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AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.24, NO.2, SPRING 1993

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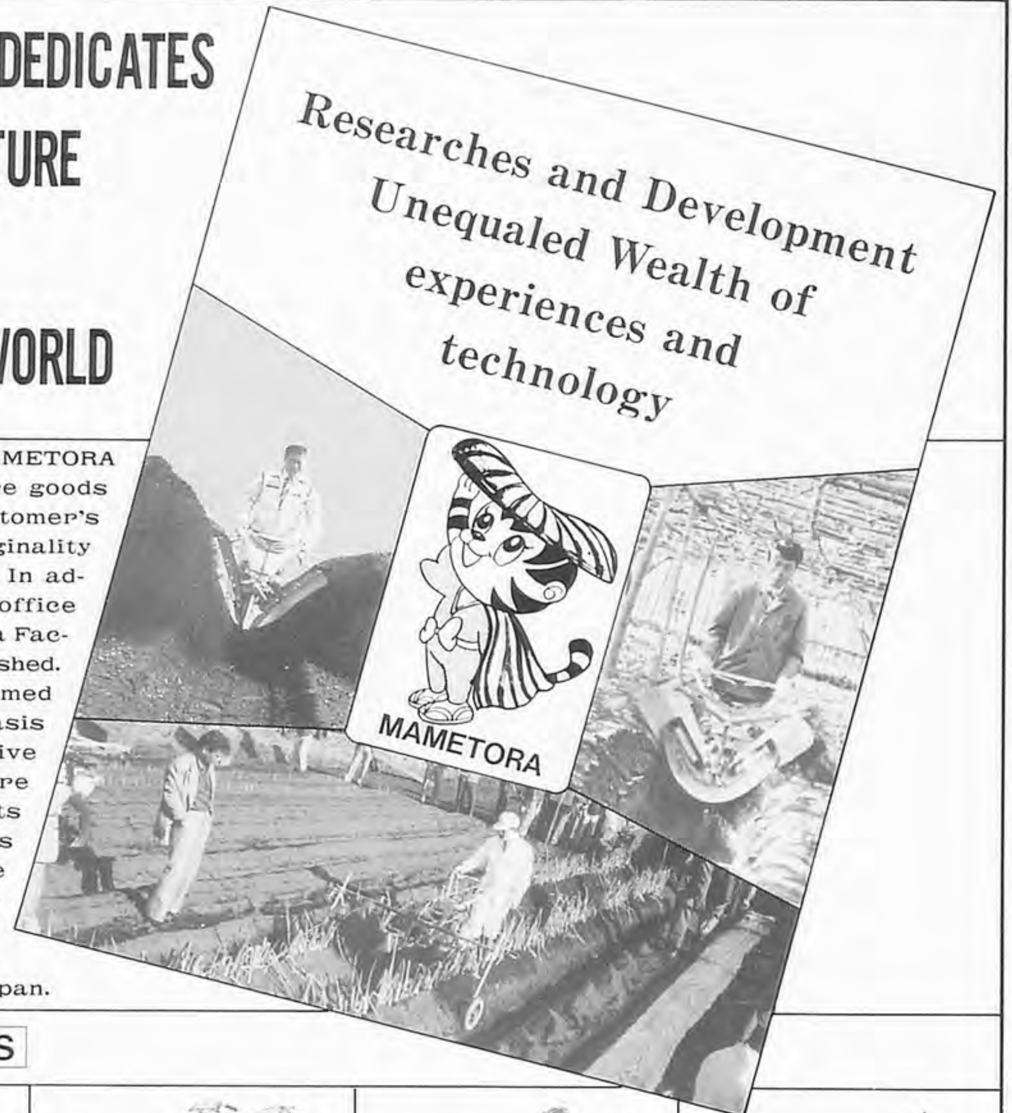

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Edited by

YOSHISUKE KISHIDA

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EDITORIAL

Greater Need to Promote Food Production

The regional conflicts that currently take place in many countries of the world are not likely to come to an end for the time being. In the meanwhile, scores of people, especially children, die from malnutrition and hunger daily in some of those regions, let alone the fact that some of these conflicts could spark greater conflagration and threaten the peace that has come at the end of the cold war. For example, the political upheaval in Russia seems to be getting worse; the killing in the former Yugoslavia continues to this day; the ugly conflict among warlords in Somalia has yet to subside notwithstanding the U.N.'s intervention; and the Hindu-Muslim confrontation in India goes unabated.

Behind all this chaos is the nagging question of food problem. Airlifting of food supplies by aid-givers is, at best, a temporary solution considering that there has already been a great deal of dislocation in the economies/resources in those regions of the world. The net result is that malnutrition, hunger and death will continue to stalk the plight of the affected population—unless the conflicts are solved soon, domestic food production is fully resumed or improved, and the exodus of the youth from rural to urban areas is stopped or minimized, among other considerations.

From where the AMA sees the food problem, it seems imperative that governments in those troubled regions give top priority to programs/projects that would improve or at least restore their levels of agricultural productivity. In this way, hunger and death, in both the short-run and long-run perspectives can be averted. To be sure, those conflicts have underscored a greater need for technology in agriculture and agricultural mechanization in the affected countries.

In this regard, I take exception in highlighting a most inspiring article entitled "Planning Farmshops for Developing Agriculture", p. 54 of this issue of AMA. The article was written and submitted by Dr. Adeyemi Aderoba who envisions that an effective way of promoting farm mechanization and rural development is through the establishment of farmshops by individual entrepreneurs or farmers' cooperatives. (I hasten to add that the appropriate agencies, private or non-private, should take the lead in promoting this idea). Dr. Aderoba identifies the factors that could trigger the establishments of such farmshops, enumerates the practical functions of farmshops, particularly in the countryside, and clearly outlines the step-by-step procedure for the gradual establishment of farmshops from initially low capital base. He also provides some economics of the farmshop.

I am tempted to complement Dr. Aderoba's vision of a very practical and promising venture by suggesting that the heavy machineries and other weapons of death now abundant and in use for killing in the troubled regions, e.g., guns, bazookas, tanks and ammunition be converted into farm tractors, bulldozers, plowshares, harrows, combines, planters, harvesters and bayonets in the farmshops—all of which should be harnessed instead in increasing agricultural productivity. For certainly, agricultural mechanization technology will have a long-lasting effect in increasing food availability in those troubled areas, in particular, and in the Third World, in general.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
April, 1993

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Prediction of Traction Potential of Wheel Tractors by Plate Penetration Method

by
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Abstract

Prediction of traction potential of wheel tractors is of vital importance from design point of view because it will help solve the traction problems of the wheel tractors. Many methods have been devised to predict the traction of the tractors, among which plate penetration method is the oldest in use. Since other methods are costly, therefore, shear plates of different sizes were designed and fabricated in the workshop of the Faculty of Agricultural Engineering, Sindh Agriculture University, Tandojam and were used to predict the traction potential of three wheel tractors, viz, Ford 6610, Ford 4600 and Fiat 640. A soil bin of about 9 m long, 1.5 m wide and 0.5 m deep was designed and constructed. The cohesion C and angle of interval friction ø were determined by means of shear plates in the soil bin. The tractors were weighed on a weigh bridge. The slip of the tractors was recorded in the field, width and length of contact were measured in the field and finally, the Janosi et al formula for traction was used to predit traction potential. The traction for each tractor were 1 275.24 kg of Ford 4600, 1 731.93 kg of Ford 6610 and 1 251.18 kg of Fiat 640.

Introduction

Traction is the force derived from the interaction between a device and a medium that can be used to facilitate a desired motion over the medium. The usual traction device converts rotary motion derived from an engine into useful linear motion.

A solution of the traction problem at a suitable speed in a practical manner and at a reasonable cost lies in the understanding of the manner in which stresses are applied to the soil and the reaction of the soil to the applied stresses. When a non-rolling device acts on soil, a friction between soil and the device takes place, therefore, in this case law of friction is applied to predict traction force. But the tyres are rolling devices and cause the soil failure involving frictional resistance. Therefore, a logical assumption on which to predict failure is the Coulomb's (1776) Law of Friction. This law was modified by Milklethwait (1944) to predict the tractive force of the tractors. The Milklethwait method was only valid for brittle failure of soils but soils generally exhibit plastic failure, hence the Janosi et al (1961) method is reasonable for predicting the tractive force of tractors. This method is based on plate penetration approach, and will provide the knowledge to the designers as to how the tractors can be designed economically.

Methodology

The Janosi et al (1961) equation for predicting the tractive force of the tractors involves the use of soil values C and ø. Various methods of determining these values have been devised. Among these methods translational box is easy to use and is well suited for easily flowing granular soils. The triaxial test machine allows the soil to be tested under varying drainage simulating conditions encountered by the civil engineers. This method is laborious and the preparation of soil samples requires considerable care and skill, specially when dealing with purely frictional and purely cohesive soils. The N.I.A.E. shear box needs a great care to ensure that the box is pushed in level and that not too much soil is removed around the box to prevent it from collapsing on its sides. The other disadvantage is that the torque applied is not fully transmitted to the entire body of the sample through the small vanes. The results obtained by this method on dry sand are low. The bevameter is capable of measuring the soil values C and ø both from load sinkage tests and by annular shear stress deformation tests and yields satisfactory results in all three types of soil. The use of shear vane is confined only to clay soils.

Since the above described instruments were not available in the Faculty of Agricultural Engineering, Sindh Agriculture University, Tandojam, the shear plates of different sizes were designed and fabricated (**Figs. 1, 2 and 3**). The plate penetration test has received a great deal of attention as a means of measuring soil characteristics. In civil engineering, loading test on large plates (30-60 mm diameter) are frequently used to assess the bearing capacity of soil for foundation when the analogy is obviously close. Models based on plate penetration results have been used to predict the performance of tractors in terms of traction. The method based on the use of plate is generally accepted as being "rough and ready" method for predicting mobility; it can not be used to differentiate between the performance of variable tractive elements or to evaluate sub-soil response beneath the tractive element. The dangers inherent with plate penetration technique lie not only in the nature of the technique but in the application of the procedure for predictive use to situation not observed in the correlation sought. The application of shear plates in the theory of traction is to predict the soil values C and ø. To determine these values the shear plates were used in the soil bin. The experimental set up of shear plates for the purpose is shown in **Fig. 4**. Different loads were placed on the shear plates and the pulling force was recorded on the spring balance (**Table 1**). The readings of force F were plotted against the weight W. The values of C and ø were found in **Figs. 5, 6 and 7**.

The weight of the tractors was needed in determining the tractive force of the tractors. Hence,

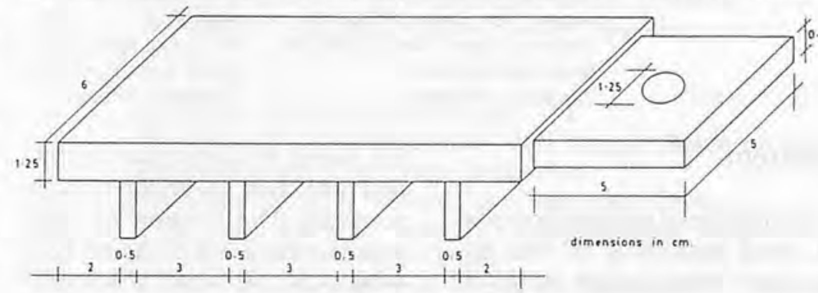

Fig. 1 Shear plate No. 1.

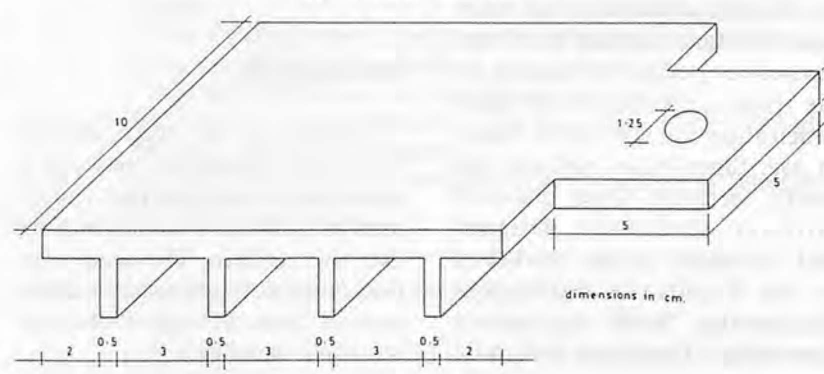

Fig. 2 Shear plate No. 2.

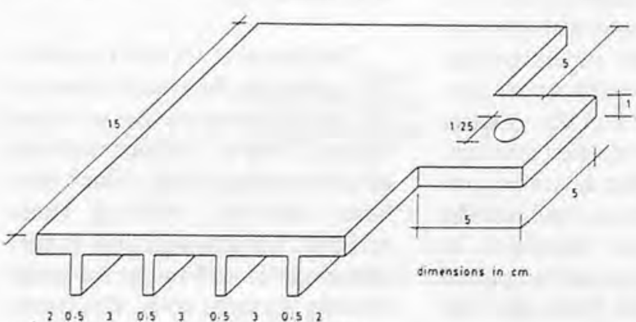

Fig. 3 Shear plate No. 3.

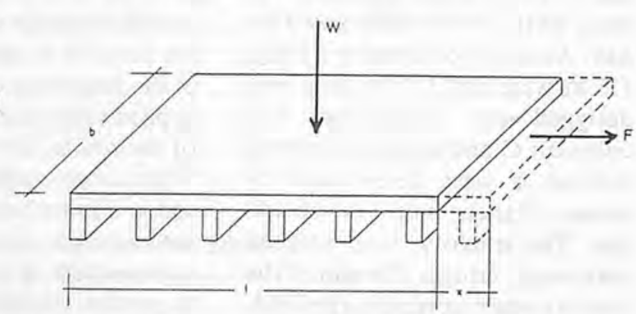

Fig. 4 Shearing force vs vertical loading for determining C and ø values of soil.

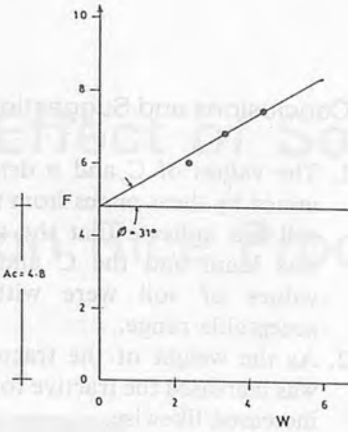

Fig. 5 Force vs load.

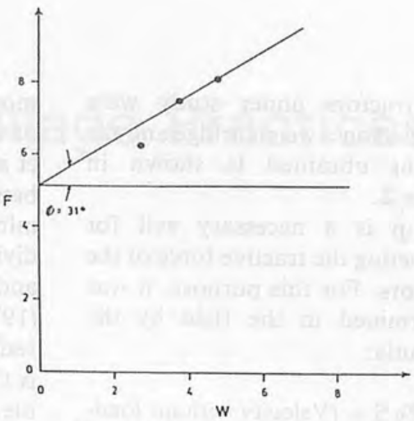

Fig. 6 Force vs load.

Table 1 Readings of Shear Plates

Load with Plate Weight (kg)	Force (kg)	Sinkage Z (cm)
Plate No. 1		
1. 2.3	6.0	0.3
2. 3.3	6.8	0.4
3. 4.3	7.4	0.6
Mean 3.3	6.7	0.43
Plate No. 2		
1. 2.7	6.2	0.6
2. 3.7	7.3	0.7
3. 4.7	8.1	0.8
Mean 3.7	7.36	0.7
Plate No. 3		
1. 3.4	7.2	0.4
2. 4.4	7.6	0.6
3. 5.4	8.2	0.8
Mean 4.4	7.6	0.6

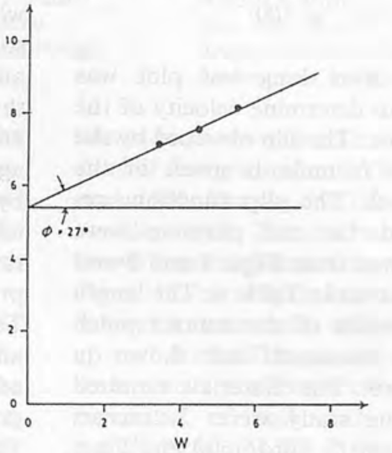

Fig. 7 Force vs load.

Table 2 Weight Distribution of Tractors

Tractor	Front Weight (kg)	Rear Weight (kg)	Total Weight (kg)
Ford 4600	720	1 480	2 200
Ford 6610	1 040	1 960	3 000
Fiat 640	760	1 400	2 160

Table 3 Percent Slippage

Tractor	Gear	Distance Covered (m)	Time Taken with Load (sec)	Time Taken without Load (sec)	Velocity with Load (m/sec)	Velocity without Load (m/sec)	Slip (%)
Ford 4600	3rd	30	20	19	1.5	1.7	13
Ford 6610	3rd	30	24	20	1.25	1.5	17
Fiat 640	3rd	30	23	21	1.36	1.43	13

Table 4 Slip Functions

Tractor	Speed km/h	Slip %	L/K	il/k	X
Ford 4600	5.4	13	55	10	0.84
Ford 6610	4.5	17	33	6.1	0.82
Fiat 640	4.68	13	55	6.8	0.83

Table 5 Wheel Base, Wheel Dia and Width of Tyre

Tractor	Wheel Base (cm)	Wheel Dia (cm)	Width of Tyre (cm)	Contact Length of Tyre (cm)
Ford 4600	217	127	41	31.75
Ford 6610	220	144	48	36.00
Fiat 610	205	126	40	31.50

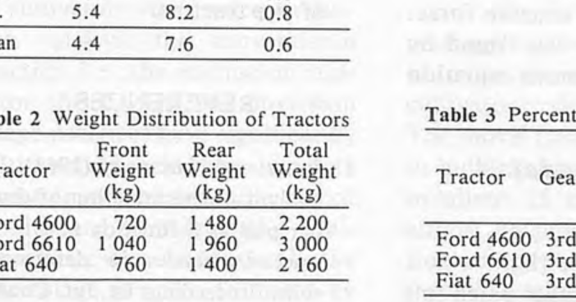

Fig. 8 Slip function.

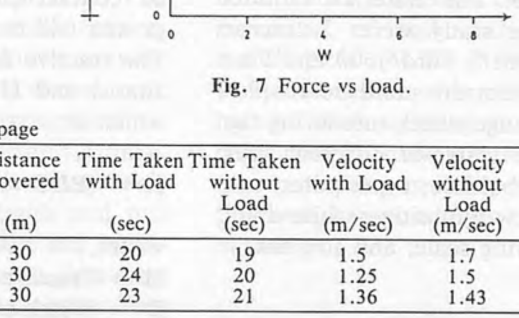

Fig. 9 Slip function.

the tractors under study were weighed on a weigh bridge and the weight obtained is shown in **Table 2**.

