for greenhouses fitted with and without reflector sheet.

Day	Polyhouse with reflector sheet				Polyhouse without reflector sheet			
	Temp. °C	RH %	Rad. kw/m²	Light Lux × 100	Temp. °C	RH %	Rad. kw/m²	Light Lux × 100
1	31.0	65.3	0.09	161	34.4	82.3	0.18	415
2	36.9	74.0	0.10	175	39.0	64.0	0.24	430
3	36.9	81.3	0.13	320	39.1	62.6	0.27	547
4	39.7	74.3	0.18	254	42.0	61.6	0.34	485
5	39.8	79.6	0.16	219	42.7	59.0	0.28	483
6	41.2	80.0	0.16	332	44.2	64.3	0.28	494
7	40.3	85.0	0.15	149	42.8	77.3	0.23	219
8	37.0	85.0	0.15	159	39.6	77.3	0.17	233
9	40.4	80.0	0.20	201	42.4	69.3	0.28	343
10	39.0	80.0	0.13	166	42.6	63.0	0.22	290
11	39.4	72.6	0.20	279	42.8	66.0	0.31	416
12	39.9	80.0	0.14	192	42.2	59.6	0.29	483
13	39.3	81.0	0.14	222	41.8	56.6	0.28	435
14	35.1	82.3	0.10	177	36.6	58.6	0.20	368
15	38.8	80.0	0.09	126	41.8	61.0	0.25	457
Avg.	38.3	78.7	0.14	195	41.2	65.4	0.40	640

age air temperature could be achieved. However, the light intensity falling on the ground was reduced drastically because the solar radiation once entered the greenhouse was absorbed by the shading screen and not reflected back to the open sky. Simpkins [5] experimentally evaluated a number of curtain materials. The authors estimated that half of the energy needed to heat a double layer, inflated polyethylene greenhouse could be saved by using a highly reflective internal curtain. Rebuck [4] observed savings up to 60% in heating requirements by using a night curtain of an aluminum foil hybrid fabric. Albright [1] tested a night curtain with both sides reflective. The greenhouse had 40 tons of rock for storage of solar energy in cold environment. During night the curtain called "thermal screen" enclosed the heated rocks and the plants grown with less than a meter of clearance above plant height. It was observed that nighttime heating requirements were reduced by about 70%. Many similar studies have been conducted during the last two decades about the use of reflector sheets as night curtains to reduce the radiation heat loss from the greenhouse to the surroundings in cold environmental conditions of Europe and Canada. However, in northern India, environmental conditions are exactly reverse and greenhouses receive excessive solar radiation during the hot months of the year. Different cooling methods (external or internal) have to be used to control the inside air temperature of the greenhouses.

In this regard, our research study was conducted using an aluminized polyester sheet inside the greenhouse during the daytime to reflect back the excessive solar radiation falling over the roof of the greenhouse.

Methods and Materials

Two greenhouses, each of single cover polyethylene sheet (UV stabilized, 200 microns) were selected at the Department of Floriculture, Punjab Agricultural University, Ludhiana Punjab, with floor area of each greenhouse of 100 m^2. Inside one of the greenhouses (called A) an aluminized polyester sheet of 24 microns was spread at a height of 2.5 m from the greenhouse floor with metalized side facing the sun. The sheet was spread only during the peak hours of the day, i.e., from 11 AM to 4 PM and was rolled during the cooler hours of the day. The height was selected such that during the morning and evening hours when the altitude angle of the sun was low, plants were able to receive direct sunlight without being reflected by the sheet. As the sun angle increased during the noon hours, the sheet reflected the excessive solar radiation falling on the greenhouse roof thereby causing

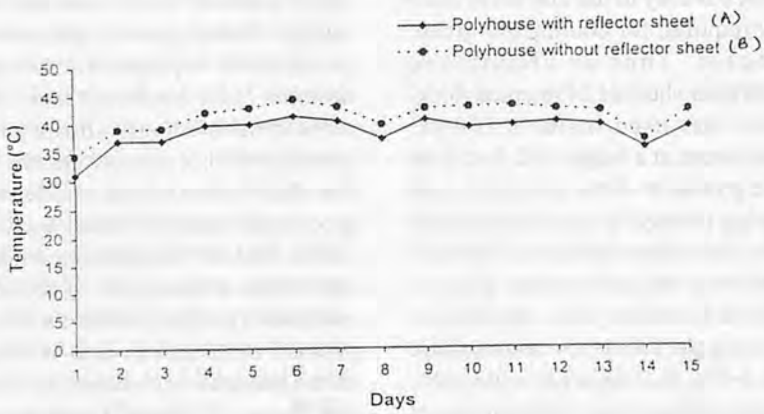

Fig. 1 Daily average air temperature.

the cooling effect inside the greenhouse.

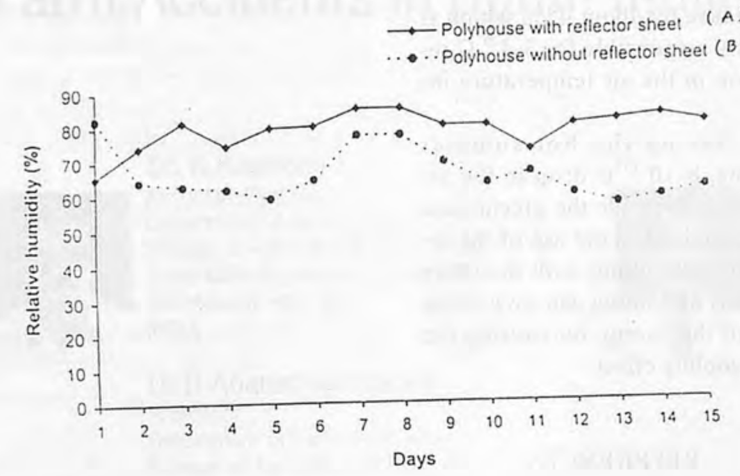

Fig. 2 Average daily relative humidity

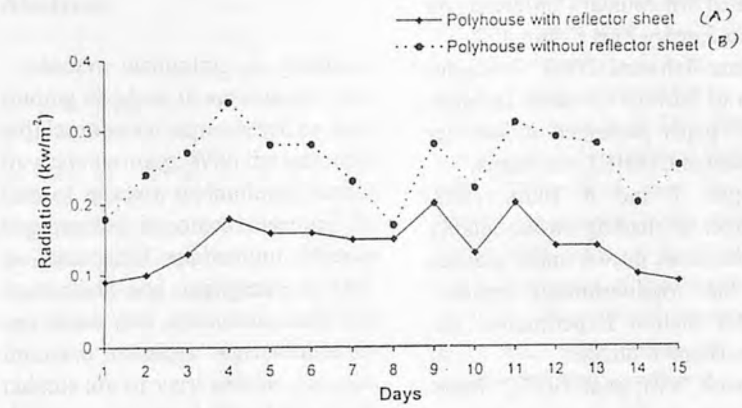

Fig.3 Daily averages solar radiations

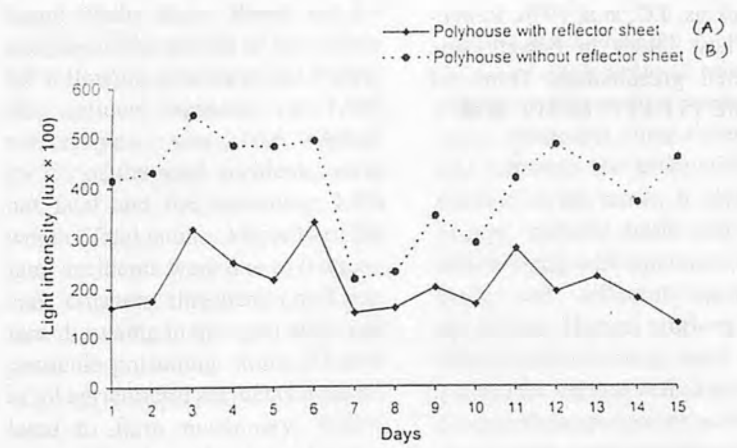

Fig. 4 Average daily light intensity

In order to find out the effect of the reflector sheet on different parameters, thermal data for both greenhouses were recorded three times a day at 9 am, 1 pm and 5 pm for the month of June, 2001. For ventilation purposes exhaust fans in both the greenhouses were kept operative during the daytime. Inside and outside air temperatures were recorded with mercury thermometers. The maximum and minimum temperatures were also recorded for each greenhouse. Relative humidity was recorded with a hygrometer. Solar radiation in Kw/m^2 was measured using the Solarimeter. A luxmeter of two lac lux was used to measure the light intensity inside the greenhouses.

Results and Discussion

The average values of the thermal parameters recorded for both greenhouses during the 24 hours have been calculated and shown in **Table 1**.

The effect of the reflector sheet on different thermal parameters is characterized for average air temperature; relative humidity; solar radiation; and light intensity as follows:

Average Air Temperature

The average air temperature each day for the greenhouse A was observed to be significantly lower than that of the greenhouse B as shown in **Fig. 1**. The average taken for all the days reveal that the average air temperature inside the polyhouse A was 3-4°C lower than that of the greenhouse B. This drop in the average air temperature was achieved due to the reflection of excessive solar radiation's falling on the greenhouse A during the peak hours of the day.

Relative Humidity

The relative humidity for the greenhouse A fitted with a reflector sheet was observed to be higher than that of the greenhouse B as shown in **Fig. 2.** The total average of the relative humidity for all the days for greenhouse A was 78.7% as compared to the greenhouse B which had 65.4% of relative humidity. This increase in RH value was attributed to the reduction in the greenhouse air temperature at the same specific humidity caused by sensible cooling.

Solar Radiation

The solar radiation entering the greenhouse A was significantly lower as compared to that in the greenhouse B for each day as shown in **Fig. 3**. The total average of solar radiation of all the days for greenhouse A was 0.14 kw/m^2 whereas it was 0.25 kw/m^2 in greenhouse B. Hence a drop of 43% in the solar radiation was observed inside the greenhouse B. Thus, it is clear from the above result that the major part of the solar radiation entered the greenhouse during the peak hours of the day. Hence using the reflector sheet only during the peak period is justified.

Light Intensity

The light intensity entering the greenhouse A was less than that entering the greenhouse B for each day as shown in **Fig. 4.** The total average of light intensity for all the days for greenhouse A was 19.5 kilo lux as compared to 64 kilo lux in the greenhouse B. However, it was observed from the literature that light requirements of different greenhouse plants for photosynthesis are about 20 kilo lux only. Thus the reduction in the intensity of light inside the greenhouse was sufficient during the summer months to meet the photosynthesis requirements of the plants.

Conclusions

Based on the results the following conclusions can be drawn:

1. The use of reflector sheet reduces the solar radiation inside the polyhouse by about 43% which is directly responsible for 3-4 $^{\circ}$C reduction in the air temperature inside.
2. During the hot summer months, 8-10 $^{\circ}$C drop in the air temperature inside the greenhouse is required. Thus the use of the reflector sheet along with the other methods of cooling can save about 33% of the energy for causing the same cooling effect.