Slip is a necessary evil for predicting the tractive force of the tractors. For this purpose, it was determined in the field by the formula:

Slip % S = (Velocity without load- Velocity with load) /(Velocity with load) × 100

A 30-m long test plot was used to determine velocity of the tractors. The slip obtained by the above formula is given in the **Table 3**. The slip functions required for the purpose were obtained from **Figs. 8** and **9** and are shown in **Table 4**. The length and width of the contact patch were measured and shown in **Table 5**. The materials required for the study were: 3 tractors Ford 6610, Ford 4600 and Fiate 640; 3 bottom mold board plow with gauge wheel; measuring tap; 3 shear plates of different sizes; spring balance; rope; poles; stop watch; weigh bridge; white chalk; measuring scale; and soil bin.

Results and Discussion

Cohesion and angle of internal friction of soil have profound effect on the tractive force of the tractors. The greater the value of C, the greater will be the tractive force and vice versa. It was, therefore, imperative that the soil values must be determined.

The values of C and ø determined by the shear plate method more or less agree with the values of C and ø determined by Mckyes et al (1977). Slip is the difference between velocity without load minus velocity with load and divided by the velocity with load and multiplied by 100. Frank (1972) defined slip as the travel reduction of the drive wheels and is the primary independent variable. Both tyre efficiency and dynamic ratio are a direct function of travel reduction of the drive wheels. He concluded that on firm soil the slip varies between 10% and 15%. The predicted slip for three tractors under study varied between 13% and 17% which agrees with the values determined by Frank. The weight of the tractor and width and length of contact patch of tractors have profound effect on tractive force. The greater the weight of tractor and the larger the width and length of contact patch of tyre, the greater will be the tractive force. The tractive force was found by Janosi and Hanomoto equation which is:

$$H = (BLC \times W \tan\phi). X$$

where,
H = Tractive force (kg)
B = Width of contact patch (m)
L = Length of contact patch (m)
C = Cohesion of soil (kg/m^2)
W = Weight of tractor (kg)
ø = Angle of internal friction
X = Slip function

From the above equation it is obvious that, the other factors being constant, the tractive force increases as the weight of tractor, its wheel width and length of contact patch increase.

Conclusions and Suggestions

1. The values of C and ø determined by shear plates from the soil bin indicate that the soil was loam and the C and ø values of soil were within acceptable range.
2. As the weight of the tractors was increased the tractive force increased likewise.
3. As the weight of the tractors increased the slip was increased. The weight of the increases on the compaction of the soil will be harmful to crop growth, hence it is suggested that there must be compromise between the tractive force, slip and weight of the tractor; so that there must be optimum tractive force and slip. This compromise from design point of view will save the material cost, reduce the soil compaction and propose the economical design of the tractors.

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■■

Effect of Soil Inversion Tillage Practices on Rice Production

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Abstract

In this study, an evaluation of the effect of complete soil inversion with the use of mold board plow once followed by cultivator twice and partial soil inversion with the tillage package comprising of disc harrow twice followed by cultivator twice on rice production vis-â-vis the conventional practice, i.e.; the sole use of cultivator thrice. The soil inversion tillage practices gave significantly better paddy yield. The complete inversion of soil with the use of mold board plow once plus cultivator twice was observed to be the best tillage practice followed by partial soil inversion for paddy production. Both the soil inversion, complete and partial, tillage practices were also found economically feasible.

Objectives

Rice is the third major crop in Pakistan. It is grown on about 10% of total cultivated land. This is a crop of irrigated areas in the country. There are large tracts of riceland in Punjab province where its cultivation is carried out on more than one million ha annually.

Enhanced yield of crops can be obtained by optimizing the physical inputs through appropriate bio-hydro-chemical technologies. But actually important is the suitable land preparation which facilitates the degree of effectiveness of the appplication of these technologies for plant nourishment and healthy growth. The most popular mechanization package in the country consists of a tractor and a shovel type cultivator to do tillage operations. The shovel type cultivator, similar to bullock drawn plow, tears soil to about 15 cm depth and has almost no pulverising and inversion action. As a result, less crop yield is obtained due to poor land preparation.

The study was conducted to assess the effect of land preparation through soil inversion tillage practices on rice production.

Review of Literature

Research regarding the interrelationship of soil, implement and crop is quite a new field. Very little work on the response of land preparation to rice crop has been presented. Compared with the sole use of cultivator, a significant increase in paddy yield has been reported with the inclusion of rotary cultivator in the preparation of medium textured and puddling of fine textured soils (Razzaq et al, 1985, Razzaq, 1987 and Dte — AR, 1989). The conventional shovel type cultivator tears soil to about 15 cm depth and rotary cultivator cuts and mixes soil up to 7-8 cm. The present study determines the effect of complete inversion of soil with mold board plow (M.B. Plow) and partial inversion with offset disc harrow, both working at greater depth than the conventional shovel type cultivator, on paddy production and, hence, is quite original in nature.

Materials and Methods

The study was carried out during 1987, 1988 and 1989 by arranging trials at the adaptive research farm, Sheikhupura and farmers' fields in the district which possessed a pivotal position in the rice tract of the Punjab province, Pakistan. The trials were laid out at 10 similar sites each year in clay loam soil with four replications using randomized complete block design on rice fine variety, B-385. The following treatments were put to the test:

1. Conventional practice; shovel type cultivator (3);
2. Complete inversion of soil;

M.B. plow (1) + cultivator (2); and
3. Partial inversion of soil; Disc harrow (2) + cultivator (2) (The figures in brackets denote the replications for which an implement was run)

The implements were run with 75 H.P. MF-375 tractor. The above treatments were split into pre-puddling and puddling tillage practices. The pre-puddling tillage practices were carried out using cultivator once, M.B. plow once and disc harrow twice in soil at ploughable moisture level. Before puddling, a uniform pass of cultivator and plank, each once, was given to all treatments for crushing clods and easy watering. Then the land was irrigated and puddling was carried out with the use of shovel type cultivator once followed by planking once. The seedlings were transplanted manually. All the agronomic and plant protection measures were uniformly adopted as per agricultural departmental recommendations.

The working depth of implements was noted. Data regarding productive tillers, grain formation, grain weight and paddy yield were recorded at the time of harvesting, average and percent increase over the conventional practice were calculated. Statistical analysis of the yield results was undertaken to ascertain the significant difference between the treatment means at 5% level and the least significant difference (LSD) calculated. On the basis of treatments expenditure and income, economic analysis was carried out to determine the cost-benefit ratio. The government support price of Rs. 142 per 40 kgs. fixed for paddy was used to calculate gross income. The total expenditure was computed using the following rates prevailing during rice season, 1989.

a. Variable expenditure
1. Cultivator
   = Rs. 86/ha/run for dry soil and Rs. 123/ha/run for puddling.
2. M.B. Plow
   = Rs. 368/ha/run.
3. Disc Harrow
   = Rs. 123/ha/run.

b. Fixed expenditure per hectare
1. Planking:
   = Rs. 37/ha/run for dry soil and Rs. 50/ha/run for puddling.
2. Charges of growing nursery:
   i. Seed
      = 10 kgs. @ Rs. 142/40 kgs.
   ii. Nursery bed preparation
      = 2 applications of 1 kg. BHC each @ Rs. 30/kg.
   iii. Pesticide
      = 2 applications of 1 kg. BHC each @ Rs. 30/kg.
   iv. Farm yard manure
      = 1 cart @ Rs. 160/cart.
3. Transplanting:
   i. Nursery uprooting
      = 2 manday @ Rs. 25/manday.
   ii. Nursery transportation
      = 1 manday @ Rs. 25/manday.
   iii. Nursery transplanting
      = 15 manday @ Rs. 25/manday.
4. Fertilizer (NPK, 135-78-78 kg./ha., each bag of 50 kgs.):
   i. DAP
      = Rs. 203/bag.
   ii. Urea
      = Rs. 145/bag.
   iii. Potassium sulphate
      = Rs. 72/bag.
   iv. Fertilizer application
      = 1 manday @ Rs. 25/manday.
5. Irrigation:
   i. Cleaning of watercourse
      = 2 manday @ Rs. 25/manday.
   ii. Labour charges for 16 irrigations
      = 10 manday @ Rs. 25/manday.
   iii. Water rates
      = Rs. 157/ha.
   iv. Irrigation by tubewell
      = 8 irrigations @ Rs. 30 each.
6. Weedicide:
   Machete
   = 1.96 lit/ha @ Rs. 206/lit.
7. Plant protection:
   i. 2 applications of granules
      = 25 kgs./ha @ Rs. 26/kg.
   ii. Labour charges
      = 1 manday @ Rs. 25/manday.
8. Harvesting with combine
   = Rs. 1225/ha.

Results and Discussion

Implement Performance

The average working depth recorded after operating each implement is given in **Table 1**.

The cultivator teared the soil 15 cm deep on the average. The M.B. plow inverted soil completely up to an average depth of 30 cm. The disc harrow easily opened soil up to an average depth of 23 cm and partially inverted by moving it to the right direction with the front gang followed by similar action to the left direction with the rear gang.

Table 1 Working Depth of Implements

Implement	Average depth (cm)
Cultivator	15
M.B. plow	30
Disc harrow	23

Table 2 Effect of Different Tillage Practices on Tillering of Rice Crop

Treatment	Productive tillers (No./plant)			Average tillers (No./plant)	Increase in tillering over control (%)
	1987	1988	1989		
Cultivator (3)	9	12	15	12	Control
M.B. plow (1) + cultivator (2)	10	13	16	13	8.33
Disc harrow (2) + cultivator (2)	9	12	15	12	—

Crop Tillering

The effect of tillage practices under study on the tillering of the rice crop is given in **Table 2**.

The above data indicate that equal number of tillers per plant were observed with the conventional practice and the partial soil inversion with the disc harrow (2) followed by cultivator (2). The complete soil inversion with the use of M.B. plow (1) followed by cultivator (2) registered 8.33% higher tillering than the conventional practice i.e.; cultivator (3). A uniform trend of the effect of all treatments on the development of tillers during the three years was observed.

Grain Formation

Table 3 shows the effect of various tillage practices on grain formation.

The above table shows that the highest number of grains per panicle were developed with the use of M.B. plow once followed by cultivator twice every year with an average increase of 28.65% over the conventional practice. The operation of disc harrow (2) followed by cultivator (2) also gave 19.30% higher grain formation than the conventional practice.

Grain Weight

The effect of various tillage practices on the grain weight is shown in **Table 4**.

As per above data, the use of M.B. plow (1) followed by cultivator (2) registered the highest grain weight every year with an average increase of 9.18% over the conventional practice. The second best result was obtained with the use of disc harrow (2) followed by cultivator (2) where an average increase of 5.27% in grain weight over the conventional practice observed.

Yield

Table 3 Effect of Different Tillage Practices on Rice Grain Formation

Treatment	No. of grains per panicle			Average No. of grains per panicle	Increase over control (%)
	,1987	1988	1989		
Cultivator (3)	118	197	199	171	—
M.B. plow (1) + cultivator (2)	215	217	227	220	28.65
Disc harrow (2) + cultivator (2)	185	206	222	204	19.30

Table 4 Effect of Different Tillage Practices on Weight of Rice Grains

Treatment	Weight (g/1000 grains)			Average weight (g/100 grains)	Increase over control (%)
	1987	1988	1989		
Cultivator (3)	19.0143	19.8003	19.9891	19.6012	—
M.B. plow (1) + cultivator (2)	20.4530	21.8129	21.9342	21.4000	9.18
Disc harrow (2) + cultivator (2)	20.6800	21.2300	19.9903	20.6334	5.27

Table 5 Effect of Different Tillage Practices on Paddy Yield

Treatment	Paddy yield (kg/ha)			Average yield (kg/ha)	Increase in yield over control (%)
	1987	1988	1989		
Cultivator (3)	2 718	3 625	3 865	3 403	—
M.B. plow (1) + cultivator (2)	3 664	3 855	4 801	4 107	20.69
Disc harrow (2) + cultivator (2)	3 450	3 630	4 287	3 789	11.34
				LSD = 305	

Table 6 Economic Analysis

Treatment	Total expenditure (Rs./ha)	Additional expenditure (Rs./ha)	Gross income (Rs./ha)	Additional income (Rs./ha)	Cost-benefit ratio
Cultivator (3)	6 767	—	12 081	—	—
M.B. plow (1) + cultivator (2)	7 049	282	14 580	2 499	1:8.86
Disc harrow (2) + cultivator (2)	6 926	159	13 451	1 370	1:8.62

Table 5 illustrates the effect of various tillage practices on the yield of paddy recorded at the time of harvesting of crop.

It is evident from the above data that the complete soil inversion with the use of M.B. Plow (1) followed by cultivator (2) recorded the highest paddy yield every year and, as an average, increase of 20.69% over the conventional practice was found. The use of disc harrow (2) followed cultivator (2) registered 11.34% higher paddy yield over the sole use of cultivator (3). The above data also show that, every year, there was a constant increase in yield which is due to enhanced soil weathering at implements' operating depth. The yield results were also commensurate with the trend of the effect of tillage practices under study on the tillering of rice crop, grain formation and grain weight as detailed in **Tables 2, 3** and **4** above.

The statistical analysis showed significant difference between treatment means at 5% level. The value of the calculated least significant difference was 305. Statistically, the soil inversion with the use of M.B. Plow (1) followed by cultivator (2) registered highly significant yield, 4107 kgs./ha on the average, as compared with both other treatments. The average yield, 3789 kgs./ha, of paddy obtained with the use of disc harrow (2) followed by cultivator (2) was also significantly better than that obtained in the conventional practice.

Economic Analysis

Table 6 shows the economic analysis of the effect of different tillage practices on rice production.

As per above analysis, the complete inversion of soil with the use of M.B. plow once followed by cultivator twice exhibited the highest cost-benefit ratio i.e.; 1:8.86. The partial inversion of soil with the tillage practice comprising of disc harrow twice followed by cultivator twice showed slightly less return worth Rs. 8.62 per unit expenditure additional to the conventional practice. The economic analysis clearly indicates that the use of M.B. plow once followed by cultivator twice as a complete soil inversion tillage package and disc harrow twice plus cultivator twice as a partial soil inversion practice in rice production were highly feasible economically.

Conclusions

1. The preparation of clay loam textured land with soil inversion tillage practices increases paddy yield significantly.

2. The complete inversion of soil with the use of M.B. plow once followed by cultivator twice proves to be the best tillage practice in rice production as it produced 8.33, 28.65, 9.18 and 20.69% and higher tillering, grains per panicle, grain weight and paddy yield, respectively, vis-â-vis the conventional practice i.e.; the sole use of cultivator thrice.

3. The partial inversion of soil with the use of disc harrow twice followed by cultivator twice is also better tahn the conventional practice as it registered 19.30, 5.27 and 11.34% more grains per panicle, grain weight and paddy yield.

4. The use of soil inverting implements, viz; M.B. plow and disc harrow at a site every year is no hindrance to its weathering as there is a continuous increase in paddy yield.

5. The complete inversion of soil with the use of M.B. plow once followed by cultivator twice and the partial inversion with the tillage package comprising of disc harrow twice and cultivator twice in rice production was also economically viable as these practices generate a return of Rs. 8.86 and 8.62 per unit expenditure additional relative to the conventional practice respectively.

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Comparison of Five Tillage Systems for Cotton Production in Rahad Scheme, Sudan

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Abstract

Five tillage systems locally in common use were studied in one of the cotton fields of the Rahad agricultural scheme in Sudan over a two-year period. The cost of the tillage operations and the effect on soil condition and crop yield were determined for a heavy duty disc harrow, chisel plow, subsoiler, disc plow, and a light harrow. Crop yield was not significantly affected by tillage systems, but there were significant differences between the profiles of soil bulk density due to tillage. Light harrow treatment consumed the least amount of fuel on a hectare and hour basis (8.2 L/ha and 7.5 L/h) and cost significantly less than other treatments (3.42 $/ha).

Introduction

Cotton (*Gossypium hirustum*) is the leading industrial crop in Sudan with an average annual production of 157 000 tons recorded over the last decade (FAO, 1989). The crop supports a large number of rural families and its sale makes a major contribution to the earnings of foreign currency. However, there are sharp fluctuations between years in cotton production in the Sudan (**Fig. 1**). These result from the rising cost of energy and its unpredictable availability, and the sporadic interventions have taken the form of: 1) distributing certified seeds, supplying field machinery, and providing irrigation equipment; 2) supporting the farmers financially through the subsidization of products and distribution of credits and incentives; 3) expanding the production areas by introducing new schemes such as the Rahad (in 1976); and 4) researching the primary factors leading ot the drop in the potential production rate (AOAD, 1983).

Seedbed preparation for cotton receives little attention in Sudan. Cotton farmers in this country believe in the value of deep plowing although they have no scientific evidence to support this belief. Limited research has generally shown benefits of shallow and minimum tillage practices over the deep and conventional tillage. However, shallow tillage practices have not been widely accepted by tenants (Willcocks, 1980, Berry and Wainwright, 1982, Klaij, 1983 and Willcocks, 1984). Variations in crop yield due to soil-implement interaction, seedbed management, and different types of tillage implements used, have been the

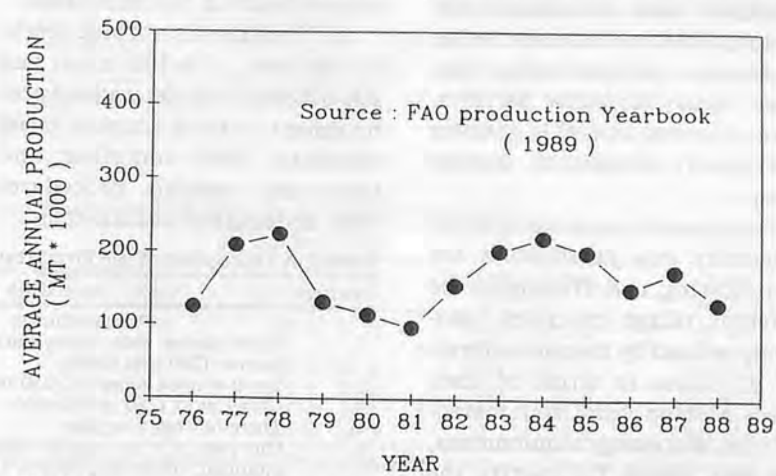

Fig. 1 Average annual cotton production in Sudan, 1976-88.

[1] Joint research project between the Faculty of Agricultural Sciences, University of Gezira (Sudan) and the Rahad Agricultural Co-operation.

[2] Research was partially funded by a grant from Ford Foundation.

focus of a number of inconclusive and conflicting reports (Doty and reicosky, 1978, Negi et al., 1980, Willcocks, 1981 and Maillard and Vez, 1982).

Cotton in Sudan is cultivated on "black cotton" clays, classified as Vertisols (De Vos and Virgo, 1969) and described as "self-loosening" soils. During soil drying, shrinkage occurs resulting in the formation of deep vertical cracks (fissures) with rough cleavage faces. Continued desication of the soil results in the formation of a loose and dusty surface layer, much of which is dislodged and accumulates within the fissures. When water enters those fissures it carries more soil with it and the swelling of the accumulated soil at the bottom of the cracks occurs due to expansion of the montmorillonitic clay. This results in considerable stress at this level (typically 1 m depth) and these pressures are relieved by an upward movement of the soil mass. This process results in an intermixing of surface material with the lower horizons (homogenization). Conseqeuntly, Vertisols are difficult to manage and are very sticky when wet and cloddy when dry (Willcocks, 1984). Accordingly, we evaluated a number of tillage practices in an attempt to overcome soil related problems and simultaneously minimize fuel consumption using implements such as deep disc plows, heavy duty disc harrows, subsoilers, and available harrows and locally developed surface sweeps.

This research was conducted to: i) identify any justification for deep plowing, and ii) compare the different tillage practices commonly utilized by the cotton farmers of Sudan in terms of their effect on crop yield, soil characteristics, and energy requirements. We also aimed to identify the practice that optimizes energy flow in the seedbed preparation stage.

Materials and Methods

The experimental site was on a fine textured "black-cotton" clay field consisting of over 55% clay located at the Northern Part of the Rahad Agricultural Scheme (12.6° Latitude, 30.1° Longitude). The programme extended over two seasons starting on mid-May 1985 and ending by April 1987. Cotton had been cultivated in the field for the 5 years preceding the experiment.

The experimental design was a randomized complete block with three replicates (blocks) and five treatments per block (**Table 1**). Each treatment plot was 0.35 ha in size and received the same tillage treatment in both seasons. A 96 kW tractor was used for first treatment while a 52 kW tractor was utilized for the remainder. All plots were ridged immediately after plowing, at an inter-row spacing of 800 mm. Cotton seeds were then hand sowed using the same seeding rate and variety adopted at the scheme (Acala 4/42 — Medium Staple). The same herbicide and fertilizer application, irrigation, and pest control measures were used on all the treatments and were similar to the normal practice at the scheme.

Soil bulk density at three depths (0-100 mm, 100-200 mm, and 200-300 mm) was determined post treatment in both seasons, using standard field sampling and laboratory analysis procedures with undisturbed soil samples.

Emerged plants were counted 2 weeks after sowing in three 1.25 m long rows, randomly selected from the center 10 rows of every plot. Counts were used to calculate the percent plant emergence by dividing it by the actual number of viable seeds sown per unit row length. Plant root development was determined eight weeks after sowing and at maturity by measuring the distance from the ground surface to the tip of the plant tap root for 10 randomly selected plants. A trench was carefully dug around each plant to expose the tap root. The total number of open bolls were counted in 10 different plants randomly selected from the center 10 rows of every plot at harvest. The seed cotton were hand picked and weighed in three separate intervals from a 1.25 m × 0.8 m strip, randomly selected from the 10 center rows of each treatment plot. The total yield per ha per season was then extrapolated using the observed yields from those strips.

A number of machine performance parameters were measured, including machine field capacity and fuel consumption. The machine field capacity (actual plowed area per unit time) was determined by measuring its actual speed (km/h), working time, idle and lost time, and the effective machine working width. The measured parameters were then used to calculate machine field capacity using the procedure described by Hunt (1979). The fuel consumption per treatment was assessed by fuel volume difference between that at the

Table 1 A Description of the Five Treatments Tested in the Experiment

Treatment	Land preparation system: Primary tillage	Secondary tillage
1.	Three meters wide, heavy duty disc harrow (200 mm depth)	One pass of light harrowing
2.	Small-winged subsoiler (250 mm depth)	One pass of light harrowing
3.	Chisel plow (250 mm depth)	One pass of light harrowing
4.	Three-bottom disc plow	One pass of light harrowing
5.	One pass of a two meters wide, semi-mounted, offset disc harrow (150 mm depth)	

beginning and that at the end of the operations per treatment (Luth et al., 1978). The fuel consumption rate was used in conjunction with other available fixed-variable cost parameters essential for determining the cost ($/ha) of each treatment using procedure by Hunt (1979).

All data was analyzed using the MSTAT (Freed et al., 1985) statistical package on an IBM-AT Computer. The analysis was carried out using the Randomized Complete Block design analysis of variance sub-routine, over multiple seasons.

Results and Discussion

The analysis of variance of data collected in all variables revealed no significant effects due to blocks or seasons. Accordingly, variations in the means of measured variables were all attributed to the treatment effect (tillage practices). There was no significant variation in the soil bulk density in the upper soil layer (0-100 mm) among the treatments (**Table 2**). There was, however, a significant variation in the soil bulk density below the layers with the chisel plough and the subsoiler resulting in less dense soil at 200-300 mm depth. The resulting soil physical condition did not affect plant root growth, percent plant emergence, percent open bolls, or yield **(Table 3)** in accordance with the findings of Cary and Rasmussen (1979) and O'Connell (1975). There were significant variations in the parameters used to assess machine performance among the different treatments **(Table 4)**. The lowest fuel consumption rate per ha was that of the light harrow which was 33% less than the highest (12.3 L/ha) recorded in the subsoiler treatment. The later treatment significantly consumed more fuel than the heavy duty disc harrow, although a smaller tractor (52 kW) was utilized. However, there was no significant difference in fuel consumption between those treatments when measured on an hour basis due to the compensating effect of their respective field capacities. Differences in hourly fuel consumption were similarly not significant between disc plow treatment and the light harrow although both were significantly lower than the remaining treatments.

Significant variations existed in the fixed-variable cost ($/ha) of land preparation per treatment. The lowest cost was that of the light harrow treatment (3.42 $/ha) while the highest was the disc plow treatment (4.17 $/ha). The cost of land preparation using the other treatments was 3.84, 3.52 and 3.6 $/ha for the heavy duty disc, subsoiler, and chisel plow, respectively. Fuel cost contributed from 42% of the total in case of the light harrow and disc plow to 62% in the subsoiler. The percent fuel cost vis-a-vis the total was 49% and 46% in the heavy duty disc harrow and the chisel plow treatments, respectively.

Conclusions

Results obtained from this experiment confirm the hypothesis that traditional land preparation methods in the cotton fields of Sudan, using deep tillage practices, are non-feasible and unjustifiable. The application of deep tillage practices did not provide any significant yield advantage over the shallow ones. On the contrary, deep tillage practices consumed more energy and were accordingly more expensive.

It is suggested, as a consequence of this research, that cotton farmers in the Rahad

Table 2 Means and Standard Deviation of Soil Bulk Density (g/cm^3) at Three Depth in the Different Treatments

Treatment[1),2)]	Soil depth (mm)		
	0-100	100-200	200-300
1. Heavy duty disc harrow	1.04 ± 0.21 a	1.40 ± 0.09 ab	1.55 ± 0.22 a
2. Subsoiler	1.11 ± 0.14 a	1.33 ± 0.04 bc	1.33 ± 0.06 b
3. Chisel plow	1.03 ± 0.01 a	1.24 ± 0.06 c	1.24 ± 0.03 b
4. Disc plow	1.15 ± 0.03 a	1.49 ± 0.05 a	1.46 ± 0.01 a
5. Light harrow	1.18 ± 0.08 a	1.31 ± 0.08 bc	1.57 ± 0.05 a

1) Means with a common letter in a column are not significantly different at a 95% probability level using Duncan's New Multiple Range test.
2) Means are computed over both seasons.

Table 3 Means and Standard Deviation of Crop Assessment Parameters in the Different Treatments

Treatment[1),2)]	Crop Parameter				
	Plant emergence (%)	Root length at 8 weeks (mm)	Root length at maturity (mm)	Number of open bolls (%)	Yield (kg/ha)
1. Heavy duty disc harrow	14.0 ± 3.6 a	293 ± 46 a	440 ± 35 a	50.8 ± 14.5 a	698 ± 57 a
2. Subsoiler	14.0 ± 2.6 a	282 ± 40 a	430 ± 104 a	53.2 ± 10.7 a	735 ± 33 a
3. Chisel plow	17.5 ± 2.6 a	290 ± 30 a	403 ± 25 a	52.0 ± 1.5 a	675 ± 50 a
4. Disc plow	12.5 ± 0.6 a	270 ± 15 a	413 ± 35 a	55.7 ± 9.1 a	736 ± 43 a
5. Light harrow	16.0 ± 4.1 a	300 ± 45 a	405 ± 26 a	50.7 ± 7.6 a	681 ± 69 a

1) Means with a common letter in a column are not significantly different at a 95% probability level using Duncan's New Multiple Range test.
2) Means are computed over both seasons.

Table 4 Means and Standard Deviation of Machine Performance Assessment Parameters in the Different Treatments

Treatment[1),2)]	Fuel consumption (Litres/ha)	Field capacity (ha/h)	Fuel consumption (Litres/h)
1. Heavy duty disc harrow	10.6 ± 0.32 b	1.84 ± 0.08 a	19.5 ± 0.44 c
2. Subsoiler	12.3 ± 0.61 a	1.68 ± 0.14 b	20.7 ± 0.26 c
3. Chisel plow	9.4 ± 0.08 c	1.45 ± 0.17 c	13.6 ± 0.28 b
4. Disc plow	10.0 ± 0.38 bc	0.71 ± 0.02 e	7.1 ± 0.11 a
5. Light harrow	8.2 ± 0.21 d	0.91 ± 0.02 d	7.5 ± 0.42 a

1) Means with a common letter in a column are not significantly different at a 95% probability level using Duncan's New Multiple Range test.
2) Means are computed over both seasons.

Scheme, and other schemes with similar operational conditions, devote to shallow tillage practices during land preparation. The application of those practices should reduce the excessive demand on energy which currently is very expensive and whose continuous availability is unpredictable. This will assist in the on-going national campaign to minimize the flux of hard currency out of Sudan in the form of energy bills.

The use of a light harrow has been shown to be the most appropriate tillage practice among the other traditionally utilized ones. Further research should be conducted, however, prior to the spread of this practice among farmers to investigate its:

1. Long-term effect (4-5 years) on crop yield and soil condition; and
2. Performance relative to other possible light tillage practices using other available equipment.

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Design, Development and Evaluation of Animal-drawn Plough-seeder for the Traditional Farmer in Sudan

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Abstract

An animal-drawn implement to perform both ploughing and seeding was designed, developed, and field-tested. The rest was carried out on clay soils. It was designed to work with either one or two bottoms and either a donkey or a horse as the draft animal. A seeder with a simple metering mechanism and a gauge wheel provided a control system for the seeds to be placed at spacings as required by the crop, and covered in the same run (with the dual bottoms) or in a subsequent run (single bottom). Ploughing and seeding are thus done simultaneously. The newly designed plough-seeder can be a replacement for the traditional ploughing and save labour, especially in the peak times and under the short rainy seasons in semi-tropical areas of developing countries.

Introduction

Governments in many less developed countries (LDC) are very concerned about food production for self-sufficiency. In Sudan people are very hopeful that utilization of the country's vast agricultural resources will eliminate the food scarcity problem — a problem that affects the rural population more than any other. However, the bulk of the illiterate percentage (80%) who live in the rural areas practice traditional shifting agriculture or as nomads raising cattle, sheep or camels. Agricultural malpractice associated with shifting agriculture such as firing-agriculture and overgrazing indisputably resulted in the subsequent desertification; a problem facing Sudan and many other countries in Africa. In recent years, due to the draughts most of the rural population, especially the youth, migrated to the urban areas on the hope of finding rather easier ways of making higher income only to find that their hopes were without any basis. Major towns of the country are flooded by youth who had no experience on almost anything resulting in overcrowding and severe social problems.

In recent years, and due to scarcity of rains, Sudan has suffered from food shortages. Short rainy seasons and traditional farming system resulted in complex timeliness problems. The only tools being used for weeding and seeding and bush clearing are hoes, axes, weeding tines (*Hashasha*). This makes it difficult if not impossible for land to be cleared for subsequent operations at the right time.

When the subject is the small farmer the problem of appropriate technology becomes an issue of developing the right information and, most important of all, the dissemination of this information — a process of reaching the small farmer in the rural areas. Those who are literally isolated and geographically living in remote areas have very little information on the subject of appropriate technology reaching them. The problem of making such a farmer technology-conscious of any level is rather broad and involves an interdisciplinary work that would put efforts by extensionists and technologists together to achieve such a challenging rather critical problem.

In an attempt to alleviate the drudgery of manual work and to make agriculture more attractive to its participants in the traditional farming areas, a University of Gezira-based research, funded by the Ford Foundation was launched with the objective of developing simple animal-drawn implements for the traditional farmer. It was simple to the extent that local blacksmiths can understand and manufacture it and for the illiterate farmer to master and handle it without fear.

Objectives

The major objectives of this research were: i) to undertake a survey of the existing traditional tools and implements in the region; ii) to design and fabricate an animal-drawn plough-seeder; and iii) to field evaluate the performance of the plough-seeder.

Research Area

The research area is composed of small villages of approximately three to four hundred people each. The total population of the area was estimated at 50 000. Land is naturally classified into Goze and Wadi land. Goze land is composed of small sandy hills and typically sown with groundnut. Wadi land, on the other hand, is composed of clay soil which is mostly sown with millet, sorghum, and sesame. Despite the fact that Wadi land is normally more fertile than Goze land, the latter is more attractive to farmers as the performance of the different agricultural operations in sandy soils (using traditional tools) requires less physical effort.

Agriculture is the main livelihood for almost all the people in the survey area. Agricultural operations in the region are conducted along traditional methods which are confined to land clearing, seeding, reseeding, weeding and harvesting. The main crops are groundnut, sorghum, millet and sesame. Although millet has long been the main crop grown for local consumption, sorghm, because of its high yield, gained significance as the future food crop in the region. On the other hand, groundnut continues to be the dominant cash crop.

Animals in the region are camels, horses, oxen and donkeys. However, despite their good nature, oxen are not commonly used as draft animals. It will probably be long before their potential as draft animals is fully explored. This is partly because only a limited number of animal-drawn implements (ADI) have been introduced into the region and cattle are considered too valuable to be used for draft purposes.

Preliminary Investigation

A questionnaire of 10 pages long and 8 main questions was structured. The questions covered, among other areas, agricultural operations, ownership of draft animals and available agricultural implements.

The ownership of draft animals is shown in **Table 1** which shows that donkeys rank first with an average ownership of 3.4 per household. Horses and camels rank second and third with averages of 0.5 and 0.23, respectively.

It was also found that about 74% of the households did not own horses and about 83% had no camels. Donkeys had a better distribution among households as 56% of them owned between 1 and 2 donkeys and 44% owned more than 2: the most dominant draft animal and that their ownership is more equally distributed. This situation had a profound effect on the specifications and designs of the plough-seeder.

The survey also showed that an average family plants 37% of its

Table 1 Ownership of Draft Animals (per household)

Animal ownership	Mean	Standard deviation	Total
Donkeys	3.40	1.74	27.2
Horses	0.50	1.52	40
Camels	0.23	0.58	18

Table 2 Utilization of Animal Power

Animal	Load carrying	Transport	Production activities
Horse	11	13	15
Camel	15	13	6
Donkey	70	67	15
Cattle	4	7	3
None	—	—	61
Total	100	100	100

Table 3 Traditional Implements in Sudan

Local name	Use	Units per household
Toria	Pulling roots seeding	5.26
Fass (axe)	Tree cutting shrub clearing	3.46
Farrar (small axe)	Tree cutting shrub clearing	0.95
Kanassa (fork)	Land clearing stack + hay collection	2.08
Gilmoia (digging hoe)	Digging hoes for seeds	1.53
Gerraia (daker) (weeding hoe)	Weeding	1.95
Gerraia (intaia) (weeding hoe)	Weeding	9.33

Table 4 Traditional Implement Holdings

Implement	per household	per active person
Fass	5.26	3.18
Toria (digging hoe)	3.46	2.04
Farrar (small axe)	0.95	0.60
Kanassa (fork)	2.08	1.26
Gilmoia (digging hoe)	1.53	0.9
Gerraia (dakar)	1.95	1.20
Gerraia (intaia)	9.33	5.58

Table 5 Labour Saving Capacity of Plough-seeder (hr)

Ploughing and seeding labour (hr/ha)

Crop	Traditional tools	Plough-seeder		Labour-saving	
		Donkey	Horse	Donkey	Horse
Groundnut	24.9	11.4	8.6	13.5	16.3
Sorghum	32.2	11.4	8.6	20.8	23.6
Millet	22.3	11.4	8.6	10.9	13.7
Sesame	58.0	11.4	8.6	46.6	49.4

land with millet, the staple food in the region. The rest of the land is shared between sorghum and cash crops (groundnut and sesame). Sorghum is traditionally considered as inferior to millet and it is mostly used for animal feed. However, in recent years farmers were forced to use sorghum for their own consumption. As **Table 2** shows 70% of the sample reported use of donkeys for load carrying and 67% use it as a means of transport. Only 15% reported the use of donkeys for production (draft) purposes. **Tables 3** and **5** list the names and uses of the traditional tools existing in the region.

Design and Performance of the Plough-seeder

Traditionally, seeding is done by making a hole in the ground using a digging hoe "Toria". Then the seeds are dropped in the holes and covered with soil. **Fig. 1** shows weeding and seeding operations using a traditional plough. However, there are some problems associated with it: i) it is labour intensive; and ii) in many cases, the seeds especially groundnut, were found sitting outside after the coverage pass is completed. With the weeding and seeding performed simultaneously, using the plough-seeder, no time is allowed for weeds to grow. The seeder was designed to be operated by the gauge wheel. The gate is opened every time the wheel makes one full revolution. In this case, however, the seed spacing must be equal to the circumference of the gauge wheel. It can also be modified to open as many times as required by the specific crop spacing. The seeding rate can also be controlled by means of a plate which can be moved in either forward or reverse direction to increase or decrease the opening.

Fig. 1 Weeding and seeding using the traditional plough.

Fig. 2 Plough-seeder under test.