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Farm Accidents in South India: A Critical Analysis

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Abstract

Modern technology is gradually finding its place in agriculture, with still large-scale dependence on family scale farming. With the introduction of modern technology, human engineering becomes essential for its successful application. Human inattention and negligence in various tasks and operations look like innocent mistakes. Agricultural accidents are of very serious concern. A survey of agricultural accidents was conducted in 12 selected villages from 7 agro-climatic regions of Tamil Nadu State. Based on the analysis of the results of the survey the following inferences are drawn: The accident incidence rate/1,000 workers/year was 10.6. About 95.7% of the total accidents: were not fatal and the remaining 4.3% were of fatal nature. Majority of the fatal accidents were due to tractors, cane crushers, threshers, chaff cutters, drowning in the open wells and pesticide poisoning. Some 77.48% of all agricultural accidents were related to farm machinery; 9.92% were related to hand tools; and 13.60% were related to other sources. Accidents due to hand tools were not fatal. The highest incidence rate per 1,000 machines per year was found in the case of cane crushers (58.67); followed by thresher (42.5); sprayer (14.5); tractor (14.3); chaff cutter (8.94); spade (0.48); and sickle (0.38). Based on the survey it is estimated that in the year 2000 there may be about 94,478 agricultural accidents in Tamil Nadu causing death of about 4,128 workers and injuries to about 90,350 workers which includes finger cuts, amputation of limbs, crushing of body parts, etc.

Introduction

Farm mechanization along with increased application of other agricultural inputs such as seeds, fertilizers, pesticides, insecticides, etc. has enhanced the productivity and production on farms. It also needs energy, suitable tools and implements along with operators for carrying out different agricultural operations. Human workers are the main forms of energy used in agriculture for various activities besides the use of electric power, mechanical power and other non-conventional energy sources. The use of agricultural tools and implements and other machines is always risky to human safety, if they are not used properly. Accidents are very common in various agricultural operations due to ignorance, lack of training, lack of knowledge about the operation and improper design of tools and implements. To avoid these accidents and to study on the safer design and use of tools and implements, the science called human engineering or ergonomics is used. Human inattention and negligence in various tasks and operations look like innocent mistakes. Surprisingly, there are indications that people accept accidents as fate and uncontrollable and thus not compelled to eliminate them systematically. However, practically all the accidents - at least their chances and severity can be controlled or minimized by adequate consideration and strategic applications of human factors.

Review of Literature

Gite (1983) reviewed that accidents and injuries of operators involved in various agricultural operations account for nearly a third of all rural injuries. One of the major equipment on which majority of accidents take place is the thresher. Tandon et al. (1988) reported data for 96 accidents hap-

Table 1. Agricultural accidents reported in selected 12 villages of Tamil Nadu

Accidents	Number
Total number of agricultural accidents	
Population engaged in agricultural / allied activities	26,522
Number of accidents during 1995-99	373
Accident incidence rate /1000 workers / year	2.812
Farm machinery related accidents	
Accident prone agricultural machinery population in the village	3,096
Farm machinery accidents during 1995-99	289
Accident incidence rate/1000 machines/year	10.6
Hand tool related accidents	
Number of hand tools in the village	36,698
Hand tools related accidents during 1995-99	37
Accident incidence rate/ 1000 hand tools /year	0.29
Other accidents	
Population of agricultural workers in the village	26,522
Other accidents during 1995-99	47
Accident incidence rate/1000 workers/year	0.2125

Table 2. Source Wise Classification of Agricultural Accidents

Source of agricultural accidents	Total No. of accidents	Total No. of machines	Incidence rate /1000 machine/ year
Accident prone agricultural machinery			
Tractor	102 (27.3)	1,424	14.33
Cane crusher	44 (11.8)	150	58.67
Chaff cutter	22 (5.9)	492	8.94
Thresher	69 (18.5)	325	42.46
Sprayer	51 (13.6)	705	14.47
Hand tools			
Spade	11 (2.9)	4,517	0.48
Sickle	25 (6.7)	13,122	0.38
Other accidents			
Snake bite	5 (1.34)	26,522	0.038
Chemicals	45 (12.06)	26,522	0.34
Total	374 (100)		

pened during 1986-88 around Delhi. The maximum accidents were due to threshers (43%), followed by tractor (35%), sugarcane crushers (10%), chaff cutters and other machines (4%). Mittal et al. (1996) conducted a study in Punjab state. According to them about 47% of accidents were caused due to sprayers followed by tractors (25%), electric motors (14%), chaff cutters (8%) and threshers (8%).

Materials and Methods

Twelve villages (including a hilly region) were selected from seven agro-climatic regions of Tamil Nadu State such that they use agricultural machinery extensively for various operations in crop production and processing activities. Contacts were established with key informants viz., village administrative officer, revenue inspectors, agricultural extension officials, etc. in the selected twelve villages through the assistant director of agriculture/ revenue authorities. All the 12 villages were visited with the help of key informants, information on agricultural accidents and related aspects were collected. Then the individual victims were contacted and the details were recorded in the proforma prescribed.

Results and Discussion

Total number of accidents

The total number of agricultural accidents, farm machinery related accidents, hand tool related accidents and other accidents reported in selected 12 villages during 1995 –99 is furnished in **Table 1**.

Tractor accidents were the highest in number which contributed 27.3 per cent of total accidents followed by threshers (18.5 %), sprayers (12.5%), chemicals (12.06%), cane crushers (11.8%), sickle (6.7%), chaff cutter (5.9%) and spade (2.9%). Machine-wise accident incidence rates were calculated on the basis of total number of each type of machine in all the villages. The highest incidence rate per 1000 machines per year was in the case of cane crusher (58.67), followed by thresher (42.5), sprayer (14.5), tractor (14.3), chaff cutter (8.94), spade (0.48) and sickle (0.38).

Classification of agricultural accidents according to type of primary events involved

Majority of the accidents resulted in cut (24.66%) of body parts while feeding cane in sugarcane crushers, removing bagasse from the bagasse outlet, feeding crop in threshers removing sugarcane stubble in the field after harvesting and digging of root crops from the soil followed by bruise (15.55%), rashes in the body (15.55%) due to the allergy in handling operation of crops in mostly sugarcane fields, crushing of body parts in cane crushers (13.13%). The sprains/strains account for 9.75% of the accidents. This can be attributed to the operation of tools in bending and awkward posture adopted by the subjects. Boils and wounds (7.23%) was mainly due to the operation with hand tools. Fracture of body parts (6.97%) was observed while operation with sugarcane crushers, threshers, getting down from the tractor without stopping the engine.

Classification of accident victims according to severity, occupational status, age and sex

The classification of accident victims according to severity, occupational status and age and sex are presented in **Table 4**. Of the total 373 accident victims reported in the 12 villages survey 16 accidents which constituted 4.28 % of total accidents were of fatal nature. The remaining 357 accidents (95.72%) were of non-fatal nature.

Majority of accident victims (78.27%) were labourers. Family labours (farmers) constituted (21.73%) of total accident victims. Male victims constituted 90.33% of total accident victims while the per-

Table 3. Classification of Agricultural Accidents According to Nature Of Injury

Type of injury	Number of accidents		
	Fatal	Non fatal	Total
Crushing	9	40	49 (13.14)
Bruise	-	58	58 (15.55)
Cut	-	92	92 (24.66)
Amputation	-	14	14 (3.75)
Sprain/strain	-	36	36 (9.75)
Fracture	-	26	26 (6.97)
Burns	-	5	5 (1.34)
Drowning	2	3	5 (1.34)
Rashes	-	56	56 (15.01)
Boils /wounds	-	27	27 (7.24)
Others – Swallowing of pesticides	5	-	5(1.34)
Total	16	357	373 (100)

Figures in parentheses represent percent of total accidents.

Table 4. Classification of Accident Victims

Classification of accident victims	Value
Severity-wise classification of agricultural accidents	
Fatal	16 (4.28)*
Non fatal	357(95.72)
Total	373 (100)
Occupational status-wise distribution of accident/victims	
Family labour	90 (21.73)*
Labourer	324 (78.27)
Total	414 (100)
Educational status wise classification of accident victims	
Illiterate	255 (61.60)*
Literate below matriculation	116 (28.02)
Matric	34 (8.21)
Graduate	9 (2.17)
Total	414 (100)
Age and sex wise classification of accident victims	
< 15	8 (1.93)*
15 –29	130 (31.40)
30 –45	180 (43.47)
> 45	96 (23.20)
Male	(90.34)
Female	(9.66)

The figure in parentheses indicates the percent of total accidents.

Table 5. Different Categories of Agricultural Accidents Reported during Village Survey

Source wise category	No. of accidents reported		
	Total	Fatal	Non fatal
Farm machinery related accidents	289	9	280
Agricultural hand tools related accidents	37	-	37
Other accidents (snake bites, drowning etc.)	47	7	40
Total	373	16	357

centage of female victims was 9.67%. The highest percentage of accident victims (43.47%) was in the age group of 30-45, followed by 15-29 group (31.40%), over 45 group (23.20%) and under 15 group (1.93%).It is apparent that the highest percentage of accident victims was in the group of illiterate (61.60%) followed by literate below matriculation (28.02%), matriculation (8.21%) and graduates (2.17%).

Extent of agricultural accidents in Tamil Nadu

In order to estimate the total number of agricultural accidents in Tamil Nadu the accident data reported from 12 villages have been grouped into three categories based on the source of accidents as shown in **Table 5**. The estimates in Tamil Nadu for each of the above categories determined as follows:

a. Estimation of farm machinery related accidents

This category includes accidents due to agricultural machinery excluding hand tools. To estimate the number of farm machinery related accidents the accident incidence rate was calculated from the total number of reported farm machinery related accidents and total number of accident-prone agricultural machines in the selected 12 villages. The accident incidence rate was multiplied by the total number of accident prone agricultural machines in Tamil Nadu State in 2000 for calculating the total number of farm machinery related accidents. Data available from 1991 Live stock census was updated using a 10% annual growth rate in number of accident prone agricultural machinery (excluding manually operated tools).

b. Estimation of hand tool related accidents

This category includes accidents caused by agriculture hand tools such as spade/pick axe, sickle, hand hoe etc. To estimate the number of hand tools related accidents the accidents incidence rate was calculated from the total number of reported accidents due to hand tools and total number of these tools in the villages. The accident incidence rate was multiplied by the total number of agricultural hand tools in Tamil Nadu. The population of hand tools in the state was estimated by multiplying the number of hand tools per worker in the surveyed villages by the total number of agricultural workers in the state.

c. Estimated number of accidents in agriculture in Tamil Nadu for the year 2000

Table 6. Estimated Number of Accidents in Agriculture in Tamil Nadu for the Year 2000

Source	Estimated number of accidents		
	Non fatal	Fatal	Total
Farm machinery related accidents	80794	2597	83391
Agricultural hand tools related accidents	809	0	809
Other accidents (Snake bites, drowning etc.,)	8747	1531	10278
Total	90350	4128	94478

Estimates for economic impact of agricultural accidents in Tamil

Nadu

In an effort to place the quantitative value on the cost of accidents, injury prevention, specialists have developed a procedure to establish an estimate of years of potential life lost (YOLL). The Total monetary loss per year due to agricultural accidents in Tamil Nadu was estimated as Rs. 226 crores.