It needs only one person for the whole operation of weeding and seeding provided that a well-trained animal could be secured. It also places the seeds more accurately. The seeder control mechanism does not involve any complicated components. Only straight linkages and flat plates are used. That makes it easy to be reproduced by the local blacksmiths. **Fig. 2** shows the plough-seeder (single bottom) under test. With the weeding and seeding performed simultaneously, moisture loss is very minimum.

The amount of labour required for the planting operation (weeding, digging seed holes, and seeding) using the traditional method is greatly reduced with the use of animal traction. The reduction recorded 83% in the case of sorghum and 50% in the case of groundnut. This is due to the use of animal traction results in reduction in labour supply. Hence, the result implies that the use of animal traction will increase labour efficiency which will be reflected as an increase in labour productivity. It will be expected that the reward to labour increase with the increase in productivity more labour will be devoted to other farm chores. The result is not inconsistent with an upward sloping labour supply curve.

Conclusion

An animal-drawn implement (plough-seeder) was developed for the purpose of doing combined operation of seeding and weeding. The implement proved successful and experiments have shown that it could make a replacement for the traditional weeding implement. Experimental work proved its significant labour-saving capacity which can be made use of in the peak times to meet the timely requirements of land preparation, especially in the areas with short rainy seasons.

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A Practical Device in Manual Paddy Threshing

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Abstract

This report describes a simple and portable manual thresher of paddy parameters like average size of bundle, maximum impact load produced and area of contact mode by the bundle at the time of threshing on hard surface were considered while designing this tool. Design parameters, namely; slope, curvature and slot size of threshing surface were optimized for better performance. The manual thresher mounted on a wooden trunk separates 7.0% more grain from paddy sheaves than by conventional threshing over hard surface. This gadget costs only US$15 but fetched an additional income of US$17 to US$20 per hectare.

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Introduction

Farmers use different tools in farm operations in order to reduce drudgery and to increase the efficiency of human labour. The "mummuty" (spade) is used to work with soil, hand hoe for weeding and stirring top soil and sickle to harvest. However, no simple threshing aid is available for manual threshing of paddy. Realizing this, a simple tool was designed and developed at Tamil Nadu Rice Research Institute, Aduthurai, Tamil Nadu.

Materials and Methods

Threshing of paddy in Tamil Nadu is done only by the following conventional method, i.e., harvested sheaves are collected and transported to the threshing floor. These are separated into small bundles of convenient size (@4kg) and held between two hands up, with the help of a rope made of paddy straw. The earhead portion of the paddy sheaves is then beaten against any hard surface like stone, wooden log, etc, three times. After giving a shake, the bundle is thrown to a side for cattle/tractor threshing.

To design a simple threshing aid the following different parameters were considered:

a) Average size of the bundle used for manual threshing;
b) Area of contact made by the bundle; and
c) Maximum impact load produced at the time of manual threshing.

Ten women labourers of different age groups were engaged in handling bundles weighing 4 kg approximately each time. Ten men labourers threshed paddy sheaves, over a balance and impact load produced were recorded. This varied from 60 to 75 kg. The area of contact was assessed by threshing bundles ofpaddy over tarpaulin with a coating of talc powder.

The maximum area disturbed during threshing was 500 × 400 mm and taken as area of contact (threshing). Thus, it was possible to fabricate a slotted threshing surface with rods. In order to meet varying height and strength of men/women threshers a factor of safety, 2, was assumed.

Actual maximum impact load
= 75 kg

Factor of safety
= 2

Therefore, design impact load for calculation purpose
= (Actual maximum impact load) × (Factor of safety)
= 75 × 2 = 150 kg

Let us assume, 10 rods of 'd' in diameter take the entire design impact load by spreading over 500 mm lenth threshing surface.

Then, load per rod

$$= \frac{150}{15} = 15 \text{ kg}$$

Length of rod
= 400 mm (i.e., width of threshing surface already determined) and simply supported at both ends.

Then, maximum bending moment, M (in simply supported beam)

$$= \frac{WL}{4}$$

It is known that, M
= (f) × (z)

where,

f = safe load 14 kg/mm^2 and

z = modulus of ridigity, mm^3

ie 1500 = 14 × z

$$\text{or } 1500 = 14 \times \frac{\Pi d^3}{32}$$

$$\text{or } 1500 \times 32 = 14 \times \Pi d^3$$

$$\text{or } d^3 = \frac{1500 \times 32}{14 \times \Pi}$$

d = 10.29 mm or say d
= 10 mm

Thus, a slotted threshing surface of 500 × 400 mm size was fabricated with 10 pieces of 10 mm diameter mild steel rods of 400 mm long and evenly spread over the whole length of 500 mm. The parameters mentioned below were optimized by repeated tests for better threshing efficiency.

a) Spacing between the rods;
b) Curvature of the threshing surface;
c) Front and rear height of slotted, curved threshing surface;
d) Mode and weight of anchorage to the threshing surface; and
e) 'Press fit' arrangement for easy assembling and dismantling.

Labour can move away from the rear side of the threshing unit and adjust themselves at the time of threshing. Hence, height adjustment was not provided.

Constructional Details

The manual thresher **(Fig. 1)** consists of three 12-mm diameter mild steel rods of 560 mm length bent to a curve shape **(Fig. 2)**. Then these rods were evenly distributed over a span of 400 mm which, 22 pieces of 10 mm diameter 400 mm length mild steel rods were welded with 30 mm spacing (centre to centre). This forms a slotted, curved and slopping threshing surface.

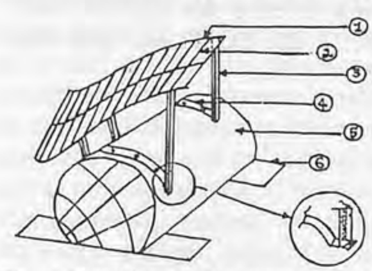
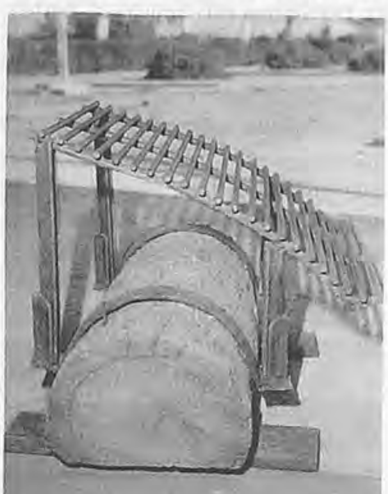


Fig. 1 Threshing aid for manual paddy threshing. ① 12 mm diam mild steel rod 560 mm long, 3 nos.; ② 10 mm diam mild steel rod 400 mm long, 20 nos.; ③ 33 × 33 mm angle legs, 210 mm high front legs, 2 nos., 330 mm high rear legs, 2 nos.; ④ 50 × 6 mm mild steel flat, 400 mm long, bent to curve, 2 nos.; ⑤ 300 mm diam coconut trunk 750 mm long, 1 no.; ⑥ 100 × 15 mm wooden plank, 500 mm long, 2 nos.

Two of 50 × 6 mm mildsteel flats of 400 mm length were bent and fixed over the surface of a coconut trunk of 750 mm long, 300 mm diameter. The four ends of these mild steel flats were bent horizontally on four 33 × 33 × 75 mm size 'L' angle pieces were welded vertically. The threshing surface with four 'L' angle legs of 33 × 33 mm cross section welded such that it can easily be inserted/taken out from the trunk and forms a "press fit" arrangement. The height of front and rear 'L' angle legs were adjusted such that after fixing on the coconut trunk, the rear and front sides of the threshing surface is 500 mm and 250 mm from ground surface, respectively.

With this press fit arrangement, the threshing surface with four legs weighing 12.5 kg can easily be attached or detached with wooden portion weighing 25 kg and can be transported as two pieces from place to place. To avoid jumping of the unit on ground during threshing action, 50 mm thick bottom portion of the circular wooden trunk was cut and removed lengthwise and two wooden planks of 100 × 15 mm cross section, 500 mm long were nailed at both ends, perpendicular to longitudinal axis of the trunk.



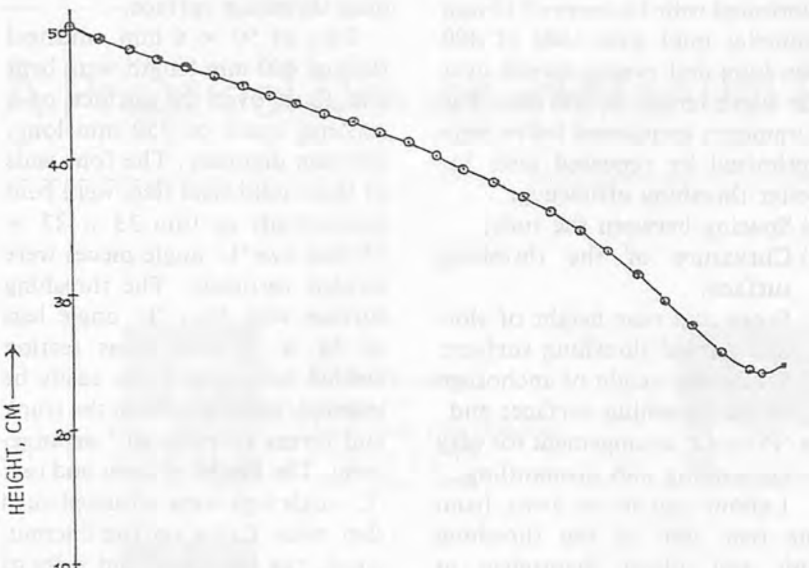


Fig. 2 Curvature of threshing surface.

Table 1 Threshing Efficiency of Manual Paddy Threshing Different Methods

Paddy variety	Threshing efficiency with threshing aid (%)		Threshing efficiency over stone, i.e., conventional method (%)	
	Threshing immediately after harvest	Threshing after one day field drying	Threshing immediately after harvest	Threshing after one day field drying
CO43	93.1	94.5	85.9	86.3
IR20	91.8	96.4	83.8	89.0
ADT38	96.8	96.9	88.7	89.0
ADT39	74.1	77.0	68.2	70.0
Mean	89.0	91.2	81.5	83.6

The thresher was field tested for its threshing efficiency of paddy with varieties like ADT 38, ADT 39, IR 20, CO 43 etc. and compared with conventional method of threshing using hard surface like stone and values recorded.

The manual threshing aid for paddy helped to separate 89% and 91% grain as against 82% and 84% in conventional method when threshed immediately after harvest and after one day field drying, respectively.

Conclusions

The design and development of a simple, portable manual thresher fulfilled the long-felt need for a simple, portable threshing aid for manual paddy threshing. It proved highly useful for small and medium farmers and landless labourers.

Higher threshing efficiency, i.e., 7% more grain separation than conventional method helps farmers to get an additional income of @US$17 to US$20 per hectare.

The device helps to reduce drudgery in threshing. It is easy to transport and fabricate and costs US$12 only.

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Combine Harvester Reel Stagger — I

Principle of Determination of Reel Stagger Based on Reel Kinematics and Crop Stem Deflection

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Abstract

Derivations of equations describing combine harvester reel kinematics, by use of the method of linear homogeneous transformations, are briefly presented. A condition constraining crop stem deflection due to the action of the reel is postulated for the case of an upright crop (as opposed to a lodged and tangled crop). An angular parameter of the deflected stem, denoted ϕ_M, is introduced. Relationships between crop stem deflection, ΔX_M, and ϕ_m, and between vertical height from the ground, Y_M, and ϕ_M (all quantities reckoned at the point of contact between the reel slat/bar and the stem) are derived from the kinematic equations and the postulated constraint on stem deflection. A relationship involving ΔX_M, Y_M, and ϕ_M, needs to be determined in order to formulate an algorithm for the determination of reel stagger, X_r. Results of an empirical study to determine such a relationship will be reported subsequently.

[Keywords] Reel Stagger, Crop Stem Deflection and Combine Harvester

Introduction

Among the parameters to be determined in the design of the combine harvester reel is the reel stagger, X_r, (**Figs. 1 and 2**) which is the displacement, in the longitudinal direction, of the reel's axis of rotation from the tip of the cutterbar. This parameter would be expected to depend on the crop to be harvested and the condition of the crop at the time of harvest. Consequently, current combine harvester designs allow for its variation.

An analysis involving stem deflection and reel stagger was presented by Klenin et al. (1985). In essence, that analysis assumed the stem deflected by the reel would behave as a straight and rigid rod hinged at the base, and then sought to determine the point in the cycle of reel operation when the cutterbar cuts the first crop stem. In the belief that unless the stem, in being deflected by the reel, breaks at the base, its actual behaviour would differ substantially from that of a rigid rod hinged at the base, the authors present here a deflection model which assumes the stem to be a vertical cantilever that may or may not be purely elastic. Furthermore, the authors find it more convenient to seek the point in the cycle of reel operation when the cutterbar cuts the last rather than the first stem.

Reel and Cutterbar Kinematics

Frame of Reference and Assumptions

Fig. 1 is a profile of the slat reel, which also illustrates the frame of reference and the parameters relevant to the analysis of reel motion. The following assumptions are made concerning the motion of the reel:

1. The reel rotates about its lateral centroidal axis at a uniform angular velocity ω (rad/s), taken to be positive in

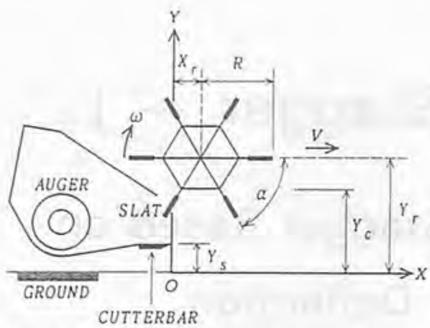

Fig. 1 Slat reel with relevant parameters.

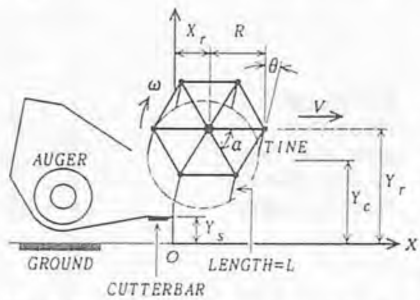

Fig. 2 Tined reel with relevant parameters.

the clockwise sense;

2. The whole header assembly advances along a straight path, in the positive X direction, over plane horizontal ground, with a uniform advance velocity, V (m/s); and
3. There is no motion in the lateral direction. The motion of any point in the reel is, therefore, planar or two-dimensional.

The Cartesian coordinate frame of reference, fixed to the ground, is defined so that, at the initial moment of consideration ($t = 0$), the Y-axis is in the lateral vertical plane containing the tip of the cutterbar and the X-axis is in the plane of the ground, as illustrated in **Figs. 1** and **2**.

Slat Position

In **Fig. 3** the initial position (at $t = 0$) of a point at the tip of a slat is denoted $P(0)$ [$\omega t = 0$; $X(0) = X_r$; $Y(0) = Y_r + R$]. At an arbitrary moment in time, t, the coordinates of the point, denoted $P(t)$, may be derived by the method of linear homogeneous transformations, widely used in the study of kinematics and computer graphics (Pettofrezzo, 1966; Crouch, 1981; Paul, 1981; Kinzel et al., 1981; Suh et al., 1967; Denavit et al., 1955). In this method, a point in n-dimensional space is represented by an $(n + 1)$-component column vector. Thus, a point (X, Y) in 2-dimensional space is represented by the column vector $\{X_1, Y_1, k\}$ in which by definition;

$$X = X_1/k \text{ and } Y = Y_1/k$$

The components of the column vector $\{X_1, Y_1, k\}$ are known as homogeneous coordinates and their use apparently originated from the study of projective geometry (Sawyer, 1955). When used in 2-dimensional kinematics, the additional component, k, can be any non-zero real number and is usually set to be unity (then $X = X_1$ and $Y = Y_1$). The use of homegeneous coordinates allows rigid body motions, such as translations, rotations, and combinations of these, to be represented in matrix notation. Returning to **Fig. 3**, it may be shown that the coordinates of $P(t)$ can be expressed as follows:

$$\begin{bmatrix} X(t) \\ Y(t) \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\omega t & \sin\omega t & (X_r + Vt) \\ -\sin\omega t & \cos\omega t & Y_r \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 \\ R \\ 1 \end{bmatrix} \quad (2.1)$$

which may be expanded to yield the following equations;

$$X(t) = X_r + Vt + R\sin\omega t \quad (2.2a)$$
$$Y(t) = Y_r + R\cos\omega t \quad (2.2b)$$

In addition, it is often convenient to represent the advance velocity in terms of the angular velocity, as follows;

$$V = \omega R_0 \quad (2.2c)$$

R_0 is the rate of advance of the header per revolution of the reel. The motion is reduced to pure rotation if R_0 is zero and to pure translation if R_0 is infinite.

The trajectory of point P, shown in **Fig. 3** for a complete cycle of reel motion, is a looped trochoid, provided $R > R_0$.

Slat Velocity

The components of the velocity of point P at time t are found by differentiating equations *(2.2a)* and *(2.2b)* with respect to time, to yield the following;

$$U_X(t) = V + \omega R\cos\omega t \quad (2.3a)$$
$$U_Y(t) = -\omega R\sin\omega t \quad (2.3b)$$

The magnitude of the resultant velocity vector is;

$$U(t) = [U_X(t)^2 + U_Y(t)^2]^{1/2}$$

or

$$U(t) = [V^2 + 2V\omega R\cos\omega t + (\omega R)^2]^{1/2} \quad (2.4)$$

The direction of the resultant velocity vector, defined to be the angle between the positive Y-axis and the velocity vector, and taken to be positive in the clockwise sense, is expressed as follows;

$$\tan(\phi(t)) = \frac{U_X(t)}{U_Y(t)} = -\left[\frac{(V/\omega R) + \cos\omega t}{\sin\omega t}\right] \quad (2.5a)$$

or

$$\tan(\phi(t)) = -\left[\frac{(R_0/R) + \cos\omega t}{\sin\omega t}\right] \quad (2.5b)$$

The acceleration components are found by differentiating the corresponding velocity components with respect to time and are given below;

$$a_X(t) = -\omega^2 R\sin\omega t \quad (2.6a)$$
$$a_Y(t) = -\omega^2 R\cos\omega t \quad (2.6b)$$

*Note that expressions for both $a_X(t)$ and $a_Y(t)$ in terms of ωt are preceded with negative signs in equations *(2.6a)* and *(2.6b)*.