Conclusion

Agricultural accidents are of very serious concern in Tamil Nadu. The accident incidence rate/1000 workers/year was 10.6. About 95.7% of total accidents are not fatal and the remaining 4.3% are of fatal nature. Majority of fatal accidents are due to tractors, cane crushers, threshers, chaff cutters, drowning in the open wells and pesticide poisoning. About 7.6% agricultural accidents are due to farm machinery, 9.6% due to hand tools and remaining 13.4% are due to other sources. Farm machinery related accidents are of fatal (3.11%) as well as (96.88%) non fatal in nature. Accidents due to hand tools are of non fatal nature. Highest incidence rate per 1000 machines per year was found in case of cane crusher (58.9), followed by thresher (42.5), , sprayer (14.5), tractor (14.3), chaff cutter (8.94), spade (0.48) and sickle (0.38). Based on the survey it is estimated that in the year 2000 there may be about 94478 agricultural accidents in Tamil Nadu causing death of about 4,128 workers and injuries to about 90350 workers which includes finger cuts, amputation of limbs, crushing of body parts etc. Total monetary loss due to agricultural accidents in the state of Tamil Nadu has been estimated as Rs.226 crore per year.

Recommendations

The following recommendations are proposed for safe operation of farm machinery and implements by enhanced comfort and reduced drudgery and for increased safety of the operator.

i. Improvement in design features

* Provision of roll over protective structure (ROPS) in the tractor can help to reduce the deaths caused in tractor accidents due to crushing of operator in overturning accidents.
* A properly designed cab is important to prevent them from dust, noise, rain, heat and cold.
* It is necessary to develop a ergonomical work space layout for tractor operator.
* Design modifications in tractors and other farm equipment are needed for easy and safe hitching of the equipment with the tractors.
* Provision of safe feeding devices in chaff cutters, sugarcane crushers and threshers.
* Proper lubrication system for the transmission system of sugarcane thresher.
* Proper guards /shields to cover the rotating parts of various prime movers and farm equipment.
* Separate brake system and danger lights with reflectors for the trailer is necessary to avoid accidents.
* Use of personnel protective equipment during operation of sprayers, operation in sugar cane fields.

ii. Training

* Formal, informal and non-formal education and training programme may be conducted by the government and non-government organization to improve the skills, knowledge and attitude of the users in a positive way.
* Training courses should be organized for tractor operators at block levels for proper and safe operation of tractors and tractor operated equipment.
* Periodical trainings need to be conducted in proper and safe operation of sprayers and dusters.
* In any of the farmers meeting at village/block/district level a programme on proper and safe use of various agricultural machines should be incorporated as an integral part.
* Extension leaflets/publicity materials for proper and safe use of various machines need to be prepared and circulated on a wider scale.

iii. Enforcement of rules and regulations by the Government

The government should pay enough attention to this aspect and should put forth some rules and regulations for the human welfare by:

i. Laying down standards for the tractor vibration, noise, etc. affecting the operator and assuring strict quality control during manufacture.

ii. Considering agriculture also as an industry. Should give provisions and concessions as given to other industrial workers, to the farmers and tractor operators. It is imperative as they are in a more dangerous environment than the other workers.

iii.Enforcement of license for the tractor drivers

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Present Status and Future Strategy on Farm Mechanization and Postharvest Technologies for Rice Production and Processing in Bangladesh

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Abstract

In Bangladesh arable land is decreasing day by day due to urbanization and industrial development, but the demand of food grain is increasing with the increase of population. As a result it is necessary to produce more food per unit land area. Farm mechanization is essential to reduce turn-around time and increase cropping intensity for increased food production. Tillage operation is mostly mechanized through the introduction of Chinese origin power tillers, however, some more farm jobs are in the process of partial mechanization through the efforts of some research, extension and Non-Governmental organizations. As a part of this effort Bangladesh Rice Research Institute (BRRI) developed some farm machinery. For cultivation of marshy land a hydrotiller was developed. The field capacity and fuel consumption of the tiller were 0.13 ha/hr and 1.5 lit/hr respectively. The rotary and rake type weeders were developed for lowland rice field in varied soil conditions. The field capacity of the weeder was 0.04 ha/hr which is 5-6 times faster than manual weeding method. The power tiller operated reaper has 0.14 ha/hr field capacity and can save about Tk 900 per ha compared to sickle harvesting. For rice, the radial flow hold-on type open drum thresher has a threshing capacity of 350 to 400 kg/hr and saves Tk 70 per ton over traditional method. The axial flow throw-in type threshers (TH 7 & TH 8) have the cleaning mechanism and equally suitable for rice and wheat. The threshing capacities of TH 7 are 500-700 kg/ha and 300-500 kg/ha for rice and wheat respectively; and can save Tk 100/ton over traditional method of threshing. However, the threshing capacities of TH 8 are 800-1000 kg/ha and 600-700 kg/ha for rice and wheat respectively; and saves Tk 130/ton over traditional method of threshing. The capacity of power operated grain cleaner 350-450 kg/hr which can save Tk 60/ton over traditional method of winnowing. The improved design of ground chula consumes 45% less fuel compared to traditional chula and suitable to use both light and high density fuels.

Introduction

Rice production is vital to the Bangladesh economy, as it contributes about 50% of total agricultural value added and engages over 65% of the total agricultural labour force. Besides rice production continues to be one of the important sources of livelihood accounting for 76% of the people's average calorie intake and 66% of protein intake (BBS, 1996). The experience of technological change led by varietal improvement in Bangladesh has significantly contributed to the growth of rice production during the last two decades. Gains in the food grain sector in Bangladesh since its independence are mostly due to technological introduction of high-yielding seed, fertilizer and irrigation technologies. Rice production has become doubled since independence without further increase in rice area. Although modern varieties cover almost 56% of the total rice cropped area, the yield level still lags behind other Asian countries.

On the other hand increasing demand for food and fibre for the county's 120 million population, growing at the rate of 2% per year, also put pressures on land for increased production through double or triple cropping. This requires more farm power inputs per unit area and farmers are looking for alternative power sources to meet the gap. In Bangladesh, presently over 70% of the energy for 9.6 million hectares of cultivable land mainly comes from human and animal sources. The average drought power shortage is about 30-35% and it rises up-to 45% during the peak periods.

For Further increase of the production per unit land area, it is very important to increase the cropping intensity which may be attained through the adoption of appropriate farm mechanization technologies. Moreover, rural labour force has started to shift from the agricultural to the industrial sector, creating acute agricultural labour shortage during peak planting and harvesting periods. In case of occurrences of flood, drought and other natural disasters mechanization is the only option which can handle problems for land preparation, crop establishment, harvesting, threshing and drying of different crops timely.

Present Status of Farm Power

Due to the shorter turn-around time between the harvesting and planting of the subsequent crops, the problem of drought power shortage is becoming more acute.

Animal Power

Majority of farmers still use drought cattle for tillage and other farm activities. The draught cattle population in Bangladesh including working buffaloes are presented in **Table 1**. The estimated draught animal requirement for about 9.6 million hectares of cultivated land with 179% cropping intensity is 8.9 million pairs. The latest Livestock Census (BBS, 1996) quoted the number of working animals as 11.2 million. On this basis a shortage of 6.6 million (59%) draught animals exists in the country.

Power Tillers

The use of power tillers has increased rapidly since 1988. From 1960 to the mid 1980s about 6500 power tillers were imported and sold to the private sector with credit subsidized by the government. Under the tax relief provision private sectors are recently importing over 25,000 power tillers annually and the number has exceeded 150,000 by 2001.

Bangladesh Rice Research Institute (BRRI) has developed a power tiller namely hydrotiller for cultivating marshy lands with no plough pans. (Appendix 1). This is still in a research stage but is being quite comfortably used in BRRI farms.

Tractors

Tractors are not a major farm power source in Bangladesh Moreover the rural infrastructure also does not permit tractors to be widely used for tillage purposes. Sutton (1993) reported a total of 5,200 tractors in the country. The sale of tractors at present are below 50 a year and most of the imports have been to the government organizations through aids programmes.

Seeding and Planting

Presently seeding and planting operations are mainly done by traditional methods. For direct sowing of paddy, BRRI has developed a drum type seeder suitable for lowland (Appendix 1). It is capable of drilling seeds in rows and may be an alternative to rice transplanting in dry season (Boro).

Rice transplanting is a highly labor intensive farm operation. The total labor requirement for rice production in 1 hectare of land was 156.2 man-days of which 44.5 man-days were consumed by seedling raising and transplanting which is 28.48% of the total labor requirement (Rahman, 1997). For manual transplanting in rows approximate-

Table 1. Human/animal and Farm Machinery Available in Bangladesh Agriculture

Power Source	No. of units (million)	Power rating (kw)	Total Power (kw $\times 10^6$)	Available power (kw/ha)
Animal Buffaloes	0.3	0.746	0.224	
Bullocks	7.6	0.180	1.368	
Cows	3.3	0.135	0.446	
Total animal	11.2		2.038	0.133
Human	35.0	0.074	2.59	0.169
Mechanical				
Tractors	0.0052	30	0.156	
Power tillers	0.1500	8	1.20	
Total mechanical			1.356	0.088
Grand total			5.984	0.390

Source: Sarker (1997)

Table 2. Performance of Rice Transplanting Machines In Boro 2000-2001 Season

Transplanting method	Field capacity (ha/hr)	Transplanting efficiency (%)	Hill/m^2	Seedling/hill during transplanting	Tiller/m^2 at harvest	Panicle/m^2 at harvest	Yield at 14% m.c (t/ha)
Machine Transplanting	0.120 a	95.9	22	4	504.75	466.40 a	6.95
Manual Transplanting	0.006 b	100	33	3	485.76	437.03 a	5.92
SRI Transplanting	0.002 c	100	16	1	299.52	283.04 b	6.90

ly 400 man-hr/ha labor is required which is roughly 30 percent of the total labor requirement for rice production (Islam, 1998). The shortage of labor are being observed during transplanting season. The yield loss due to delayed planting were 60.0, 55.4 and 9.0 kg/ha/day in Boro, Aman and Aus season, respectively (Sattar, 1999). Therefore, test and adaptation of mechanical rice transplanter having faster work rate is essential.

A two-row Japanese rice transplanting machine was evaluated at BRRI farm. It needs to raise seedling in trays and adaptable for 12 to 18 days old seedlings. This machine was found to be 20 times faster than manual transplanting (**Table 2**). If adequately introduced it may be an appropriate rice transplanting technology for the Bangladesh farmers.

Weed Control

Weed control mainly depends on the indigenous hand tools. The field capacity of indigenous weeding fork was found 0.004 ha/hr at a weed density of 250 weeds/m^2 (Islam et al.1985). The operation of rotary type weeder is possible in lowland rice fields where seedlings are transplanted in rows. BRRI has developed a weeder for lowland paddy, having a working capacity of 0.04 ha/hr and costing only Tk 400.00. It is lighter than Japanese type weeder and does not clog even in heavy clay soil. BRRI has also developed a rake type weeder made of iron spikes, wooden frame and bamboo handle namely Kishan weeder (Appendix 1). This weeder is lighter and cheaper than BRRI weeder. It is workable both in light and heavy soil conditions and has a field capacity of 0.04 ha/hr.

Insect Control

Insecticide application to the crop field in Bangladesh mainly depends on the knapsack type sprayer. The working capacity of a knapsack type sprayer is about 0.05 ha/

Table 3. Participants Opinion on the Performance of BRRI Rice-wheat Thresher and Reaper, 2001

Sl No.	Information sought	Wheat threshing		Paddy threshing		Paddy threshing		Paddy reaping	
	Response(%)	Yes	No	Yes	No	Yes	No	Yes	No
1	Performance satisfied	75	18	68	19	69	29	49	48
2	Want to Purchase	95	2	96	2	96	4	87	11
3	Max. Price offered								
	a) >Tk. 10,000	36		34		38		32	
	b) < = Tk. 10,000	51		58		58		55	
	Price not offered	13		8		4		12	
4	Group Ownership	74	20	79	16	78	19	65	28
5	Want to hire	91	3	86	8	82	16	76	14
6	Hire charge offered								
	a) <100/bigha	18		22		32		20	
	b)>100/bigha-<200/bigha	55		49		42		50	
	c) >200/bigha	18		15		12		15	
	d) No charge offered	9		14		14		15	
7	Necessity in Agril. Operation	97	3	97	3	98	2	91	4
8	Safety operation	94	6	96	4	84	3	81	13
	Total respondent	307		100		550		97	

Note: 1 bigha= 33 decimal

Table 4. Comparative Performance and Economic Analysis of BRRI Developed Threshers over Traditional Methods of Threshing

Sl. No.	Factor	Traditional	Pedal thresher	BRRI open drum	BRRI rice - wheat TH-7	BRRI rice - wheat TH-8
		Threshing machine/method				
1	Capacity					
	Rice (kg/hr)	65.90*	50-54 (1)	350-400	500-700	800-1000
	Wheat (kg/hr)	-	90-155 (2)	-	300-500	600-700
2	Price with engine (Tk)	300 (3)	1800	15,000	35,000	60,000
3	Operating cost (Tk/hr)	12.50 (4)	7.98	42.40	34.78	34.78
4	Threshing cost					
	Rice (Tk/ton)	189.68	169.78	121.14	86.95	57.96
	Wheat (Tk/ton)				115.93	69.56
5	Life (yr)	-	3	10	10	10
6	Fuel consumption (Litre/hr)	-	-	1.1	1.2	12
7	Unthreshed loss (%)	4.12	1.0	1.0-1.7	0.15	0.15
8	Damage loss (%)	2.97	0.9	0.38	1.0	1.0
9	Cleaning off (%)	0	85.0	81.78	90.0	90.0
10	Man power	2	1-2	3	2	2

Note: 1. One person threshing; 2. Two person threshing; 3. Cost of beating drum; 4. Labour cost at Tk. 50.00/ *For traditional threshing (Beating + Treading)
Beating : 84.86% threshing was completed in 25% of time
Treading: 15.14% threshing was completed another 75% of time

hr. By conventional knapsack type sprayer it was found difficult to control brown plant hopper in rice fields as it lives mostly at base of the plant where it is shaded and moist. To overcome this problem a T-type nozzle was designed and fabricated in BRRI workshop and incorporated in the knapsack type sprayer. This nozzle sprays liquid sideways between plants and capable of spraying 850 and 1100 ml/min at a pressure of 1.0 and 2.5 kg/cm^2 respectively.

Harvesting

Crop harvesting in Bangladesh mainly depends on human labour with traditional sickles. The working capacity of a labour with sickle is only 0.01 ha/hr. Labour shortage is a acute problem during crop harvesting season in Bangladesh. For the last couple of years BRRI has experienced with the modified design of power tiller operated reaper for harvesting rice and wheat (Appendix 1). Farmers opinion on the performance of BRRI developed rice-wheat reaper are presented in **Table 3**.

Threshing

Manual threshing by drum beating and animal treading are common practices in Bangladesh. Pedal threshers are, however, used in many parts of the country. BRRI has been conducting research and development work on different types of mechanical threshers namely hold-on type open drum thresher for rice and throw-in type threshers for rice and wheat (TH 7 and TH 8, Appendix 1). These machines were demonstrated to the farmers' field during Boro, Aman and wheat harvesting seasons during 2000 and 2001 in the different districts i.e. Thakurgaon, Dinajpur, Rajshahi, Naogaon, Chapai Nababgan, Natore, Chuadanga, Gopalganj, Gazipur, Tangail, Mamensingh, Comilla, Chittagonj, Noakhali and Hobiganj of Bangladesh in collaboration with the Department of Agricultural Extension (DAE). Field performance of BRRI developed threshers in comparison with traditional methods of threshing are presented in **Table 4**.

Cleaning

Traditionally farmers of Bangladesh clean their dried grain in natural wind blowing with the help of KULA. This system is not workable in rains and other natural calamities. To overcome these difficulties, BRRI has developed a power winnower through the modification of Japanese type manual winnower (Appendix 1). This winnower can be operated by power tiller and shallow tube well engines and electric motors. The capacity of this winnower is 350-450 kg grain/hr which is capable of saving Tk 60/ton over traditional method of winnowing.

Storage

In rural Bangladesh food grains are stored in traditional storage structures i.e. Dole, Ber, , Motka, Gola etc. There are some modern systems to store food grain. In public gowdons grains are stored in gunny bags for short terms, however, they are stored in silos for long terms. Insect frequently attack the stored product in these stores easily. A 5 ton capacity storage structure namely Grain Pro cocoon was tested at BRRI for storage of seed paddy. The Cocoon was set up in the threshing yard store house of BRRI in May, 2000. About 3650 kg of paddy in gunny bags were put in five layers inside the Cocoon; and it was made hermetically sealed by zipper mechanism. Oxygen level inside the Cocoon reduced to bellow 3% within a week and it maintained throughout the study period. At the end of the storage period of 210 days, the seed viability was above 90%. Insect population was also reduced to nearly zero. Live insects were dead inside the Cocoon due to high concentration of CO_2 and low level of oxygen in the hermetic storage environment.

Milling

The rice milling industry in Bangladesh consists of about 1,00,000 small rice mills, 380 medium semi-automatic mills and 25 large automatic mills. Recently Bangladesh is producing a considerable amount of fine and aromatic rice. The price of fine grain aromatic rice is 2-3 times higher than that of coarse grain rice in the domestic market. It is also reported that the farmers can not sell their aromatic rice in the domestic market at fair prices. On the other hand the existing processing technology is not capable of producing export quality fine and aromatic rice. The main problem with the existing milling system are low milling recovery, high breakage, cracked and chalky kernels and mixture of damaged grain and impurities. A package of processing technology is to be developed to solve this problem. The technology package should address the following operations i.e. field and crop conditioning at later part of growing stage, harvesting at optimum maturity and appropriate methods of drying, milling, cleaning and grading.

Efficient Utilization of Traditional Fuel

Traditional chula is a very inefficient device and consumes more fuel to provide unit heat energy. In an experiment it was found that these chula can utilize only 5-15 percent of the total heat energy during burning of the fuel. So, the rest i.e. 85-95 percent of the heat energy is lost. Bangladesh Council for Science and Industrial Research (BCSIR) has developed different types of improved Chulas. These Chulas are only suitable for high density fuel i.e. tree branches, wood, cow dung charcoal etc. To overcome this problem BRRI has modified the ground traditional chula for improved fuel efficiency (Appendix 1). The modifications were (a) the height of Jhika was reduced from 5 cm to 1.5 cm, (b) a screen was incorporated at a depth of about 25 cm from the top to hold the fuel during burning and (c) a port was provided by the side of the chula in order to supply oxygen from the bottom of the fuel and to remove ashes. This chula consumes 40-45% less fuel compared to traditional chula and suitable to use both light and high density fuels.

Constraints to Adoption and Popularization of BRRI Machines

i. Very limited fund is available to conduct machinery research at farm level.

ii. Very limited number of prototypes to take up adequate extension programs for the farmers and the manufacturers.

iii. People believe that locally developed machinery is always inferior to their imported counterparts.

iv. Local manufacturers do not have adequate technical know how to fabricate prototypes from the working drawings supplied by BRRI or other sources.

v. There is no systematic training programs for development of skill and knowledge of machine operators/farmers.

vi. Lack of awareness among the farmers to use machines in agricultural operations.

vii. Lack of effective linkages among the researchers, manufacturers, farmers, and extension people.

Conclusions

Japanese type power transplanter is 20 times faster than manual transplanting method, but the cost of imported transplanter is quite high. However, if adequately introduced, it may be an appropriate rice transplanting technology for the Bangladesh farmers.

BRRI rotary and Kishan weeders are workable both in light and heavy soil conditions. These weeders are 5-6 times faster than manual weeding method and also easy to handle.

BRRI power tiller operated reaper is about 12 times faster and saves Tk 900 per ha compared to manual harvesting method.

BRRI hold-on type open drum thresher is about 7 times faster and saves Tk 70 per ton over traditional method. It is suitable to keep the straw intact.

The throw-in type threshers(TH 7 & TH 8) operated by existing power tiller engines are suitable for both rice and wheat. These threshers are 12-16 times faster than traditional method and save about Tk 100-130 per ton over traditional method of threshing.

BRRI power winnower is about 6 times faster and saves Tk 60/ton over traditional method of winnowing.

BRRI improved chula consumes 45% less fuel compared to traditional chula and suitable to use both light and high density fuels.

Future Research Guidelines for Mechanization

1.Development/adoption of a suitable rice-transplanting machine to avoid delayed planting.

2.Development/adoption of reapers suitable for soft and water logged crop field.

3.Development/adoption of suitable dryer for paddy.

4.Development of processing technology of fine and aromatic rice for quality product.

5.Development/adoption of technology for better utilization of renewable energy.

6.Strengthen demonstration and adaptive research of BRRI developed machinery/technology in the farmers' field.

Future Policy Implications for Mechanization

1.A system/mechanism is to be developed for the dissemination of farm machinery and post harvest technology to the farmers as modern varieties are being disseminated by DAE.

2.Promote local manufacture of agricultural machinery to meet the domestic demand and future export potential.