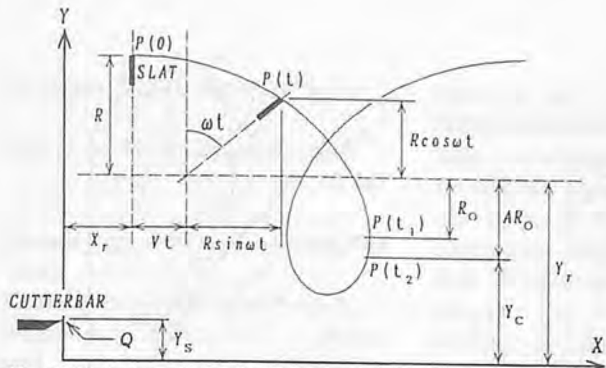

Fig. 3 Trajectry of a point, P, in a slat.

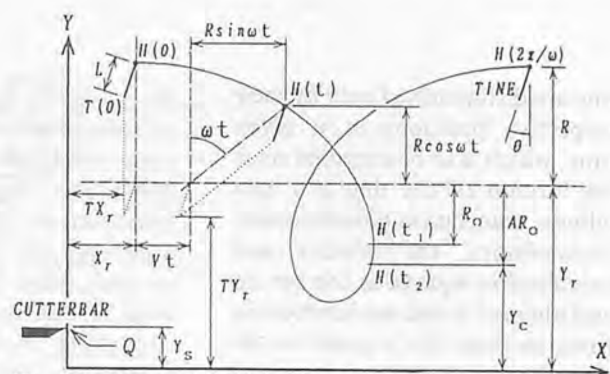

Fig. 4 Trajectry of the hinge, H, of a tine.

The magnitude of the resultant acceleration vector is;

$$a(t) = [a_X(t)^2 + a_Y(t)^2]^{1/2} = \omega^2 R \qquad (2.7a)$$

or, since this magnitude is independent of t, we may write;

$$a = \omega^2 R \qquad (2.7b)$$

The direction of the resultant acceleration vector is;

$$tan(\psi(t)) = \frac{a_X(t)}{a_Y(t)} = \frac{-\omega^2 R sin\omega t}{-\omega^2 R cos\omega t} = tan\omega t \qquad (2.8a)$$

or

$$\psi(t) = (\pi + \omega t)^* \qquad (2.8b)$$

The magnitude of acceleration of any point in the reel does not vary with time. However, the resultant acceleration vector is always directed towards the axis of rotation of the reel, similar to centripetal acceleration in pure rotation.

Similar equations for the position, velocity, and acceleration of a corresponding point on a trailing slat, which lags the leading slat rotationally by an angle α, may be derived by writing $(\omega t - \alpha)$ in place of (ωt) in all the above equations.

Tine Position (Tined Pick-up Reel)

The tined pick-up reel has lateral reed bars instead of slats. Attached onto these bars are hinged tines which are slender rods lying in longitudinal vertical planes, and at some inclination, θ, to the lateral vertical planes containing the axes of their hinges. The tines are usually constrained by appropriate mechanism so as to translate without rotating.

Fig. 2 is a profile of the tined reel. To determine the position of a tine, it is necessary to determine the position of two distinct points along its length, such as the axis of its hinge, denoted H, and its tip, denoted T. **Fig. 4** illustrates the derivation of the position of a tine on this type of reel. Referring to this figure, for the hinge axis which would be at point $H(0)$ at time $t = 0$, and at point $H(t)$ at an arbitrary time, t, we may write;

$$\begin{bmatrix} X(t) \\ Y(t) \\ 1 \end{bmatrix}_H = \begin{bmatrix} cos\omega t & sin\omega t & (X_r + Vt) \\ -sin\omega t & cos\omega t & Y_r \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 \\ R \\ 1 \end{bmatrix} \qquad (2.9)$$

The above matrix equation may be expanded to yield the following equations:

$$X_H(t) = X_r + Vt + Rsin\omega t \qquad (2.10a)$$

$$Y_H(t) = Y_r + Rcos\omega t \qquad (2.10b)$$

Similarly, for the tip which would be at $T(0)$ at time $t = 0$, and at $T(t)$ at an arbitrary time t, we may write:

$$\begin{bmatrix} X(t) \\ Y(t) \\ 1 \end{bmatrix}_T = \begin{bmatrix} cos\omega t & sin\omega t & (TX_r + Vt) \\ -sin\omega t & cos\omega t & TY_r \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 \\ R \\ 1 \end{bmatrix} \qquad (2.11a)$$

Here we note, with reference to **Fig. 4**, that;

$$TX_r = X_r + Lsin(\pi + \theta) \qquad (2.11b)$$

$$TY_r = Y_r + Lcos(\pi + \theta) \qquad (2.11c)$$

where;

L is the distance from the hinge axis to the tip of the tine. In some cases tines are not entirely straight.

θ is the angle of inclination of the tine to the vertical. This angle has been termed reel pitch (Nave et al., 1972) but the authors prefer the term *tine rake angle*.

For consistency, all angles are measured relative to the positive Y-axis, and taken to be positive in the clockwise direction, leading to the form taken by equations *(2.11b)* and *(2.11c)*. Expanding equation *(2.11a)* and using equations *(2.11b)* and *(2.11c)* leads to the following:

$$X_T(t) = Xr + Vt + Rsin\omega t - Lsin\theta \qquad (2.12a)$$

$$Y_T(t) = Y_r + Rcos\omega t - Lcos\theta \qquad (2.12b)$$

The velocity and acceleration of the tines are obtained by differentiating the corresponding position and velocity equations with respect to time. In doing so, all terms which are not functions of time disappear. Thus, the velocity and acceleration of the tip of a tine do not differ from the velocity and acceleration of the hinge of the same tine. The motions of the tip and hinge of a tine are distinguished only by their respective positions at a given time, which is to be expected since the motion of the tine is a curvilinear translation (irrotational). Furthermore, the velocity and acceleration equations for the tip and hinge of a tine are identical in form to those for a point in the slat of a slat reel.

Cutterbar Position (Slat and Tined Reels)

With reference to either of **Figs. 3** and **4**, it can be shown that the position of a point, Q, at the tip of the cutterbar, relative to the frame of reference, may be represented as follows:

$$\begin{bmatrix} X(t) \\ Y(t) \\ 1 \end{bmatrix}_Q = \begin{bmatrix} 1 & 0 & Vt \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 \\ Y_s \\ 1 \end{bmatrix} \quad (2.13)$$

Which may be expanded to yield;

$$X_Q(t) = Vt \quad (2.14a)$$
$$Y_Q(t) = Y_S \quad (2.14b)$$

The velocity of the cutterbar assembly is in fact the advance velocity of the header, which has been assumed to be constant as stated earlier.

Constraint on Crop Stem Deflection

In constructing a model for the deflection of crop stems by the reel the following assumptions were made:

① A bunch of deflected stems can be considered to behave as a single vertical cantilever fixed at the base.

② The resultant force, F, acting to deflect the stem, is directed normal to the tangent to the curvature of the deflected stem at the point of action of the force.

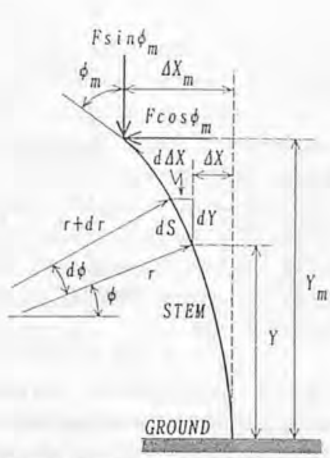

Fig. 5 Model of stem deflection.

The model of stem deflection used in this work is illustrated in **Fig. 5**.

It is postulated that proper coordination between the operation of the reel and that of the cutterbar requires that the stem deflected by the reel be cut by the cutterbar while the reel still tends to increase the deflection of the stem. With this condition satisfied, the effectiveness of the reel in delivering the stem onto the gathering table, after the stem is cut by the cutterbar, should be assured. Thus the stem should be cut before or just at the moment in time when the velocity vector of the point in the reel slat/bar which contacts the stem becomes tangent to the deflected stem. This limiting condition is illustrated in **Fig. 6**. It follows that:

$$\phi_M = \phi(t_M) - 2\pi \quad (3.1)$$

It should be evident from **Fig. 7** that the reel stagger, X_r, can be expressed as follows:

$$X_r = [R^2 - (Y_r - Y_M)^2]^{1/2} + \Delta X_M \quad (3.2)$$

As can be seen in **Fig. 7**, both ϕ_M and ΔX_M are expected to take on negative values. On the other hand, X_r can be either negative or positive.

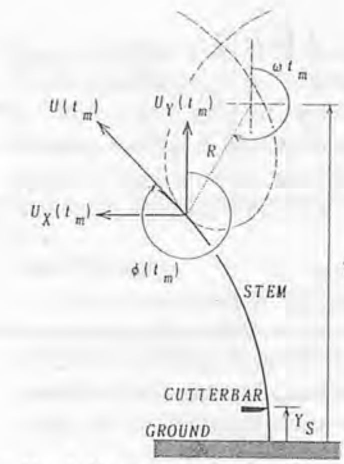

Fig. 6 Moment of stem cutting.

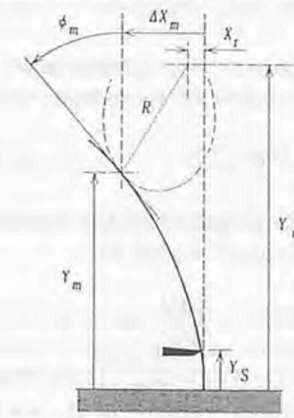

Fig. 7 Sem deflection and reel stagger.

Relationships Involving Reel Kinematics and Stem Deflection

Timing of Entry of Reel Slat/Bar into the Crop

The fundamental functions of the reel are deemed to be the following:

① To prop the uncut crop against thrust in the direction of advance of the header; and

② To deliver the already cut crop onto the gathering table.

Both these functions should be satisfied if, at all times that the reel engages the crop, the slats, or reel bars, move with a velocity, relative to the fixed frame of reference, whose X-component is either negative or zero. Thus if point P, on a slat, enters the crop at a time t_2 (**Figs. 3** and **4**) then by using equation *(2.3a)*, we may write:

$$U_X(t_2) = V + \omega R\cos\omega t_2 \leqq 0 \quad (4.1a)$$

or

$$R\cos\omega t_2 \leqq -V/\omega \quad (4.1b)$$

Thus

$$R\cos\omega t_2 = -AV/\omega = -AR_0;$$

where $A \geqq 1$ (4.2a)

and

$$\omega t_2 = \pi - \cos^{-1}[\frac{AR_0}{R}] \quad (4.2b)$$

The *Y*-coordinate of point $P(t_2)$ should be equal to the height of the crop, thus, in accordance with equation *(2.2b)*:

$$Y(t_2) = Y_r + R\cos\omega t_2 = Yc \quad (4.3a)$$

or

$$Y_r = Y_c + AR_0 \quad (4.3b)$$

In **Figs.** 3 and 4, AR_0 must be less than *R* or the reel slats/bars would not engage the crop at all. Thus, we may write:

$$Y_r = Y_c + AR_0;\ R/R_0 > A \geqq 1 \quad (4.4)$$

Here we note that $\omega = \pi N/30$, where *N* is the rotational speed in revolutions per minute. Thus:

$$R_0 = V/\omega = 30V/\pi N$$

and by using this result in equation *(4.4)*, we may write:

$$Y_r = Y_c + \frac{30AV}{\pi N};\quad 1 \leqq A < \frac{\pi NR}{30V} \quad (4.5)$$

These equations are applicable in the case of a reel entering upright (as opposed to lodged) crop. Current reel theory (Kanafojski et al., 1976; Klenin et al., 1985) postulates that *A* should be unity, probably based on the premise that the *direction* of the resultant velocity vector of a slat or a reel bar, as it enters the crop, should preferably be vertically downward $\{\tan(\phi(t_2))=0\}$. However, we note that Klenin et al. (1985) also point out the need to limit the *magnitude* of the slat's (or reel bar's) velocity, as it enters the crop, in order to minimize shattering losses. The postulate that *A* should be unity fails to consider the *magnitude* of that velocity. Furthermore, analytically, we can only deduce that *A* should be *equal to or greater than* unity, and, to the authors' knowledge, the postulate that *A* should be unity has yet to be corroborated by empirical data.

Timing of the Cutting of a Deflected Crop Stem

As stated in equation *(3.1)*;

$$\phi_M = \phi(t_M) - 2\pi$$

Thus $\tan\phi_M = \tan\phi(t_M)$ (4.6)

By using equations *(2.5b)* and *(4.6)*, it can be shown that;

$$R_0\cos\phi_M = -R\cos(\omega t_M - \phi_M) \quad (4.7)$$

and that

$$\omega t_M = \cos^{-1}[\frac{R_0}{R}\cos\phi_M] + \pi + \phi_M \quad (4.8)$$

The situation expressed by equations *(4.7)* and *(4.8)* is illustrated in **Fig. 8**. Finally, by noting that $Y_M = Y(t_M)$ and then using equation *(2.2b)*, we obtain the following:

$$Y_M - Y_r = R\cos\omega t_M \quad (4.9)$$

and by noting that $\Delta X_M = X(t_M) - X(t_2)$ and using equation *(2.2a)*, we obtain the following;

$$\Delta X_M = R[\frac{R_0}{R}(\omega t_M - \omega t_2) + \sin\omega t_M - \sin\omega t_2] \quad (4.10)$$

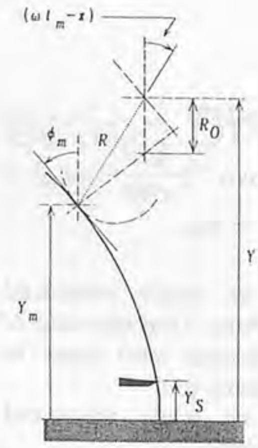

Fig. 8 Relationship between wt_m and $\o_m$.

Summary and Discussion

Six mathematical relationships have been derived in the preceding sections, which might prove useful in an actual reel design situation. These are summarized below in the order in which they might be used. Some of the equations have been altered slightly from the originally derived versions so as to allow the use of more common engineering units of measure:

$$Y_r = Y_c + \frac{30AV}{\pi N};\quad 1 \leqq A < \frac{\pi NR}{30V} \quad (1)$$

where

Y_r is the height of the reels axis of rotation above the ground, in metres

Y_c is the nominal height of the crop in metres

A is a dimensionless number

V is the header advance velocity in m/s

N is the reels rotational speed in rpm

R is the radius of the reel in metres

$$\omega t_2 = \pi - \cos^{-1}[\frac{30AV}{\pi NR}] \quad (2)$$

where

ωt_2 is an angle measured in radians. Thus the value of the arccosine term must be in radians too.

π is the ratio of a circles circumference to its diameter

(3.14159)

$$\omega t_M = cos^{-1}[\frac{30V}{\pi NR}cos\phi_M] + \pi + \phi_M \quad (3)$$

where

ωt_M is an angle measured in radians. Thus the value of the arccosine term must be in radians too.

ϕ_M is an angle measured in radians.

$$Y_M - Y_r = Rcos\omega t_M \quad (4)$$

where

Y_M is the height from the ground to the point of contact between the reel slat/bar and the deflected crop stem, in metres.

$$\Delta X_M = R[\frac{30V}{\pi NR}(\omega t_M - \omega t_2) + sin\omega t_M - sin\omega t_2] \quad (5)$$

where

ΔX_M is the deflection of the crop stem at the point of contact between the reel slat/bar and the stem, in meters.

$$X_r = [R^2 - (Y_r - Y_M)^2]^{1/2} + \Delta X_M \quad (6)$$

where

X_r is the reel stagger in metres.

In the equations summarized above, the quantities A, N, R, and V would be determined from other design considerations, including minimization of grain losses and vehicle (combine harvester) locomotion. The quantity Y_c is a crop property that is not in the control of the machine design engineer. The four equations *(3)*, *(4)*, *(5)*, and *(6)* contain five unknowns, (namely ωt_M, ϕ_M, Y_M, ΔX_M, and X_r) and, therefore, cannot have a unique solution. It is, therefore, necessary to obtain additional information before these equations can be used in an actual design situation. It is expected that the quantities, ϕ_M, Y_M, and ΔX_M, would have a definite relationship which may be determined through an empirical study of the crop stem deflection characteristics. Results of such an empirical study by the authors will be reported subsequently.

Conclusions

1. Equations describing the kinematics of the conventional combine harvester reel, of both the slat type and the tined type, as well as the cutterbar, were derived from first principles using the method of linear homogeneous transformations. The use of this method enabled a unified approach to the derivations for both the slat reel and the tined reel.
2. A condition limiting the extent to which a crop stem engaged by the reel should be deflected before it is cut by the cutterbar, so as to ensure the proper coordination of the functions of the reel and the cutterbar, was postulated. A deflection model assuming the stem to behave as a vertical cantilever fixed at the base, which may or may not be purely elastic was proposed.
3. Based on the kinematic equations and the postulated limiting deflection of the stem before it is cut by the cutterbar, six mathematical equations were derived which may be used as a set to determine the reel stagger.
4. It was found that more information would be required before the six equations could be used in an actual design situation. The additional information is expected to be derived from an empirical study on the deflection characteristics of the crop stems. The results of such a study by the authors will be reported subsequently.

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Modification of A Natural Air Convection Dryer

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Abstract

This study has attempted to investigate the effect of two modifications on the performance of an air convection dryer used to bring wet grain to safe moisture content for storage. The modifications introduced were:

i. floating the heating medium and
ii. introduction of a suction fan to increase air flow to the plenum chamber.

The main factors tested were initial moisture contents and fan speeds while the parameters used to analyze the results obtained were drying time, rate of drying and drying efficiency.

Results obtained show that drying time, drying rate and drying efficiency improved the performance of the dryer but not significantly when compared with those obtained for non-modified drier.

Introduction

There is a great need for large increase in food production throughout the world but it is more so in developing countries due to large increase in pupulation.

There is, therefore, an urgent need to develop drying and storage facilities for crops at low costs.

Thought has been given to designing a drier and storage facility that could be constructed with local materials and within the financial reach of local farmers in developing countries. The drier which is basically a batch drier is simple enough to operate and to build on a farm using available local materials. The dryer has a flue as a heat source and utilises the force created by the buoyancy of natural convection as a driving force to move heated air through the grain without any mechanical device.

The objective of this investigation is to modify the dryer for an increase in its performance. In carrying out this objective, experiments were designed to look at two factors, namely:

i. two initial moisture contents, (30% and 25% wet basis); and
ii. two fan speeds, 440 rpm and 310 rpm on the drying time and drying efficiency of the modified dryer and compare these with those obtained for the unmodified dryer.

Modifications on the Dryer

The first modification introduced was that the oil drums (heat medium) were lifted 0.20 meter above the ground level of the pit trench. This would enable complete utilization of heat conducted outright round the three drums. Formerly the oil drums were placed resting on the stock pit and heat utilized was that only conducted out of the exposed part of the drums. This accounted for only about 50% of the heat available.