3.BRRI Agricultural Engineer is to be given authority to monitor the quality of the farm machinery produced in different engineering workshops in the country. For that BRRI engineer should receive special training on the metallurgical and quality control issues.

4.Create local enterprenourship for the production and use of farm machinery through manufacturers, NGOs, traders, dealers farmers etc.

5.Promote custom hire service of various farm machinery through comparatively farmers, farmers' group, agro-traders, NGOs etc.

6.Agricultural Training Institutes (ATI) under DAE should have a definite curriculum on Farm Mechanization and Post harvest Technology; and they are to be provided with a set of potential farm machinery developed by BRRI, BARI, BAU etc. for the training purposes.

7.Courses on Farm Machinery and Post harvest Technology for rice production are to be included in the training programme for unemployed young men and women organized by Ministry of Youth and Sports.

8.Rural women are to be motivated and trained on the use of farm machinery suitable for women i.e. weeder, thresher, winnower, drier, improved Chula etc.

9.Agricultural machinery and equipment manufactured locally or imported have to be certified for quality standards from the authorized agency.

10.Promote agricultural credit facilities at low interests to individual farmers and farmers' cooperatives for the acquisition of agricultural machinery through government, non-government and private financial institutions i.e. Bangladesh Krishi Bank, Commercial Banks, Grameen Bank, etc.

11.Establishment of special agro-processing zones for perishable and non-perishable agricultural produce for domestic and export markets.

12.Provision of crop and farm machinery insurance facilities to the farmers.

13.Government should provide a fair price of farm product to the farmers.

14.Provide training on farm machinery operation and maintenance for government, non-government and private level extension workers, operators, farmers etc.

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APPENDIX 1

1. BRRI Hydrotiller

Features

Suitable for cultivation marshy land and soil lacking plough pan

Suitable where power tiller/tractor/bullocks sink and cannot work

Can be made in a local workshop

Helpful for quick cultivation after flood, storm etc.

Capacity – 0.14 ha/hr

Fuel consumption 5.5-6.5 lit/ha (petrol)

Price: Tk.55000.00 (Approx)

Limitations: Can not cultivate dry land

A petrol engine is necessary

2. BRRI Drum seeder

Features

Suitable for sowing sprouted rice seed in rows

Can be made in a local workshop

It saves labour for transplanting of rice

Capacity –0.14 ha/hr

Price: Tk.4000.00 (Approx.)

Limitations: Fairly leveled land is necessary

3. BRRI Weeder

Features

Male and female workers can use comfortably

Suitable for all soil types

Light weight and allows longer working period

Capacity-0.04 ha/hr

4-5 times faster than hand weeding

Easy to operate and transport

Saves Tk. 6814/ha over hand weeding (Hand weeding Tk.8840/ha)

Price: Tk 400.00 (Approx)

Limitation: Line transplantation is required

4. BRRI Kishan Weeder

Features

Male and female workers can use comfortably 00

Good for both Short and long weeds

Light weight and allows longer working period

Suitable for both line or traditional transplantation

Can be made easily at local blacksmith shops

Capacity – 0.02 ha/hr

Saves Tk. 4380./ha over hand weeding

Price: Tk. 50.00 (Approximately)

5. BRRI Rice-wheat Reaper

Features

Can be operated by conventional power tillers

Who already have power tillers can buy only the reaper part

Easy to operate, Power tiller drivers can operate

Helpful for quick seed processing

Capacity- 0.16 ha/hr

Advantage over traditional method 10:1

Can be owned by middle/large farmers

Saves 900/-Tk. /ha over sickle harvesting(Sickle harvesting Tk.2800/ha)

Price: Tk. 30000.000 (Approx)

Limitation: Can not harvest lodged crop

Labour required for binding

6. BRRI Open drum power thresher

Features

Male and female workers can operate easily

Helpful for quick seed processing

Small farmers can own individually

Capacity - 350 to 400 kg/hr

Can be made locally in small workshops

Can be powered by PT/STW/Motor

Straw remains unbroken

Saves Tk. 70.00/ton over traditional method (Traditional Tk. 190/ton)

Price: Tk. 7500.00 (without engine)

Limitation: Can not clean grains

7. BRRI Rice-wheat thresher (TH-7)

Features

Male and female workers can operate easily

Helpful for quick seed processing

Can be made in local workshops

Suitable for both paddy and wheat threshing even in rainy days

Middle farmers can own individually

Capacity-500 to 700 kg/hr (straw length 40-60 cm)

-300 to 500 kg/hr (wheat, straw length 40-60 cm)

Can be powered by PT/STW/Motor

Threshing and winnowing are completed in a single operation

Saves Tk. 100/ton over traditional method (Traditional Tk. 190/ton)

Price: Tk. 22000.00 (without engine)

Limitation: Not suitable for longer straw

8. BRRI Rice-wheat thresher (TH-8)

Features

Male and female workers can operate easily

Helpful for quick seed processing

Can be made in local workshops

Suitable for both paddy and wheat threshing even in rainy days

Large and rental farmers can own

Capacity- 800 to 1000 kg/hr (paddy with straw length 40-60 cm)

- 600 to 700 kg/hr (wheat with straw length 40-60 cm)

Can be powered by PT/STW/Motor

Threshing and winnowing are completed in a single operation
Saves Tk.130/ton over traditional method (Traditional Tk. 190/ton)
Price: Tk. 40000.00 (without engine)
Limitation: Not suitable for longer straw

9. BRRI Power winnower

Features:

Male and female labour can operate this machine easily
Helpful for quick seed processing
Can be made locally in small workshops
Suitable for both paddy and wheat cleaning
Capacity- 800 to 1000 kg/hr
Can be powered by PT/STW/Motor
Saves Tk.60/ton over traditional winnowing (Traditional Tk.88/ton)
Price: Tk. 10000.00
Limitation: Can not grade properly

10. BRRI Improved Chula

Features:

This chula is the developed version of the ground traditional chula
The fuel is burnt on a screen made of iron or clay
There is a port by the side of the chula to supply oxygen to the fuel
The port is also used to remove ashes from the chula
Both light and high density fuels can be used in this chula
Fuel consumption is 40-50% less compared to ground traditional chula
Price: Tk. 40000.00 (without engine)
Limitation: Needs continuous attendant

Mechanization of Polish Agriculture in the Transition Period

by
Jan Pawlak
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Summary

Difficult economic situation and low labor productivity in Polish agriculture (in 2002 Gross Value Added per one person working in agriculture amounted to US $) 2359 generate a recession on farm machinery market. At present, the sales of new-built tractors amount to about 10% of the level achieved at the end of the 1980s. Nevertheless, the number of machines on farms increased. In 2002, there were 1364.6 thousand tractors on farms, by 15.2% more than in 1990 and by 4.7% more than in 1996. The growth in the number of farm machines in Poland is a result of imports of second-hands and prolonging the useful life of machines in use.

Introduction

In Poland, the process of transition from central planning to a market economy started in 1989. The situation there seemed favorable. Unlike other Central and East European countries and former Soviet republics, the share of private farms in the use of the agricultural used area (at least 75% in private use) as well as in the agricultural production was dominating. There were people able to run farming operations. There was also the material base on private farms: farm buildings, equipment and herds. However, before starting the transition to the market economy the individual farmers acted under conditions of non-market general economy system. The prices of inputs for agricultural production as well as for agricultural products were centrally established and - to the end of the 1970s - relatively stable. Therefore, most of the farmers were not prepared to a new situation created by the transformation process. Besides, the state policy during the period of centrally planned economy caused farm sizes not to change significantly since 1950. Therefore, the start was difficult, though much better as compared to the one described by Havrland and Kapila (2003), concerning former the Soviet Central Asian Republic.

The purpose of this paper is to analyze the situation of Polish agriculture during the transition period with special regard to farm mechanization.

In spite of differences in natural conditions as well as social and economic situation in particular countries and regions of the world, there are also many common problems to be solved in developing and transition countries. Therefore, at least some results of this analysis might be useful for readers from other continents.

Material and Methods

The data published by the Central Statistical Office - GUS (2003, 2203a and 2003b) on Agricultural Censuses 1996 and 2002 were used as a base of the study. During the period between the two censuses there were changes not only in the equipment of agriculture with means of mechanization, but also in resources of agricultural used area (AUA) and in the structure of farms. Therefore, in order to provide the base for comparisons, indexes of number of machines as related to the land area and number of different categories and size groups of farms have been calculated and analyzed.

Results and Discussion

In 2002 there were 2933.2 thousand farms in Poland. Comparing to the situation of 1996, the number of entities decreased by 133.3 thousand, i.e., by 4.3%. The number of farms exceeding a ha of agricultural used area (AUA) also decreased by 90.7 thousand farms (by 4.4%). In 2002 there were 1956.1 thousand farms. The average AUA of a farm in 2002 was 5.76 ha and was bigger by 1.8% than in 1996. The area of a farm with AUA more than a ha amounted to 8.44. The acreage of AUA on farms in 2002 was 16.9 million ha, of which 13.1 million ha were arable land composed of 271.0 thousand ha of orchards, 2.5 million ha of meadows and 1.0 million ha of permanent pastures.

The liberalization of prices in 1990 resulted in worsening relations between market prices of agricultural products and prices of means of production for farming. The difficult economic situation of the significant part of the population limited demand for food products. Economic problems of main importers of Polish agricultural products caused the volume of exports to decrease. Those factors influence the impact both on the market of means of production and on the structure and number of farms performing agricultural activity, level of use and ways of land utilization.

Through the end of the 1980s the economy of rural areas in Poland was dominated by agricultural activity. Nowadays farming produces an income for almost 60% of rural inhabitants, but for most of them it is neither the only nor the main source. Over 1.8 million of the 14.8 million rural inhabitants receive health and retirement pensions. Farming in Poland is increasingly polarized. The numbers of the very small and very large farms grow, the number of medium-sized farms declines.

In 1990 there were 1126.1 thousand registered jobless people in Poland (6,5% of the economically active population). In December 2002, the number of registered unemployed people amounted to 3115.1 thousand (18.0% of the economically active population). Over 34% of the registered unemployed in Poland live in the country, but hidden unemployment in farming is estimated at 900,000 people. The unfavorable situation in the labor market limits the outflow of labor force from agriculture to other industries. In 2002, the number of working exclusively or mainly in agriculture was 2192.9 thousand people (13 persons per 100 ha of AUA), in which 2016.0 thousand were on private farms.

The educational structure of people working on farms was less gainful as compared to those working in the non-agriculture sector. The biggest share among those working exclusively or mainly on their farm had people with vocational and primary education – 78.0%, and people with secondary or high education constituted 21.9%. For persons working outside agriculture the percentages constituted 35.3% and 64.4%.

Delays in structural transformation, low levels of education, lack of specialization and under-developed links between agriculture and business cause that labor productivity, measured in terms of Gross Value Added per one person working in agriculture, compare badly with other countries. In 2002, the Gross Value Added per person working in agriculture amounted to 2359 US $ (almost 8 times lower than in Germany), and per a hectare of AUA - 306 US $. Labor productivity in farming is only about ¼ of the national average. Agriculture's contribution to the Gross Value Added declined rapidly from 8.5% at the beginning of the 1990s to 3.1% in 2002. But this drop was not accompanied by an equally rapid decline in employment. Farming still employs too many people: they can neither be used effectively nor provided with decent incomes. The average disposable income per person is 25% lower than in towns, rural disparities in income are greater and poverty is more severe.

The difficult economic situation and low labor productivity in Polish agriculture generate a recession on farm machinery market. At present, the sales of new-built tractors amount to about 10% of the level achieved at the end of 1980s. In 2001, the shipments of new-built tractors as related to the number of tractors in use was 0.3%. The data published by Farm Machinery Industrial Research Corporation (2002) shows that the value of the same index for Japan was 3.6%. The growth in number of farm machines in Poland is a result of imports of second-hands and prolonging the useful life of machines in use. Only farms of the highest scale of production invested in new-built equipment, including high-tech imported machines. Tractors and farm implements are growing older and the technological advance is slow in Polish agriculture.

Until the 1970s, private (individual) farmers were, because of doctrinal reasons, destitute of possibilities to purchase tractors. Mechanization of their farms was to be based on services of state controlled (formal-

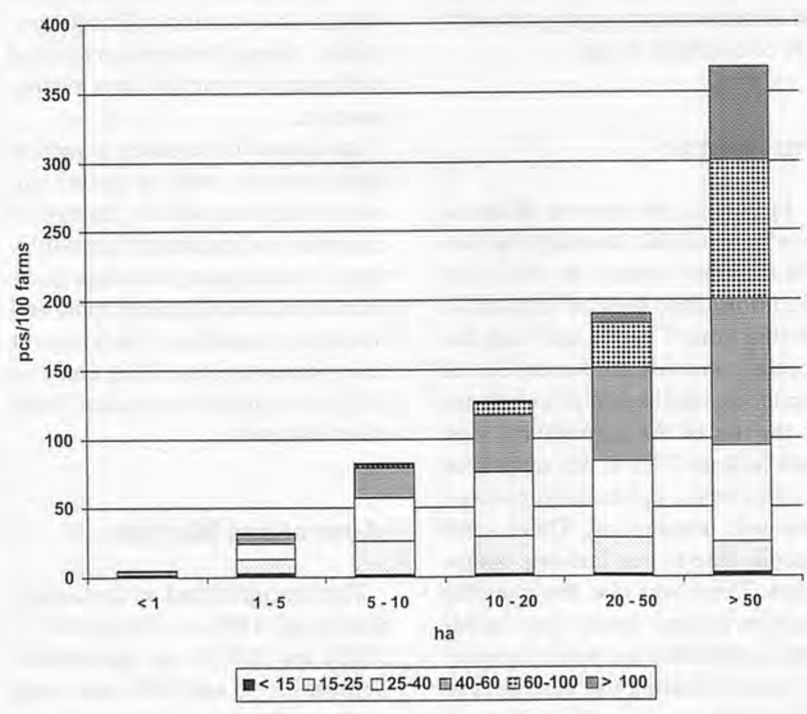

Fig. 1 Tractors per 100 farms based on their power.

ly cooperative) machinery bases. Under such conditions horses dominated on individual farms. The growth in the number of tractors in the machinery bases did not cause the reduction of horses. Those tractors were mostly engaged in transports for nonagricultural enterprises. Low effectiveness of this form of mechanization in Poland was not an exception. Egyptian experiences shows that the government tractor hire scheme has failed to be effective or economically viable over the long term (El Hossary 1997). In Poland, the process of changes in power structure started only after opening possibilities to private farmers to purchase their own tractors. As compared to the situation in 1970, the decrease in number of horses was noted: by 28.3% in 1980, by 62.1% in 1990 and by 86.7% in 2002.

In 2002, there were 1364.6 thousand tractors on farms, by 15.2% more than in 1990 and by 4.7% more than in 1996. On private farms the increase was, respectively, 31.8% and 6.9%. In the public sector the amount of tractors was systematically decreasing, which was connected to the change of proprietary structure in the agriculture. As compared to 1990, the number of tractors decreased in the described sector by 92.4% and as compared to 1996, by 56.6%.

The number of tractors, as related to the number of farms, was increasing proportionally to the growth of the area of AUA of farms. In the group of farms up to 5 ha it reached the number of 32 units per 100 farms. In the group of farms of 50 ha and more the number of the tractors was 368 units per 100 farms (**Fig.1**), and on farms of 1000 ha and more - 1750 units per 100 farms.

In 2002, there were about 8 tractors per 100 ha of AUA. The number of tractors, as related to the unit of AUA, was decreasing as the size of farms grew. In the group of farms up to 5 ha it reached the number of more than 13 units per 100 ha, and in the group of farms of 50 ha and more there was 1.7 units per 100 ha (**Fig. 2**).

In the structure of tractors, the vehicles with medium power dominate: up to 25 kW -28.7%, 25 to 40 kW – 34.7%, 40 to 60 kW – 27.6%,

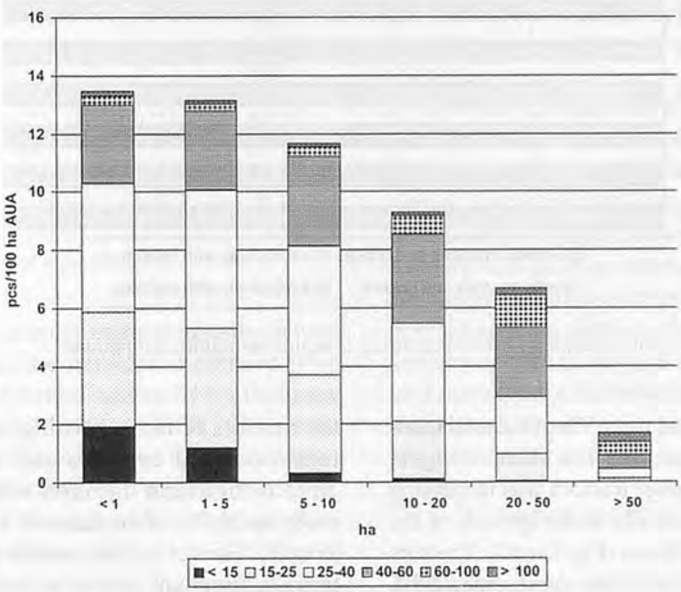

Fig. 2 Tractors per 100 ha AUA based on their power.

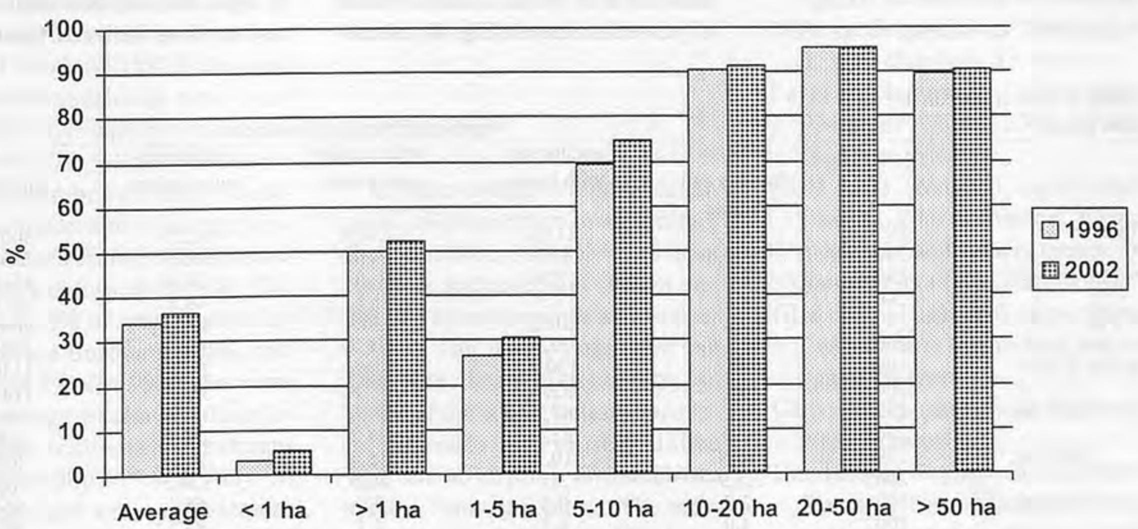

Fig. 3 Farms with tractors in per cents of total farms.

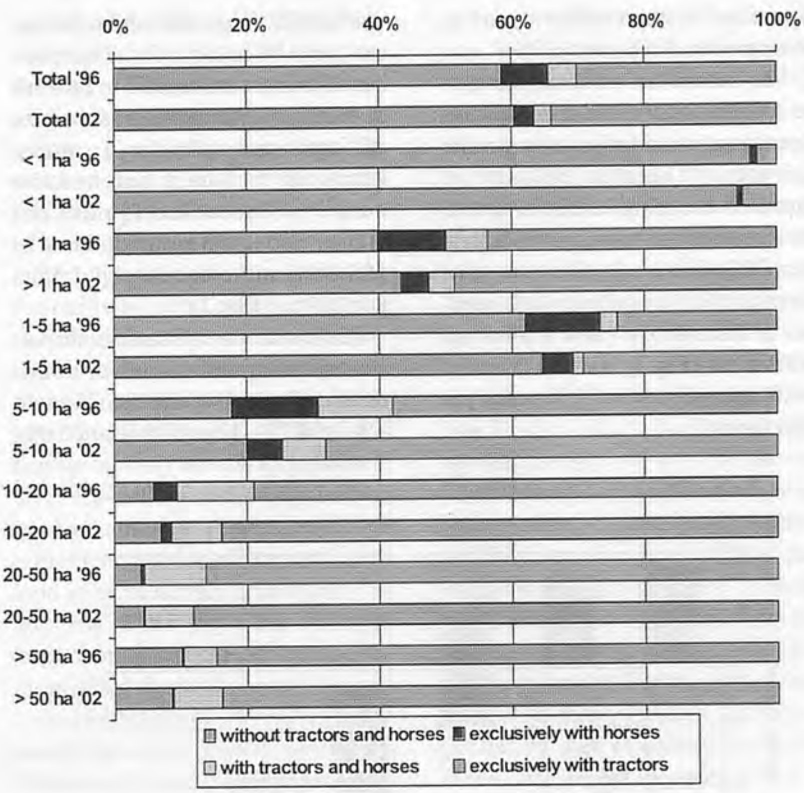

Fig.4 Per cent structure of farms according to equipment in traction power

60 kW and more 9% of the total number of tractors. The share of higher power range tractors was increasing proportionally to the growth of the AUA of farms (**Fig.1** and **2**). Tractors of 60 kW and more represented 2.9% of total tractors in a group of farms 1-5 ha AUA and 45.8% in a group of farms of 50 and more ha AUA.