The second modifications was the introduction of a two-speed suction fan to aid the speed of natural air going into the plenum chamber of the dryer. The two speeds used in the experiments were 310 rpm and 440 rpm.

Description of the Dryer

The dryer (**Fig. 1**) was built of concrete blocks. A flue and stoking pit trench were first dug as a foundation before the concrete walls were mounted. The flue for the drier consists of three, 208.18 litre oil drums laid end to end, and raised 0.2 metre above ground level of the pit trench to enable complete utilization of heat conducted out of the drums.

The height of natural ground level from the stoking pit trench level is 2.11 metre. The dimension of the tray 0.31 metre thick is 2.44 m × 2.44 m × 1.07 m. The height of the dray floor from the top of the flue is 1.52 m.

There is a pyramidal plywood cover of 1.5 m high (**Fig. 2**) on top of the dryer. A small window, 0.61 m × 0.61 m is cut as entrance on one side of the cover to enable the experimenter to enter the dryer to lay thermocouples, load and off load grains and also to spread and mix the grains as desired.

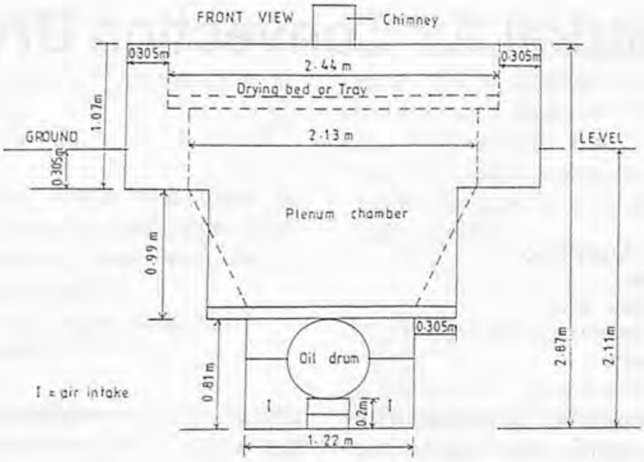

Fig. 1 The dryer.

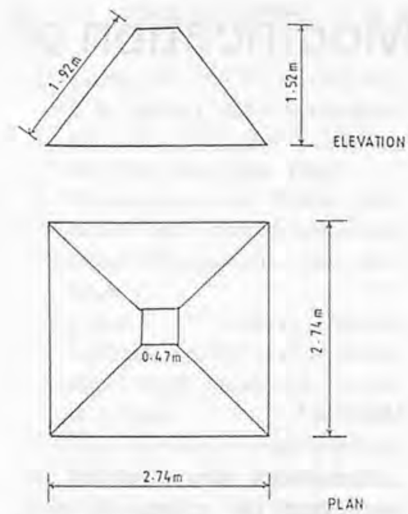

Fig. 2 Pyramidal plywood cover.

Literature Review

General

Drying of grains is very important in preventing bacteria, fungi and mould growth on grains, hence retain maximum quality of the grains. There are two types of drying: natural and artificial. Drying of agricultural products according to Sherwood (1936) occurs in two distinct stages, namely;

i. the constant rate period and
ii. the falling rate period.

Willits et al. (1976) states that because of the temperatures and moisture content involved, only a few agricultural products display the constant rate drying period. Potatoes and yams are examples of such crops that display constant rate drying period while cereals do not display constant rate period except when harvested at a very immature state. The falling rate period represents the major phase of the overall drying time and most agricultural products being dried exhibit only falling rate phase.

Air Flow Rate

The effect of air flow rate depends on the stage at which drying occurs. Van Arsel and Copley (1964) found that the effect of air flow rate is more pronounced at the constant rate period compared to the falling rate period. Brooker et al. (1974) found that the internal resistance of moisture movement in the falling rate period compares with the surface mass transfer resistance which makes the air flow rate to have little effect on the drying rate. Ryu (1972) developed an equation for predicting the rate of air flow in terms of the grain depth, the height of drying floor and the temperature rise,

$q = 0.0024\ H \quad TD^{-0.76}$ (in foot pound system)

where q is the rate of airflow per unit floor area
H is the height of drying floor from the centre of flue
T is the temperature rise from the inlet air temp. to the mean plenum temp.

This equation in the Cent. Gram System is:

$q = 0.0013\ H \quad D^{-0.76}$ cm/min

used for the purpose of calculating the airflow rates in the experiments.

Drying Performance

Forster (1982) claimed that the performance of a dryer can be measured in terms of capacity, efficiency, reliability, and dried grain quality. Of all the terms listed, efficiency is a much more important consideration in drier selection and the quality of the dried product. He also mentioned that efficiency may be expressed in terms of fuel efficiency, sensible heat utilization efficiency and drying efficiency. Drying efficiency is based on how well a drying system converts sensible heat to latent heat which can be expressed as follows:

Drying efficiency, %

$$= \frac{\text{heat utilized for moisture removal}}{\text{heat available for moisture removal}} \times 100\%$$

$$= \frac{\text{weight of water evaporated} \times \text{latent heat of vap.}}{\text{weight of fuel utilized} \times \text{heatvalue of fuel}} \times 100\%$$

Methodology

Some of the experiments were performed without fan assisted air flow while the others were performed with suction fan at 440 rpm and 310 rpm to assist the airflow.

The inlet air temperature was monitored by using an ordinary centigrade thermometer. The temperature of the drying air were measured by using temperature probes placed at four strategic positions in the tray containing the grains being dried, namely; bottom, middle, top and corners of the grain mass. Readings were taken at the start of each experiment and at every 6-hour intervals.

Initial moisture contents of grain sample were 30% and 25% and each sample weighed about 500 kg. In order to know the relative humidity of the surrounding air, the wet and dry bulb hygrometer was used and the speed of the fan was measured by a Tacometer.

In order to avoid heavy cost on the purchase of corn materials for the replications, wetting had to be carried out. In this process, a calculated amount of water to raise the m.c. to 30% or 25% was added to the corn grains and turned for 3 days.

The weight of the wood used for drying at each trial was known and recorded as well as the ambient air conditions each time a set of readings was taken.

In order to compare some results obtained with those already obtained for the unmodified drier, results available in Adeyemo, T.L. 1979 (M. Sc thesis) were used.

Table 1. Description of All Drying Tests

Test No.	Description
A1	440 rpm fan speed, 30% (wet basis) initial moisture content, 1.5 m high cover.
A2	Replication II
A3	Replication III
B1	440 rpm fan speed, 25% (wet basis) initial moisture content, 1.5 m high cover.
B2	Replication II
B3	Replication III
C1	310 rpm for speed, 30% (wet basis) initial moisture content, 1.5 m high cover.
C2	Replication II
C3	Replication III
D1	310 rom fan speed, 25% (wet basis) initial moisture content, 1.5 m high cover.
D2	Replication II
D3	Replication III
H1	Control experiment; 25% (wet basis) initial moisture content no fan assistance; 1.5 m high cover.
H2	Control experiment; 30% (wet basis) initial moisture content, no fan assistance 1.5 m high cover.

Note: All replications were carried out with grain depth of 10 cm.

Table 2. Test Results for the Modified Dryer

Test No.	Initial m.c. %	Final m.c. %	Weight of H_2O removed kg	Weight of wood used kg	Drying time (hr)	Av. drying time (hr)	Rate of drying kg H_2O/hr	Average rate of drying kg H_2O/hr	Termal of drying efficiency %	Average drying or thermal efficiency %	Fuel consumption kg wood kg H_2O	Average	Airflow rate cm^3/cm^2 min average
A-1	29.50	12.50	97.60	61.40	20.00		4.88		8.27		0.63		
A-2	30.20	13.30	100.35	64.20	19.50	20.17	5.15	4.88	8.13	8.18	0.64	0.64	0.66
A-3	29.00	12.40	97.10	62.00	21.00		4.62		8.14		0.64		
B-1	24.80	13.00	85.30	48.10	22.80		3.74		9.22		0.56		
B-2	25.10	13.25	86.10	49.25	23.30	23.07	3.70	3.75	9.09	9.10	0.57	0.57	0.70
B-3	25.60	12.90	90.35	52.50	23.10		3.81		8.95		0.58		
C-1	30.00	13.00	95.50	60.00	18.75		5.09		8.28		0.63		
C-2	29.11	12.90	92.75	58.35	16.50	17.75	5.62	5.43	8.27	8.44	0.63	0.62	0.62
C-3	30.55	13.20	100.25	59.50	18.00		5.57		8.76		0.59		
D-1	25.00	12.25	85.60	62.50	20.00		4.28		7.12		0.65		
D-2	25.40	11.50	88.68	55.20	19.00	21.00	4.67	4.24	8.35	7.77	0.62	0.64	0.75
D-3	24.80	11.90	90.40	60.00	24.00		3.77		7.83		0.66		

Results and Discussion

Results

For this investigation, a total of 6 experiments were carried out using 30% (wet basis) initial moisture content and 6 experiments were also carried out using 25% (wet basis) initial moisture content. Two suction fan speeds, low speed (310 rpm) which discharges air at 5.35 m/s and high speed (440 rpm) which discharges air at 7.57 m/s. Description of all drying tests are presented in **Table 1**.

Results obtained during the investigations were recorded and presented in **Table 2**. Results used as a control for the non-modified dryer obtained from previous work by Adeyemo (M.S. thesis 1979) for comparison cases are presented in **Table 2**.

The test symbol denoted 'A' is for high fan speed and initial moisture content of 30% (wet basis) while that denoted 'B' is for high speed but initial moisture content of 25% (wet basis). The test symbol denoted 'C' is for low fan speed with initial moisture content of 30% (wet basis) while that denoted 'D' is for low fan speed with initial moisture content of 25% (wet basis).

Discussion

Drying grain from 30% initial

moisture content to 13% final moisture content with high speed fan took an average time of 20 hours while that with low fan speed took an average time of 17.75 hours. On the other hand, for an initial moisture content of 25% (wb), and high fan speed, the average time taken was 23.07 hrs while that obtained at 25% (wb) initial moisture content and low fan speed was 21 hours. Thus it can be seen that the dryer performed best in terms of drying time when initial moisture content was 30% (wb) and speed of fan was 310 rpm, (17.75 hrs vs 20.00 hrs). This compares well with the performance of the dryer for initial moisture content of 25% (wb) and low fan speed against high fan speed, (21.00 hrs vs 23.07 hrs).

The average rate of drying was 4.88 kg H_2O per hour for initial moisture content of 30% (wb) and high fan speed against 5.43 kg H_2O per hour for the same initial moisture content but low fan speed. This is an indication that the performance of the dryer is better with low fan speed and initial moisture content of 30% (wb).

However, for all the experiments performed and for all cases considered, the average drying or thermal eficiencies of the dryer were 7.77%, 8.18% 8.44% and 9.10%. These figures fall within the same range and it can be said that the efficiency of the drier was relatively maintained for the cases considered.

The performance of the dryer was compared with the situation before modifications were introduced. Results used were taken from Adeyemo, T.L. (1979 M. Sc. thesis). The initial moisture content of the non-modified dryer was 25.00% (wb) **Table 3**. and hence comparison was done with the same initial moisture content for the modified dryer. While the average drying time for the unmodified dryer was 12.50 h, that for the modified drier with high fan speed was 23.07 h and that with low fan speed was 21 hours. The average rate of drying for the non-modified dryer was 6.24 kg H_2O per hour while that of the modified dryer with high fan speed was 3.75 kg H_2O per h. and that with low fan speed was 4.24 kg H_2O per hour.

Table 3. Test Results for the Unmodified Dryer

Test No.	Initial m.c. %	Final M.C. %	Rate of drying kg H_2O/ hr	Average rate of drying kg H_2O/ hr	Average thermal drying efficiency %	Average fuel consumption kg wood/ kg H_2O	Average drying time (hr)
E-1	24.43 25.00	13.00 13.00	6.21 6.27	6.24	34.96	0.61	12.50

However, the average fuel consumption for the non-modified dryer was 0.61 kg wood per kg water and that for the modified drier with high fan speed was 0.75 kg wood per kg water when that with low fan speed was 0.64 kg wood per kg water.

By the measure of the fuel consumption, the modified dryer gave better performance when the fan was at high speed.

Furthermore, looking at the average drying efficiency results, the two initial moisture content levels did not show any significant effect on the performance of the dryer for low fan speed (8.44% vs 7.77%). However, the performance of the dryer was generally better at low fan speed.

Conclusion

The following conclusions can be drawn from the investigations carried out:

1. As air flow rate increased, the average drying time decreased at 25% initial moisture content (23.7 hrs vs 21.00 hrs)
2. Increase in drying rate equally increased the drying efficiency of the drier for 440 rpm fan speed, (4.88 kg H_2O/hr vs 5.43 kg H_2O/hr): (8.18% vs 8.44%).
3. The average thermal efficiency of the dryer is better at low fan speed (310 rpm) compared with the result at high fan speed (440 rpm) for the same initial moisture content, (8.44% vs 8.18%).
4. When the modified drier was viewed with the unmodified dryer, in respect of fuel consumption, the difference was small

$$(0.57 \frac{\text{kg wood}}{\text{kg } H_2O} \text{ vs } 0.55 \frac{\text{kg wood}}{\text{kg } H_2O})$$

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Complementation of Load-factor-improvement Tariffs with Low-wattage Cooking in Nepal

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Abstract

Use of a peak-demand tariff constraining domestic peak load exhibits great potential as a means of smoothing electrification system peaking characteristics in Nepal. Unfortunately, where tariffs of this nature have been implemented to the present time, their use has been typified by additional lighting throughout the daytime hours. In contrast to this, low-wattage cooking technology provides a productive alternative for consumers subscribing to a peak-demand tariff. The present study uses an economic analysis to show that such a technology: (1) undercuts the cost of cooking with a conventional metered-tariff and (2) under certain conditions becomes very competitive with the cost of cooking with purchased fuelwood. The study concludes by proposing that isolated rural electrification systems in Nepal, characterized by low load factor and crucial shortages of fuelwood, offer a logical starting point for implementation of low-wattage cooking to complement a peak-demand tariff.

Statement of the Problem

Rural electrification in Nepal is a costly investment, requiring the expenditure of scarce foreign capital. To effectively utilize this scarce resource in the most equitable manner, the authors are of the opinion that one paramount area that should, and indeed can, be addressed using simple technologies and tariffs is the constraint of domestic peak loading. In the long term the development of small industries, agriculture, transportation, and other loads may lead to enhanced utilization of Nepal's hydroelectric infrastructure during domestic off-peak hours. In the short to medium term, however, the constraint of domestic peak load is one of few readily implementable options for maintaining supply integrity and allowing a greater number of consumers to benefit from use of this scarce resource.

This paper approaches the problem of peak load control in the domestic sector by proposing the hypothesis that nonconventional approaches to rural electrification being tested in several pilot projects, demonstrate distinct advantages over their conventional counterparts which serve as a model for project implementation throughout Nepal at the present time. **Fig. 1** presents evidence of a nonconventional tariff's ability to control system peak loading. It contains data for two types of consumers at the Salleri Electricity Utilization Project (SELUP): (1) 500 W peak-demand consumers whose load is constrained to 500 W by a miniature circuit breaker and (2) metered consumers. The individual plots were generated by summing and normalizing survey respondents reported lighting times over a 24-hour period. In the absence of significant cooking and other loads in most survey households these plots, generated on the basis of reported lighting times, are assumed to be a reasonable approximation of consumption patterns in the two survey samples over a daily cycle.

Considering 500W peak-

Acknowledgement: The authors wish to gratefully acknowledge cooperating parties at the Butwal office of the Nepal Electricity Authority, Baglung Small Hydel Project, Salleri Electricity Utilization Project, and Andhi Khola Hydel and Rural Electrification Project.

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For further imformation the reader is referred to: Nafziger D.L. 1990. Impacts and Implications of Electrification Ideology in Nepal's Domestic Sector. Unpublished Ph.D. dissertation. Department of Agricultural and Biological Engineering, Cornell University, Ithaca, NY, 14853, USA.

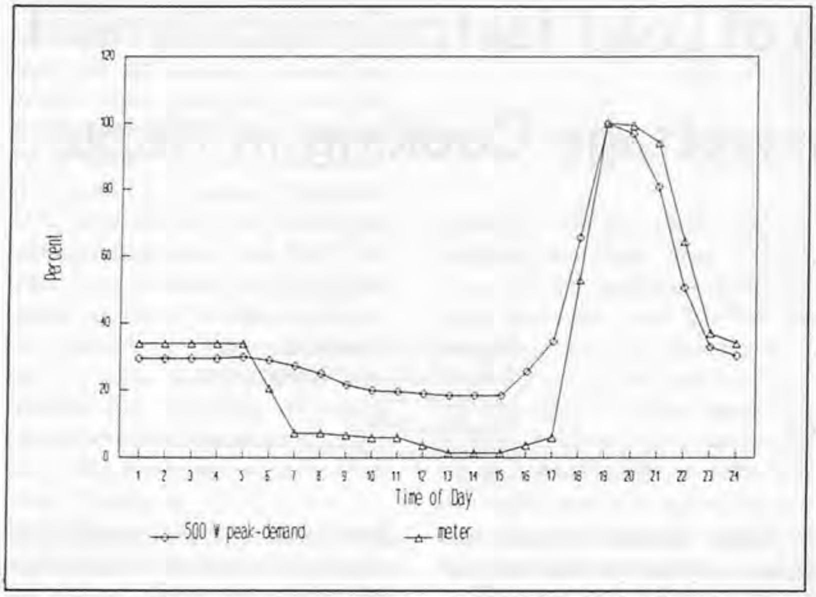

Fig. 1 Ratio of instantaneous-to-peak load for selected SELUP tariff groups.

demand consumers first; **Fig. 1** shows that subscribers to this option lack motivation to conserve electricity during the daylight hours. This may be attributed largely to the fact that whether electric lights are turned off or on, the monthly energy bill remains unchanged. The load factor for 500 W peak-demand consumers in **Fig. 1** is 36.6 percent. Turning to consider metered consumers, **Fig. 1** clearly shows greater motivation to conserve than in the former case. Intuitively these results seem correct when considering that metered consumers pay in proportion to their consumption and are thus penalized when they fail to conserve. This conservation results in metered consumers recording a lower (30.1%) load factor over the 24-h time period. Although less than the load factor of their peak-demand compatriots, this load factor still considerably exceeds the 21% value derived when averaging across 10 Nepal Electricity Authority (NEA) small hydro sites (WECS, 1988). In the authors' opinoin the higher load factor among Salleri metered consumers is attributable in no small part to the 57 units of energy contained in the Rs. 100 minimum monthly charge they pay.[1] Since consumers pay for these units whether they are used or not, this provides incentive toward higher levels of consumption and thus yields a higher load factor than that found in conventional NEA systems. This point notwithstanding, **Fig. 1** nevertheless demonstrates in overt terms the potential of peak-demand tariffs to smooth system load characteristics more effectively than metered tariff alternatives. The most obvious criticism to this method of load stabilization, clearly implied in the discussion above, is that peak-demand consumers appear to use their installed capacity primarily for additional lighting. While this may be desirable to an extent, it also has practical limits. If a peak-demand tariff is to have far-reaching implications, it ultimately must go beyond additional lighting to address more productive applications. An examination of such productive end uses in conjunction with a peak-demand tariff constitutes the central problem addressed in the present paper.