In 2002, as compared to 1996, the number of farms owning tractors increased by 2.1% and was 1075.6 thousand unionist which made up 36.7% of the farms in total (**Fig.3**). However, the number of farms without any power increased in all size groups except the group of 5-10 ha (**Table 1**). Also the per cent share of farms without source of power increased (**Fig. 4**), as a result of significant reduction in number of farms with horses. Only in the group of largest enterprises the per cent of farms with tractors and horses increased. However, on such farms horses were not used as source of power.

In 2002, as compared to 1996, the number of agricultural machines increased in the whole agriculture (exception: forage harvesters, pick-up trailers and bucket milking machines, which number considerably decreased). The biggest, because by around 50%, increase was in the amount of balers and pipe-line milking machines, and around 30% of coolers for milk in buckets, grab-loaders, harvester threshers and tractor sprayers. The number of other machines increased by 4% to 17% (**Table 2**).

In 2002 more than 97% of the agricultural machines were used on private farms exceeding one ha of AUA. The share of individual farms owning harvester threshers made up average 5.9% of total farms. The area group of 50 – 100 ha of AUA was the biggest and made up 65.6%.

Small scale of production on majority of farms in Poland cause the average annual use of machines to be low and operation costs relatively high. The implementation of mutual services between farms would

Table 1. Power on Polish Farms

Size groups	Year	Number of farms in thousands				
		without tractors and horses	exclusively with horses	with tractors and horses	exclusively with tractors	in total
Total	1996	1797,1	215,6	130,9	922,9	3066,5
	2002	1770,6	87,0	75,7	999,9	2933,2
< 1 ha	1996	981,1	7,5	0,6	30,6	1019,7
	2002	919,1	7,3	1,1	49,7	977,2
> 1 ha	1996	815,9	208,2	130,4	892,3	2046,8
	2002	851,5	79,8	74,7	950,2	1956,2
of that 1-5 ha	1996	699,5	130,2	29,6	271,0	1130,3
	2002	741,1	53,4	17,8	334,7	1147,0
5-10 ha	1996	93,5	67,2	57,6	302,8	521,1
	2002	85,8	22,4	27,7	291,0	426,9
10-20 ha	1996	18,8	10,3	35,4	242,4	306,9
	2002	18,9	3,7	20,6	223,5	266,7
20-50 ha	1996	2,9	0,4	7,0	65,4	75,7
	2002	4,0	0,3	7,1	84,5	95,9
> 50 ha	1996	1,3	0,0	0,6	10,7	12,7
	2002	1,7	0,0	1,4	16,6	19,7

Source: Data of the Central Statistical Office and author's calculations

Table. 2 Specified Machines and Agricultural Equipment in 1996 and 2002.

Specification	In thousand pieces		Pieces per 100 units	
	1996	2002	1996	2002
Tractors	1302,9	1364,6	7,29[1]	8,07[1]
Trucks	86,4	144,5	0,48[1]	0,86[1]
Trailers	668,0	726,4	3,74[1]	4,30[1]
Loaders	160,7	209,4	0,90[1]	1,24[1]
Multi-tillers	85,0	285,1	0,62[2]	2,18[2]
Fertilizer sprayers	442,7	540,8	2,48[1]	3,20[1]
Manure spreaders	484,2	504,2	3,52[2]	3,86[2]
Potato planters	344,8	404,8	25,69[3]	50,38[3]
Field tractor sprayers	372,2	473,2	2,70[3]	3,62[3]
Orchard tractor sprayers	35,7	45,7	14,33[3]	16,85[3]
Tractor mowers	439,7	522,5	2,46[1]	3,09[1]
Harvester threshers	97,1	123,8	1,05[3]	1,40[3]
Potato diggers	332,0	401,5	24,74[3]	49,98[3]
Potato harvesters	76,5	81,4	5,70[3]	10,14[3]
Sugar beet harvesters	27,0	32,5	5,96[3]	10,72[3]
Pick-up trailers	98,0	96,2	0,55[1]	0,57[1]
Balers	104,7	147,6	0,59[1]	0,87[1]
Self propelled forage harvesters	5,5	4,8	*	2,45[3]
Other forage harvesters	7,7	8,3	*	4,25[3]
Bucket milking machines	294,2	261,9	8,68[4]	9,12[4]
Pipe-line milking machines	7,4	10,7	0,22[4]	0,37[4]
Coolers for milk in buckets	128,3	170,6	3,78[4]	5,94[4]
Bulk milk coolers	28,4	79,6	0,84[4]	2,77[4]

[1] per 100 ha AUA, [2] per 100 ha of arable land, [3] per 100 ha of relevant crops, [4] per 100 cows

Source: Data of the Central Statistical Office and author's calculations

enable better a use the farm machinery resources on small farms. This form of co-operation makes it possible to reduce investment and operation costs. It also makes the implementation of new technologies easier.

Significant progress has been noticed in the field of rural infrastructure in Poland after 1990. The provision of running water, sewage systems, gas and telecommunication all improved in rural homes. During 1990-2002 1592.9 thousand new rural households were connected to water-supply system (increase by 179.5%). At the same time the number of rural households connected to a sewage system increased from 39.1 thousand up to 365.3 thousand (by 834.3%). In 1995 41.5% of total population using sewage treatment plants, and in 2002 56.7%. In 1999, there were 1,704 sewage treatment plants in rural areas with a total treatment capacity of 680,619.9 m^3/day. In 1999, 229 new sewage treatment plants were started.

In 1990-2002 the number of rural households connected to the natural gas-line network increased from 847.4 thousand to 847.4 thousand (by 209.5%). In 2002, there were 1824,4 thousand registered telephone owners – 62.3% of all farmers' households (compared to 11.1% in 1980, 11.9 in 1990 and 23.3% in 1996). The average number of telephone owners was 149.8 per 1000 inhabitants. The development of infrastructure was possible, thanks to the state politicians.

Conclusion

In order to improve the efficiency of mechanization in agriculture the modernization of the farm structure and reduction of farm machinery operation costs will be necessary. The improvement of the farm structure will depend on the shape of the whole national economy, because it is closely linked with the absorption of manpower surplus from agriculture. The macroeconomic situation will, therefore, decide the future changes in the sphere of production factors in agriculture and their efficiency. However, the ways to speed up changes can and should be found within agriculture itself.

The co-operation between farmers and turnover of agricultural products is one way to increase farmers' incomes.

Appropriate organization of the multi-farm machinery use could help reduce farm machinery operation costs and speed up the progress in mechanization. This is very important under conditions of limited investment possibilities, typical for low-income farms in developing countries.

In order to speed up desirable changes in agriculture, state support is needed which should be provided in the form of cheap credit for acquiring agricultural land, machinery and other investments, development of infrastructure in rural areas, financing research and development as well as for technological and market information and advisory systems.

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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.

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REMOVAL OF ARSENIC FROM TUBE WELL WATER FOR DRINKING PURPOSE

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Removal of arsenic from tube well water is possible by passing through wood charcoal, chemical treatment, sedimentation method or removing the layer floating in arsenic water. It was found in the experiment of chemical treatment that when arsenic water was treated with calcium oxide, it produced arsenic free water. In this method more than 90 percent removal of arsenic, by adding 0.1% (by weight) calcium oxide with arsenic contaminated water. After 10 hrs the water became arsenic free. Arsenic water was passed through the wood charcoal with different flow rates and was found that with a critical flow rate the average removal of arsenic up to 98% percent was possible. When arsenic water (0.45 mg/lit) was kept in a big tank (about 3000 liter's capacity) for about 9 days, the arsenic concentration level was reduced in the top few layers to acceptable level (0.05 mg/lit). When arsenic water came in contact with free air, a thin layer was formed which was nothing but arsenic compound which was about 0.7 mg/lit. In this way arsenic level can be reduced to acceptable level by repeated removal of the floating layer. Any method can be used to produce arsenic free water which can be recommended for use safely in the rural areas.

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EVALUATION OF INTENSIVE DECOMPOSITION OF ORGANIC SUBSTANCES AT VARIOUS LEVELS OF ANAEROBIC FERMENTATION IN REACTOR UNIT

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A study on animal dung with a humidity of 93% on 2nd and 3rd relative levels of fermentation mass in a reactor, showed an essential difference in organic substance (OS) concentration. The difference is more visible for dung with a humidity of 95%.

For the process of anaerobic fermentation, or for an anaerobic fermentation feeding, not only OS quantity is necessary but also their possibilities and speed of biological decomposition.

The experimental studies were carried out to determine the specific possibilities and biological decomposition speed of OS fermentation mass at varying reactor levels.

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Performance Evaluation of Alternating – Current Motor Operated Walking Tractor

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A single phase of one kW, at 1440 rev/min, 6.1 was shown in a continuous rating alternating current induction motor of a walking tractor in motion was developed. The performance of the tractor was assessed with varying widths of sweep blade, depths of operation and forward speeds. A 200-mm width of sweep blade at 80 mm depth of operation and 1.05 km/h forward speed were satisfactory for weeding operation. The operational cost of weeding and inter-culture of the walking tractor was US$ 9/ha as compared to US$ 42/ha in manual operation.

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STRENGTH CHARACTERISATION OF PALM KERNEL

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The stress requirements of three species of palm kernel, dura, tenera and pisifera, have been investigated. Two thousand and fifty (2050) kernels were classified into different size ranges by diameter (d) as d<15, 15ÅídÅí20 and d>20 (mm), using vernier calipers, and approximating to the shape of the kernel. One thousand, eight hundred (1,800) and, 250 kernels were, respectively, used for compressive strength and shear strength tests. The kernels were then subjected to varying degrees of compressive and shear loading at various moisture contents. Analyses of the results showed a direct functional relationship between the compressive and shear strengths of palm kernel and its size at a constant moisture content. The moisture content of the samples varied between 19.5% and 25.0%, and it was also observed that for a given size of the kernel, the strength of kernel bears an inverse proportionality relationship with the moisture content of the kernel.

■■

NEWS

AgriChina in Shanghai
31 August - 2 September, China.

(DLG). With dispatch of the information and application package, preparations for the agricultural exhibition agriChina 2004 have now begun. As the organisers, Deutsche Messe AG and German Agricultural Society (Deutsche Landwirtschafts-Gesellschaft, DLG) report in a press release, the premiere of agriChina will be held from 31 August to 2 September 2004 at the Shanghai New International Expo Centre (SNIEC). Two renowned exhibition organisers are thus offering interested firms an outstanding platform for their take-off in a large and expanding agricultural market in Eastern Asia. The deadline for registrations is 15 April 2004.

agriChina consists of three parts: a specialist exhibition with stands run by machinery manufacturers and service providers, a top-flight expert forum with expert lectures and presentations, and a visit programme with visits to firms, organisations and/or public facilities.

The exhibition part is divided into three sectors

・Agricultural machinery and plant production with technologies for drilling, fertilising, plant protection, irrigation processes, harvesting machinery, harvest processing, conditioning and storage, tractors, special tractors, and transport technology.

・Livestock husbandry and livestock management for poultry, pigs, beef and dairy cattle with animal breeding, animal husbandry, animal nutrition and animal health, as well as processing and marketing.

・Fruit and vegetable growing with crop husbandry technology, greenhouse cultivation, harvesting machinery, processing, packing and conservation.

Tel: ++49/(0)69/24788-202,Fax: -112; e-mail: f.rach@DLG-Frankfurt.de URL: www.dlg.org

Conference on Postharvest Technology & Quality Management in Arid Tropics
24-26 January 2005, Oman.

Sultan Qaboos University, Sultanate of Oman

Postharvest Technology is critical to the successful handling and marketing of good quality and safe food products. The long supply chain of many products and the arid tropical handling environment in Oman and similar climates, present additional technological challenges for product conservation and quality maintenance. This first International Conference on postharvest technology in the region will provide an international forum to discuss the latest technological developments and scientific innovations for reducing losses, maintaining product quality and adding value to food and agribusiness supply chains, and enhancing the competitiveness of agricultural and seafood products in the Gulf Region and Oman in particular.

The major themes of the conference include:

Pre-harvest factors affecting postharvest quality and losses
Postharvest handling systems and ergonomics
Optimal refrigerated and controlled atmosphere storage systems
Drying and packaging technology
Postharvest treatments to maintain quality
Focus on seafood postharvest
Quality and supply chain innovation
Food traceability and safety management
Postharvest economics, market access and other emerging issues
Education and training in postharvest management

Important Deadlines:

Submission of abstracts: 15 March 2004
Notification of acceptance: 30 April 2004
Submission of full paper: 30 August 2004

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5th European Conference on Precision Agriculture (5ECPA)
2nd European Conference on Precision Livestock Farming (2ECPLF)
9-12 June 2005, Sweden.

Themes

Within this conference we will focus on the following themes.

- Feed quality management
- On farm analysis technology
- Robotics, autonomous vehicles and controlled traffic
- Environmental effects of precision agriculture and precision livestock farming

- Precision horticulture and viticulture
- Automation in livestock farming
- Implementation, education and training

Web page

More updates and information on the conferences can be found on http://www-conference.slu.se/ecpa/index.htm or http://www-conference.slu.se/ecplf/index.htm

VI ALIA Congress (CLIA 2004)

November 22-24, 2004
San Jose, Costa Rica.

For information about the Congress, visit our website:
www.clia2004.org
Fax: (506) 224 9598
e-mail : congresoalia@costarricense.cr

2004 CIGR International Conference

11-14 Oct 2004
Beijing China,

AAAE Co-Sponsored
Topics:

Soil, water and environmental engineering; Post harvest technology for bio-products and food safety; information technology for agriculture; Agricultural engineering for sustainable and small farming; and Modern agricultural equipment and facilities.

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EuroTier 2004:

Excellent stand registration figures

Higher than in record year 2002- Remarkable developments - World market leaders with larger stands in poultry sector - DLG concept takes off

(DLG). So far over 1,100 exhibitors, including many new exhibitors, have registered for the International DLG Exhibition for Livestock and Poultry Production and Management EuroTier 2004. The German Agricultural Society (Deutsche Landwirtschafts-Gesellschaft, DLG) as organiser can thus present excellent figures. The floor space booked exceeds even that booked at the same time for the last exhibition, the record EuroTier of two years ago. In view of the currently uncertain markets and the fact that the European agricultural reform has not yet been implemented, the DLG sees this as a sign that manufacturers too are expecting a gradual recovery of the livestock and poultry management market. At the same time the registration figures highlight EuroTier's leading position as the main exhibition in the livestock and poultry management sector worldwide.

CIOSTA, CIGR, EurAgEng and VDI-MEG feel honoured to invite you to the XXXI CIOSTA-CIGR V Congress at the University of Hohen-heim in the South of Germany.

Founded as an agricultural college, the Uni-versity of Hohenheim has developed its own profile. Besides agricultural sciences, it offers on its unique campus biology, food sciences and economics. The University of Hohenheim is proud to cover the whole spectrum of agricultural sciences and research with an interdisciplinary approach.

Further information on EuroTier 2004 is available from the Deutsche Landwirtschafts-Gesellschaft (DLG), Eschborner Landstr. 122, D-60489 Frankfurt am Main, Tel. +49/(0)69/24788-254 or -259, Fax: +49/(0)69/24788-113, E-mail: g.ott@DLG-Frankfurt.de or in the Internet under www.eurotier.de or www.worldpoultryshow.com.

XXXI CIOSTA-CIGR V Congress "Increasing Work Efficiency in Agriculture, Horticulture and Foresty".

September 19-21, 2005
University of Hohenheim, Stuttgart,Germany, September 19-21, 2005.

Since 2000 teaching has been organized in Bachelor and Master Courses including modular course structure and credit point system. Besides the traditional fields of study such as animal sciences, plant sciences, agricultural economics the University of Hohenheim offers unique master courses such as Soil Sciences, Agricul-tural Engineering, AgriBusiness, EnviroFood, Tropical Agriculture.

The Institute of Agricultural Engineering focusses on the following research topics: Technology of fruit and vegetable growing, viticulture, plant protection technology, irrigation technology, harvest technology, agricultu- ral tractor tyre technology, farm buildings and housing systems, milking, animal waste manage-ment and treatment, emissions and indoor air quality.

Topics

- . Methods and modelling
- .Process engineering and controlling
- . Calculation and planning
- . Farm management
- . Ergonomics and work place design
- . Work safety, prevention and risk analysis

COORDINATOR: Dr. Monika Krause E-mail: ciosta@uni-hohenheim.de

Phone: +49(0)711/459-3231 (only Tuesday) Fax: +49(0)711/459-4307

INTERNET: http://www.uni-hohenheim.de/ciosta-cigr

ISMAB 2004

The 2nd International Symposium on Machinery and Mechatronics for Agriculure and Bio-systems Engineering (ISMAB2004, JAPAN)

Sept. 21-23, 2004

Kobe city Japan

T

This symposium is organized by Japanese Society of Agricultural Machinery, and co-sponsored by Korean Society of Agricultural Machinery and Chinese Institute of Agricultural Machinery, Taiwan.

This assembly will be provided for exchanging ideas and results, and transmitting scientific information from East Asia to the world.

Sponsored by the Japanese Society of Agricultural Machinery

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Under the grant-in-aid by "MEET IN KOBE 21st Century" program of Kobe Convention & Visitors Association:

Conference Contact Topics Organized Sessions

To be made according the full paper format and sent to the conference contact until June 30th.

Mailing account is changed as below. ismab@kobe-u.ac.jp

Registration

Regular menber: JPY 31,000 (USD 250, only for bamk transfer)

Students: JAPY 10,000 (USD 80, only for bamk transfer)

Accompanying paerson: JPY 6,000 (USD 50, only for bamk transfer)

On details: please see in 2nd Call and Registration Form.

Tentative Schedule:

Day 1st : Opening session & Reports of Poster sessions

Kobe Univ. Centennial Hall

Day 2nd:: Poster sessions & Organised sessions (oral)

Day 3rd: Technical Visit & Excursion to rocal Town

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TOPICS

ISMAB2004 topics include, but are not limited to,

Bio-systems Engineering
Bio-mechatronics
Biological Engineering
Bio-energy & Alternative Energy
Power & Machinery
Post harvest Technology
Food & Processing Engineering
Precision Farming & Agriculture
Automation in Agro-industry
Robotics in Agriculture
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Bioinformatics
Environmental Technology
Nano technology

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MEDIA ALERT

(New York, Aplir 20, 2004)-Marcle Dekker, Inc., proudly announces the publication of **Sustainable Agriculture and the International Rice-Wheat System(ISBN: 0-8247-5491-3)** edited by RATTAN LAL, The Ohio State University, Columbus, U.S.A.; PETER R. HOBBS and NORMAN UPHOFF, Cornell University, Ithaca, New York, U.S.A.; and David O. Hansen The Ohio State University, Columbus, U.S.A.

Locally Made Equipment for Teaching and Research in Agricultural Engineering

R. H. MACMILLAN
Senior Fellow, International Development Technologies Centre
University of Melbourne
r.macmillan@devtech.unimelb.edu.au

These manuals were written to make available simple designs of basic equipment intended to be made by institutions for their own use in teaching and research in agricultural engineering and associated technologies. They are directed at the study of the functional performance of various machines and items of equipment and particularly at the important elements which determine that performance.

As well as providing drawings showing the main dimensions of the equipment, the manuals also include basic theory, design considerations, and techniques for their calibration and use. The designs are based, as far as possible, on the use of industrial components. In addition to specifying part numbers and sources of supply for purchased components, the latter have also been specified, where possible, in terms of size / capacity / performance so that suitable alternatives may be used.

A range of types of transducer from simple manually read devices to more complex electronic units may be used with the designs. In this way the latter can serve a range of users and can remain in use as the level of instrumentation grows.

They were originally printed and distributed to interested people by the Editor in 1991 and are now being made available to a wider readership by being republished in a slightly amended form on the ePrints Repository of the University of Melbourne. They can be down loaded free of charge at the addresses given below.

The manuals and associated drawings may be freely copied for non-commercial purposes. However acknowledgement of the source of the designs is requested in any publications resulting from their use.

List of Titles in The Series

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International Agricultural Engineering Conference

6-9 December 2005
Asian Institute of Technology
Bangkok, Thailand

Organized by Asian Association for Agricultural Engineers(AAAE) and Asian Institute of Technology

Futher details about registration, costs, program and tours will be sent upon receipt of the completed 'Expression of Intent ' form. For any inquiry, please contact the address blow:

FAX +66 2 254 6200

E-mail : aaae@ait.ac.th;
emann@ait.ac.th

http://www.aaae.ait.ac.th/index.html

BOOK REVIEW

Agricultural Systems Management

(USA)

by Robert M. Peart, W. David Shoup

1.Description

Offering practical and informative exercises in nearly every chapter, this text/reference presents valuable computer strategies for solutions to challenges commonly faced in agricultural production, processing, and management and covers topics that are integral to real-world agricultural system management including precision agriculture, crop and operation simulation, geographic information systems, project scheduling, systems reliability, machinery performance and cost, and linear optimization.

published by Marcel Dekkekr, Inc.
http://www.dekker.com

Sustainable Agriculture and the International Rice-Wheat System

(USA)

by Rattan Lal, Peter R. Hobbs, Norman Uphoff, David O. Hansen

1.Description

Addressing a topic of major importance to the maintenance of world food supplies, this reference identifies knowledge gaps, defines priorities, and formulates recommendations for the improvement of the rice?wheat farming system?revealing new systems of rice intensification and management while illustrating the application of no-till and conservation farming to the rice?wheat system with case studies from India, Nepal, Pakistan, and Bangladesh.

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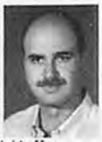
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