Research Methodology

In addressing the problem stated above the authors considered the substitution of fuelwood with electricity in the most energy intensive activity performed in the domestic sector: that of preparing food for human consumption. Justification for exploring the problem from this perspective is provided by the observation that 66 to 92% of total fuelwood is consumed in this activity among survey households in the present study. Thus, the potential demand for electricity as fuelwood substitute is greatest in this area. Further justification is provided by the observation that substitution in this area potentially leads to the greatest impact(s) both upon deforestation rates and upon rural women, who account for 75% of regular fuelwood gatherers in the present study.

The reseach approaches the problem of substituting electricity for fuelwood in the preparation of food for human consumption from the perspective of an economic analysis. This approach rests upon the assumption that economic considerations represent a reasonable proxy for the actual criteria considered by household decision-makers when choosing one cooking technology to the exclusion of another. Obviously this represents a simplification, particularly in light of the fact that practical experience of the authors shows that social factors also highly influence such decisions.

Actual data used in addressing the research problem were gathered from four sites in Nepal. **Fig. 2** shows these sites with respect to the capital city of Kathmandu. Two sites are con-

[1]An exchange rate of US$1 = Rs. 25.57 applies throughout this report.

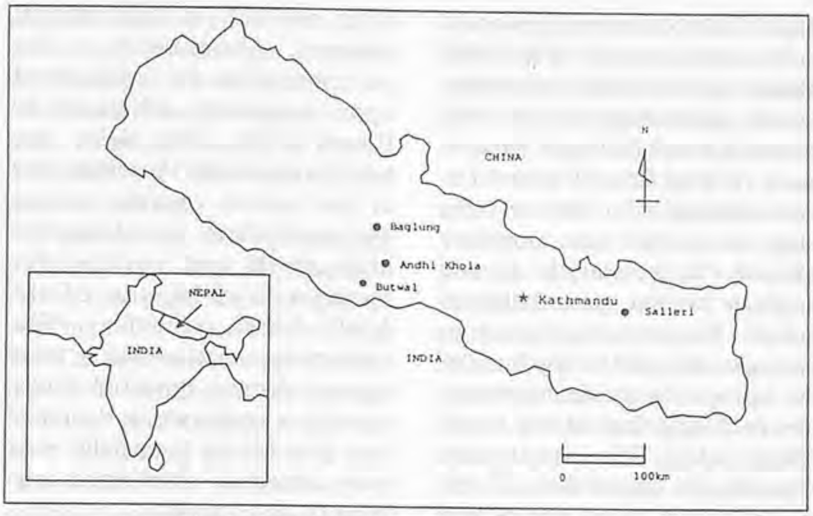

Fig. 2 Map of Nepal showing the research sites.

sidered example of conventional electrification for the purposes of this study: Baglung and Butwal. Alternatively, Andhi Khola and Salleri are termed nonconventional electrification sites. Baglung is an isolated 175 kW run-of-river plant primarily serving 575 residential consumers. Butwal is supplied by a 1 000 kW run-of-river plant and also a 20 MVA grid connection. It serves approximately 3 300 residential consumers. Andhi Khola is scheduled to commerce power production from a 5 100 kW plant in fall 1990. At present approximately 440 consumers are served in a pilot project powered from a grid connection. Finally, Salleri is an isolated 200 kW run-of-river plant serving approximately 275 residential consumers. In addition to residential loads, each of the systems above also serve industrial, commercial, and noncommercial loads. As residential consumers dominate in each system, however, these data provide a reasonable approximation of the relative scale of electrification involved in each case.

Assumptions

Tables 1 and **2** summarize assumptions regarding cooking devices and cooking fuels respectively. Some explanation is necessary. The ceramic cooking heater identified in **Table 1** is manufactured in Nepal. It consists of a fired-clay stand approximately 15 cm in diameter and 10 cm in height. Several points on the upper circumference of the stand are elevated slightly to support the cooking vessel. A long, coiled resistance wire provides power for the cooking process. The ceramic cooking heater draws 1 kW of peak load which constrains its use to metered tariffs.

The *bijuli dekchi* technologyy in **Table 1** refers to a low-wattage cooking technology developed by Development and Consulting Services, Butwal, Nepal (van Wijhe, 1986). (Bijuli translates into English as "electricity" and *dekchi* refers to the particular style of cooking pot from which the device is manufactured.) **Fig. 3** in the Appendix shows this technology being used. At present *bijuli dekchis* are manufactured on a trial basis and sold as a set consisting of three sizes: 8, 4, and 2 liter capacity. When water is preheated in the 8 liter *bijuli dekchi* and then poured into the 4 or 2 liter vessel for cooking rice or other foods, the cooking times are comparable to those achievable using fuelwood. Each *bijuli dekchi* draws a 200 W load. At present they are being tested in conjunction with the 250 W peak-demand tariff at the Andhi Khola Hydel and Rural Electrification Project (AHREP). Load is constrained to 250 W by use of a "cutout." This is an electromechanical device historically used in Norway *circa* World War II for distributing electricity more

Table 1 Assumptions Regarding Cooking Devices

Item	Traditional fuelwood stove	Ceramic cooking heater	*bijuli dekchi* technology
Live of device (years)	5[a]	2[a]	5[b]
Heat absorbed by pot and contents (%)	9[a] to 16[a]	38[c] to 50[a]	78[c]
Capital cost (Rs)	15[d]	100[d]	1 500[c]
Annual maintenance cost (Rs)	10[a]	50[b]	25[b]
NEA electrical connection required (amperes)	na	15	2.5

[a]WECS (1985).
[b]Assumed by the authors.
[c]van Wijhe (1990).
[d]Assumed by the authors, treating the initial investment in cooking vessels as a sunk cost.

Table 2 Assumptions Regarding Cooking Fuels

Location	Purchased fuelwood (Rs/bundle)	Metered tariff (Rs/kWh)	Peak-demand tariff (Rs/month)
Butwal	21.2	1.20[a]	--[b]
Baglung	76.4	1.20[a]	--[b]
Salleri	15.5	1.75	80[c]
Andhi Khola	16.0	0.82	60[d]

[a]The Rs. 11 flat rate of the NEA tariff (charged for 0-25 kWh) is neglected. This is due to the relatively high kWh consumption incurred when cooking with electricity, combined withthe fact that lighting load accounts for consumption of most units in this region of the tariff.
[b]Peak-demand tariff is not an option at these sites.
[c]500 W peak load limit.
[d]250 W peak load limit.

Fig. 3 'Bijuli dekchi' technology used by two community motivators in its promotion at AHREP.

Fig. 4 A cutout to limit peak load at AHREP.

equitably in isolated systems with limited generation capacity. **Fig. 4** in the Appendix shows a cutout installed in an AHREP pilot project household. The use of *bijuli dekchis* in conjunction with a 250 W peak-demand tariff allows only one *dekchi* to be operated at any given time. This technology is also suitable, however, for use in conjunction with a metered tariff, in which case it is possible to operate several *dekchis* simultaneously.

As an example of how the assumption in **Tables 1** and **2** were used when applied to the case of fuelwood, the authors first calculated that a typical family in the survey sample consisting of 4.3 adult-equivalents requires approximately 2 414 MJ of useful energy to prepare tea, snacks, and main meals on an annual basis. Then, taking this theoretical minimum energy requirement, the authors converted it into an equivalent weight of fuelwood by utilizing the factor 15.5 MJ/kg (Foley and Moss, 1985). The result was a theoretical requirement of 156 kgs of fuelwood annually. **Table 1** notes that the efficiency of a traditional fuelwood stove is assumed to be in the range of 9 to 16%. Applying these values to the theoretical requirement of 156 kgs yields an actual fuelwood requirement ranging from 974 to 1 731 kgs annually. To convert this range to an equivalent monetary value it was necessary to assume a given weight per fuelwood bundle. The authors assumed an average value of 25.9 kg/bundle, the value obtained during extensive field weighings at the Andhi Khola site. This assumption allowed for conversion of the weight values listed above into equivalent values of 37.6 to 66.8 bundles required for the preparation of tea, snacks, and main meals on an annual basis. Finally, these bundle values were multiplied by the "Rs/bundle" figures summarized in **Table 2** to yield the annual cost of cooking using fuelwood. A similar procedure was followed using the assumptions contained in **Tables 1** and **2**, to convert the 2 414 MJ energy requirement into equivalent monetary values of electricity.

A time period of 10 years was assumed for the analysis. The authors invested considerable thought prior to selecting a discount rate. Ultimately two rates were selected. In one case a 10-percent value was used, reflecting a rate approximating those often assumed in conventional analyses. Alternatively, a 30-percent rate was also tested, based upon arguments advanced by French (1979). This higher rate tends to emphasize the initial costs of the various cooking options and, particularly, accentuates the high capital cost required for scenarios involving use of the *bijuli dekchi* technology. The authors hypothesize that if these options display potential under worst-case assumptions, then they may possibly be financially even more attractive after these constraints are relaxed.

Discussion

Table 3 summarizes the unit cost of cooking fuels. The 10^9 normalizing factor is arbitrarily chosen to facilitate comparison of the table values. This section will focus upon examination of these results. Referring first to the general headings of the table there are three areas considered: cooking with (1) purchased fuelwood; (2) a metered tariff; and (3) a peak-demand tariff. The metered-tariff option considers use of both a ceramic heater (at 38 to 50% efficiency) and the *bijuli dekchi* technology (at 78% efficiency). The fixed rates under the peak-demand tariff option

Table 3 Per-Unit Cost of Cooking Fuels (Rs/10^9 Joules)

Location	Purchased fuelwood		Metered tariff			Peak-demand tariff	
	min	max	Ceramic cooking heater min	Ceramic cooking heater max	*Bijuli dekchi*	*Bijuli dekchi* min[a]	*Bijuli dekchi* max[b]
			30% discount rate				
Butwal	104	184	220	285	189	--[c]	--[c]
Baglung	370	656	220	285	189	--[c]	--[c]
Salleri	76	134	314	407	257	125	187
Andhi Khola	79	139	154	199	154	110	156
			10% discount rate				
Butwal	207	364	436	565	352	--[c]	--[c]
Baglung	735	1 303	436	565	352	--[c]	--[c]
Salleri	152	267	623	812	481	220	342
Andhi Khola	157	276	306	394	277	190	281

[a]"Min" values assume 50 percent of the monthly flat rate is attributed to cooking.
[b]"Max" values assume 100 percent of the monthly flat rate is attributed to cooking.
[c]The peak demand tariff is not an option at these sites.

preclude consideration of cooking efficiency. As per the footnote in **Table 3**, the minimum and maximum values in this case thus arise from attributing 50 versus 100 percent of the monthly flat rate to cooking.

Considering the "30-percent discount rate" data first; **Table 3** shows that generally, the cost of cooking with a ceramic heater significantly exceeds that of cooking with purchased fuelwood. Even at Andhi Khola, the site with the lowest per-unit charge (Rs. 0.82/kWh), cooking with a ceramic heater is not competitive with purchasing fuelwood. The one site offering exception to this trend is Baglung, where due to a severe fuelwood shortage electric cooking is indeed competitive. Unfortunately, very limited electricity production capacity at the Baglung site effectively prevents this substitution of electricity for fuelwood from taking place.[2].

In addition to the ceramic cooking heater, it was noted previously that it is also possible to cook using the *bijuli dekchi* technology in conjunction with a metered tariff. This should not be confused, however, with the comments below regarding its use with a peak-demand tariff. When using the *bijuli dekchi* technology in conjunction with a metered tariff the annual energy charge is calculated assuming a 78-percent efficiency and applying the appropriate per-unit tariff. **Table 3** considers this possibility to show that generally this option is more competitive than cooking with a ceramic heater. Although the initial outlay for the *bijuli dekchi* technology significantly exceeds that of the ceramic heater, its higher efficiency yields lower energy costs, which more than offset the required initial investment. Only at the Andhi Khola site is the minimum cost of cooking with the ceramic heater technology (Rs. $154/10^9$ J) comparable to that of the *bijuli dekchi.*

Continuing within the "30-percent discount rate" data by considering the case of cooking under a peak-demand tariff; **Table 3** shows that this scenario generally undercuts the cost of cooking with the *bijuli dekchi* technology under a metered tariff. How this difference is perceived, however, depends greatly upon what portion of the monthly flat rate it is possible to attritute to lighting versus cooking. **Table 2** earlier showed the monthly flat rates at Salleri and Andhi Khola to be Rs. 890 and Rs. 60, respectively.[3] The monthly pre-electrification expenditure for kerosene lighting at the Butwal, Baglung, and Salleri sites was Rs. 32, 64, and 93, respectively. These data suggest that electricity users might generally be willing to attribute at least 50% of the monthly flat rate to lighting. Assuming that consumers perceive a 50-50 balance, **Table 3** shows that the minimum cost of cooking under a peak-demand tariff significantly undercuts the cost of cooking with either a *bijuli dekchi* or a ceramic heater under a metered-tariff scenario — to the point of becoming competitive with purchased fuelwood. In the Andhi Khola case, for example, the minimum cost of cooking with a peak-demand tariff (Rs. $110/10^9$ J) intersects 48% of the interval defined by the minimum and maximum values of cooking with purchased fuelwood (Rs. 79 to $139/10^9$ J).

Turning to consider the "10-percent discount rate" values in **Table 3**, the primary observation is that a lower discount rate provides more equal weighting to costs across the 10-year period of the analysis. This effect is most overt in minimizing the significance of the Rs. 1 500 initial investment for the *bijuli dekchi* technology. With less weight attached to this expenditure, the cost of cooking under a peak-demand tariff becomes even more competitive with that of purchasing fuelwood. At the Andhi Khola site for example, assuming 50% of the monthly flat rate for the peak-demand tariff is attributable to cooking, this charge now covers 72% of the interval defined for cooking with purchased fuelwood — compared to 48 percent in the preceding case.

Based upon the discussion above, two observations merit recapitulation: (1) the cost of cooking under a peak-demand tariff is, in most cases, considerably less than that of cooking with a metered-tariff, and (2) under certain conditions the cost of cooking under a peak-demand tariff becomes very competitive with that of cooking with purchased fuelwood.

Implications

In the context of implications for future electrification planning in Nepal, the results above show that cooking under a peak-demand tariff displays greater economic potential than cooking under a metered-tariff scenario — to the point of becoming competitive with purchased fuelwood. As comments introducing this paper noted, however, economic considerations are but one component of the overall problem. Beyond this, actual field testing of the *bijuli dekchi* technology at

[2]The Baglung system has 175 kW peak output, with over 500 kW of connected load.

[3]To put these figures into clearer perspective it may be noted that a male-adult worker employed to perform manual labor at the Andhi Khola project was paid approximately Rs. 30 daily in 1989.

AHREP to the present time has demonstrated that technical and often more-dominant social factors are indeed addressable in an effective manner. Evidence of this technology's effectiveness in conjunction with a peak-demand tariff at AHREP is provided in **Fig. 5**, which summarizes the ratio of instantaneous-to-peak power for two domestic-supply feeders over a 24 hour-period in May 1990. The "Galyang-bazaar" sample consists of 154 residential consumers in an urban area with no other loads connected. Approximately 72% of these households subscribe to various levels of a peak-demand tariff. The remaining 28% use a two-tier meter, which again limits peak load by charging a higher rate for consumption above a specified wattage. The "Aserdi-village" sample consists of 165 consumers in a rural village, all of which subscribe to a peak-demand tariff. Again, no other loads are present. Load factors in **Fig. 5** are 62.6 and 74.5% for the "Galyang-bazaar" and "Aserdi-village" samples, respectively. Contrasting these results with the 21-percent average value for 10 NEA remote hydro sites noted when introducing the research topic provides indisputable evidence of a peak-demand tariff's ability to significantly improve load factor — and the *bijuli dekchi* technology's contribution toward effective utilization of that additional consumption.

In considering the practical application of these research results, the author proposes small isolated systems such as Baglung to be a logical starting point. At present all residential consumers at Baglung subscribe to a standard metered-tariff which allows consumption *ad libitum* without bearing the cost their higher peak loads impose upon system capacity. The result is a supply where even under load shedding conditions system voltage regularly drops to half of its rated (220 V) value. Implementation of a peak-demand tariff at this site would facilitate restoration of supply quality. Concurrently, the use of low-wattage cooking would provide consumers with a productive use for their installed capacity, with the additional benefit of potential impact upon Baglung's severe deforestation problem.

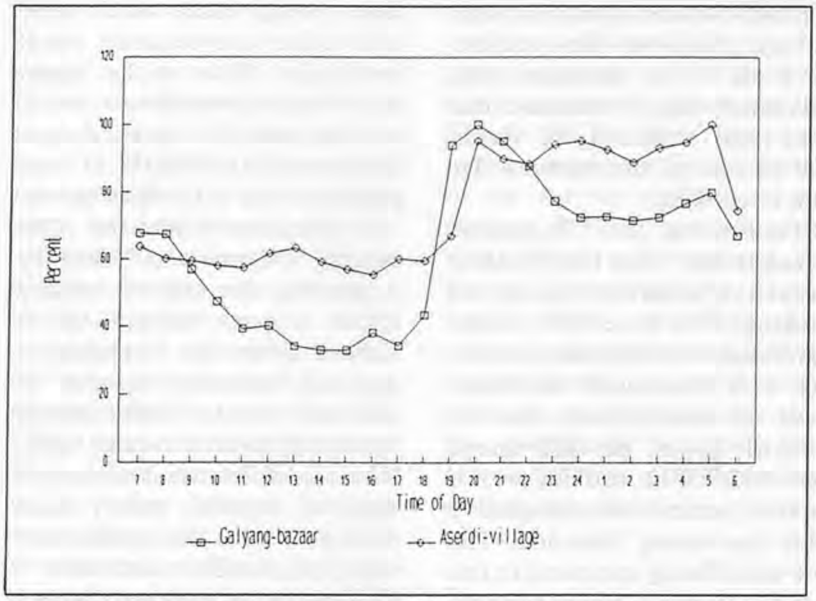

Fig. 5 Ratio of instantaneous-to-peak load for selected AHREP domestic feeders.

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Infestation, Damage and Grading of Cocoyam

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Abstract

The infestations during cultivation as well as the mechanical damage during harvesting, handling and transportation of cocoyam corms are highlighted. Quality improvement by cleaning is also discussed.

It is revealed that sorting out infested and mechanically damaged corms before storage or sale improves the storage life and economic value. Cleaning the corms facilitates the sorting out process, and improves the quality, storage life and the consumers' level of acceptability of the product. It is also found that reduction in drop height and other impacts during loading, unloading and transportation reduce corm damage.

Introduction

Cocoyam (*Xanthosoma sagittifolium* and *Colocasia esculenta*), a tuberous crop, is one of the major carbohydrate food sources for over half the population in West Africa and other tropical countries. It can be boiled, roasted, fried or mashed and eaten with vegetable soup or stew. It can be dried and made into cocoyam powder used in making a thick pap eaten with soup and vegetables. In Cameroon, undried cocoyam is grated into a paste used together with the leaves and smoked meat or smoked fish to prepare "ekwan". In West Africa, it is boiled and pounded to make "fufu" which is eaten with soup and vegetables. In Ghana, it is also chopped and boiled with palm oil, meat or fish and vegetables to make "nuhuu". It is also popular in Hawaii where it is used to prepare "poi", a national dish (Purseglove 1976). The young leaves are eaten as vegetables in preparing sauce and soup in West Africa and the West Indies, notably Trinidad (Baryeh 1982).

Cocoyam has a central tuberous corm surrounded by smaller edible corms. According to the United States National Academy of Sciences (1978), cocoyam compares with potatoes nutritionally. It has 2 to 3% protein, 0.2 to 0.4% fat, 13 to 29% carbohydrate, 1.0% fibre and it is rich in vitamins B and C (Pursegrove 1976). The leaves contain 3% protein, 0.8% fat, 6% carbohydrate and 1.4% fibre, and they are an excellent source of vitamin C (Pursegrove 1976).

Harvested cocoyam can be preserved in an aerated, cool, dry place for about 2 months with little effect on quality (U.S. Natl. Acad. of Sci. 1978) if there are no physical injuries on them. It is traditionally preserved for up to 3 months by digging a 300 to 500 mm deep pit, putting the corms in it and covering them with mud (Baryeh 1982). Physical damage, as well as disease and insect infestation reduce the storage life and, consequently, the economic value of cocoyam. The presence of physical injury in cocoyam increases the rate of physiological reaction which eventually affects the degree of pathological degradation as has also been mentioned for yams by Nwandikom (1990).

In the studies here, infestation, physical damage and grading of cocoyam to help in its storage and sale to the consumer are presented.

Infestation During Cultivation

The central corm of the crop is generally used for planting either whole or chopped. Sometimes, however, small edible corms can also be planted but the central corms usually grow faster than the smaller edible corms. The planting may be done on ridges or on the flat. Planting material is inserted 100 to 150 mm in the ground and covered with loose soil. It grows well in reasonably good, loamy soil rich in organic matter, in low to medium altitudes with 1 500 to over 2 500 mm of evenly distributed annual rainfall. It also likes some shade. Planting spacing is 250 to 500 mm. A hectare of cocoyam farm under these conditions can yield an average of 45 to 50 tons of edible corms within 6 to 15 months depending on the species (U.S. Natl. Acad. of Sci. 1978). Some cultivated cocoyam crop is shown in **Fig. 1**.

A number of diseases which attack the cocoyam leaves during cultivation have been outlined by

Fig. 1 Growing cocoyam plant.

Fig. 2 Infested cocoyam corms.

Fig. 3 Undamaged cocoyam corms.

Fig. 4 Physically-damaged cocoyam corms.

Theberge (1985). These inclulde diseases like the dasheen mosaic virus, bacterial leaf necrosis, cladosporium leaf spot, leptosphaerulina leafspot and concentric leafspot. Most of these leaf diseases usually, eventually affect the corm size and at times its quality. Sclerotium or southern blight, which is a fungus disease, attacks the crop itself first and eventually attacks the corms too. The corms eventually rot but the rot is usually shallow. In the advanced situation, however, the entire plant wilts and dies. Phytophthora leaf blight usually attacks the leaves initially, eventually attacking the corms and making them rot. The colour of the rotting corms is either pink or light brown. Cocoyam root rot is another fungal disease which usually destroys the entire root system except for a few apparently healthy roots nearest the soil surface. When the corms are attacked, the cells in the inner part become soft and disassociated. On the Adamawa Plateau of Central Cameroon, there has been cases of insect and termite attack on corms as shown in **Fig. 2**.

In order to avoid these diseases or infestations, the soil must be cool, well drained and well aerated. Medium night and day temperatures and relative humidity fluctuations reduce infestations, too. Another solution is for crop breeders to breed disease-resistant cocoyam varieties. Trials with some of these disease-resistant varieties have been reported by Lyonga et al (1986). Farmers must also be taught to use clean planting material. Chemical treatment for growing cocoyam, as outlined by Lyonga et al (1979) reduces the onset of disease and insect attack. Chemical treatment of planting material and occasional spraying also protect the crop and corms. Some of these treatments are outlined by Lyonga et al (1986).

Damage During Harvesting

Harvesting of cocoyam is done manually with hoes, machete or cutlasses. During this operation, some corms may sustain cuts from the harvesting tool while some may undergo complete breakage. Some farmers are careful in harvesting their corms and the result is that very few corms sustain large cuts and breakage as they harvest while others are not so careful and, consequently, obtain a considerable amount of physically damaged corms at harvest. Such physical injuries can be reduced through careful handling of the harvesting tool and patience. Some harvested corms may have loose soil and clods attached. Great care is needed to protect the corms from sun damage when harvested. The cuts and sun damage sustained during harvest, loose soil and clods on harvested corms reduce their storage or preservation time and economic value. Some clean corms are shown in **Fig. 3**, while **Fig. 4** shows corms damaged during harvesting. The sharp thin cut in **Fig. 4** is due to a machete digging into the corm while the wider cut is due to the machete scrapping off a small part of the corm.

Damage During Handling and Transportation

Harvested corms are usually carried in baskets, jute bags or carts from the farms to a storage room or directly to the market for sale to the consumer. In the market place, the corms may be stored before selling to the consumer. Some go from storage directly to the consumer. The farmers themselves consume some corms directly from the farm and store some for later consumption in their homes. These activities are shown schematically in **Fig. 5**.

From the farm to the market or storage, the corms sustain some light scuffing. Some bruises and more scuffing are imparted to the corms when they are poured out of the baskets, bags or carts.

From storage to urban markets, the corms are bagged and transported in carts, trucks or trains

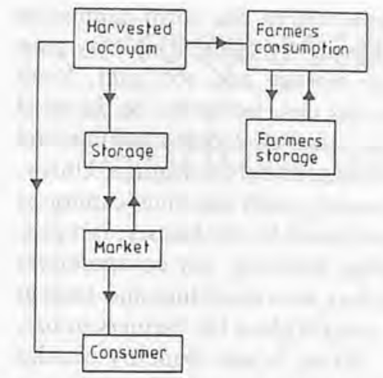

Fig. 5 Handling and transportation activities of corms.

depending on the distance and the available transportation facilities. This also involves loading and unloading. During such handling and transportation, the corms may sustain scuffing, bruises, cracks, abrasions or crushing because:

1) Some corms are loaded on top of others. In such a case, corms at the bottom undergo pressure from those on top. If the pressure exceeds the yield stress of the corms, then some crushing or abrasion may occur.
2) Corms rub against each other during transportation. The friction force between the corms then cause some bruises and scuffing.
3) Corms may experience impact, static or fluctuating loading or a combination of these during loading and unloading resulting in abrasions or cracks.
4) If corms are not in bags or are loosely packed in bags, some may roll during transportation. The rolling resistance causes bruises and scuffing. Corms which roll into each other or against the sides of the truck, cart or train wagon, may sustain abrasion, cracks or crushing due to the impact.

Surface scuffing and bruises result in partial skinning of corms allowing diseases to spread more easily and reduce the attractive appearance and hence the economic value of the corms. Such damage

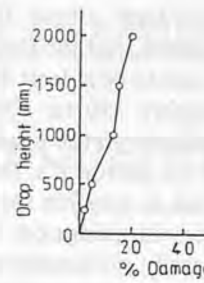

Fig. 6 Drop height against percent damage.

may be reduced by careful loading and unloading and by packing the corms with paddings of straw between them. Loose packing and direct packing into trucks, carts and wagons without using bags should be avoided.

A study conducted on preference of damaged and undamaged cocoyams in Kumasi (Ghana), a large cocoyam consumption city, and in five towns near Kumasi in cocoyam producing areas, indicated that 92% of the consumers prefer undamaged cocoyam. The 8% who accepted the damaged corms admitted that they did so due to the lower cost of the damaged corms.

With regard to storage, damaged corms can be stored for shorter periods than undamaged ones. Such damage exposes the cocoyam cells to the atmosphere accelerating it to rot. Mechanical damage is, in fact, the major reason why corms fail to meet consumer and storage standards.

An impact study has been made as a guide to cocoyam transporters and loaders. Freshly harvested corms were cropped from various heights onto a hard surface. The percent damage and probability of severe damage on the corms were assessed visually. The results are shown in **Figs. 6** and **7** which indicate that the percentage of the corms damaged by dropping does not change very much with drop height but the probability of severe damage increases significantly with the

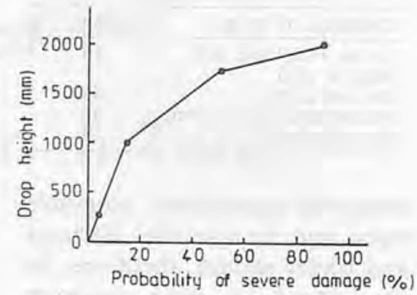

Fig. 7 Drop height against the probability of severe damage.

drop height. According to Bishop (1990), the results should vary with temperature for potatoes. Hence, this is likely to be the case for cocoyam. In the tropics, however, temperature variations are small and hence insignificant. Therefore, in loading and unloading the corms, drop height must be as low as possible.

Cleaning of Corms

Cleaning of harvested corms before selling is not practised by farmers and cocoyam traders. Some harvested corms were, however, cleaned and presented to some randomly selected consumers in Kumasi. The following two types of cleaning were done:

1) removal of loose soil and clod by brushing corms with a hand brush; and
2) brushing soil and clod off corms and washing them with water.

Misener and McLeod (1989) have cited potato cleaning methods in Canada and Europe while Sides and Smith (1970) have also cited several other methods available in the U.S.A. and Canada. Some of these methods may be adapted for cocoyam corms but the tropical farmer cannot afford the cost of such equipment. The consumer acceptance of the different types of cleaned corms is shown in **Table 1** which indicates that there is a definitte preference for soil-free corms. Soil-free corms have

Table 1 Consumer Acceptance of Clean and Unclean Corms

Condition of corm	Acceptance (%)
Corms with loose soil and/or clod	10
Brushed corms	45
Brushed and washed corms	40
No preference	5

improved appearance, economic value and storage life. Farmers and trader should, therefore, be encouraged to clean cocoyam corms for storage and sale in order to maximize sale proceeds.

Grading of Corms

Cocoyam grading involves sorting into two or more grades depending on one or more of these parameters: type, size, physical damage and infestation. The two main types of cocoyam varieties in Ghana, namely; the pink and white, were considered in this study. Investigations on the preference of these varieties in Kumasi showed that both varieties are equally liked by consumers.

Cocoyam grading is done by farmers and farm produce sellers. Usually about 15% of the corms that a farmer or trader will consider as good will be rejected by the consumer. Hence, farmers and traders should be aware of the consumers' or market quality requirements. Consumers generally do not like small, damaged or infested corms. Sometimes farmers or sellers pass a few of these corms as good quality to incrase their profit at the expense of the consumer. This is especially the case when the crop is out of season during the dry season. This problem can be eliminated if the corms are well sorted, graded and stored for the lean season.

The use of natural light for grading in the tropics is best because the quality of natural light stays fairly constant unlike in the temperate zone where the quality of natural light constantly changes. Besides, natural light is the cheapest light source. Bishop (1990) suggests that the illumination level should be at least 500 lux and preferably 750 to 1000 lux with no shadow on the inspection table and as uniform a level of illumination as possible for potatoes. This illumination level, which is easily obtainable in the tropics, is recommendable for cocoyam grading too.

When too many corms are inspected per hour, the farmer or trader gets tired. Consequently, some corms which should not pass for storage get passed for storage and rot later. As a guide, about 0.7 to 1.0 tonne of corms can be graded per hour to yield satisfactory results.

Sophisticated grading techniques are available for potatoes and some of these can be adapted for cocoyam. One of these is the method of pinpointing impact damage by using the SCAE electronic potato which records the impact "history" over a grading line (Bishop 1990). Sorting potatoes into different sizes using manual and power-operated oscillating sieves are practised in India (Shyam, Singh and Singh 1990). Sophisticated electronic vision equipments which have the advantage of being accurate and capable of both size and quality grading may also be used on cocoyam. The problem is that most tropical farmers cannot afford the cost of such sophisticated machines. As a result, occular grading techniques are used.

During grading, corms with serious cracks, bruises and abrasions and broken corms are selected for immediate sale at a slightly lower price for immediate consumption since such corms cannot be preserved for long. Corms infested on the surface are easy to detect by visual inspection and are selected for immediate sale or complete rejection depending on the degree of infestation. Infestations within the corm cannot be detected by eye and so may pass for storage and rot later. Such corms can, however, be detected by optical-electronic machines and eliminated before storage. Unfortunately, such machines cannot be purchased by the farmer. It is possible, however, for co-operatives to buy such machines and keep at a central place for farmers to use.

Sizing is also done by occular inspection. In order to execute a good size grading, corms must be free of soil and clod as these add to their size and make a small tuber appear large. It is, therefore, better to clean such corms before size grading. Corms are usually graded into three sizes: large, medium and small. Here again, machines used for potato sizing may be adapted for cocoyam. Farmers may not be able to afford the cost but co-operatives may be able to purchase such machines for farmers to hire and use.

Conclusion

Cocoyam plays a very important role in the meals of a greater part of the population in West Africa and other tropical countries. Like most other crops, it is susceptible to infestation during cultivation and physical damage during harvest, handling and transportation. Both infestation and physical damage can, however, be minimized to increase both storage life and consumer acceptability. Cleaning corms also increases both storage life and consumer acceptability.

The corms may be graded according to type or size taking into consideration infestation and damage, for sale and storage. More care is needed in grading and natural light is recommended for efficient grading.

(Continued on page 50)

Prospects and Problems of Agricultural Mechanization in Tonga

by
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Abstract

The Kingdom of Tonga in the South Pacific Region has a population density of about 15 persons/km^2 which almost approaches the density in many developed countries. However, the country is under the category of one of the under-developed countries of the world.

In comparison to many under-developed countries, it has abudant agricultural and fishery resources. Even though the soil, water and socio-economic conditions are not very much favourable for the development of agriculture, still the country has been producing a variety of vegetables, food crops, fruits and fruit trees.

Agricultural and agro-based products consistently account for around 90% of the total export earnings of Tonga. Traditional methods of farming characterize much of the agricultural production efforts even as the Government, as early as 1980, started to promote partial farm mechanization. At the present time, the promotion of more and more agricultural mechanization continues to gain momentum.

Introduction

The Kingdom of Tonga comprises of five groups of islands in the Pacific Ocean. These groups of islands are located in the Southwest of Western Samoa, Southeast of Fiji Islands and Northeast of New Zealand.

The five main groups of islands, namely; Tongatapu, Vava'u, Ha'apai, 'Eua and Niua lie approximately between the longitudes of 173°40′ and 177°15′ and the latitudes of 15°23′ and 23°30′ (CPD, 1981).

The total area of the Kingdom covers approximately 360 000 km^2 of which the total land area is about 6 700 km^2 which is made up of 171 islands. Of these 171 islands, only 36 are inhabited. The total population was 94 535 in 1986 which constitutes an average density of population of about 15 persons/km^2 (Statistics Department, 1987) and approximately 1.66 acre or 0.66 hectares of land per person.

Climatic Conditions

Due to topography, scattered geographic location and North-South littoral extension, the climatic conditions of the kingdom, are somewhat variable for each group of islands.

The Vava'u group of islands having a maximum altitude of about 210 m above sea level, has the highest annual rainfall of 2 773 mm compared with the average annual mean rainfall of the kingdom of about 2 216 mm.

The period from October to May in most of the territory gets the most precipitation. The drought period starts from June through September. This means that for one-third part of the year, there exists a scarcity of water for agricultural production.

No pertinent data regarding the temperature, is found for the Kingdom except at the Vaini Research Station which is situated in Tongatapu.

The maximum temperature of 31.5°C was recorded in February, 1989 and the minimum temperature of 9.7°C was in August of the same year. The maximum temperature varies between 28-31°C and the minimum temperature between 9.7-18°C.

The maximum evaporation happens during the month of December while the duration of sunshine is maximum at 8.4h a day. On the other hand, during the month of June the amount of evaporation in June was 3.1 mm with a duration of 6.8 h of sunshine a day.

These indicates that even when the kingdom lies geographically within the tropics certain aspects of climate tend to keep it in subtropical conditions (Lamipeti, 1990).

Soil Conditions

The soils in Tonga have not yet been classified according to the Department of Agriculture of the U.S.A. However, much of the soils were predominantly derived from andesitic volcanic ash deposited on coralline limestone and the rest was derived from coral rock which are usually found close to the sea.

Values of pH are neutral or slightly alkaline with high levels of calcium and magnesium. Phosphorus levels tend to be low and the rates of phosphate retention are moderate or sometimes high (Potter, 1986). The levels of organic matter and available nitrogen may also be limited.

The mean soil temperatures were 23.53°C, 24.92°C, 24.95°C and 25.24°C at depths of 10 cm, 20 cm, 30 cm and 100 cm, respectively (Vaini, 1989). The water retention capacity is low due to high porosity of the soil structure.

Even though there exists a few unfavourable conditions, the soils are rather productive and are suited to a wide variety of fruits, coconuts, and many other crops.

Vegetation

The climate and soil conditions favour the continuous year-round production of varieties of root-crops, vegetables, fruit, tree-crops and grasses.

Among the root-crops, yam, different varieties of taro, sweet potato, potatoes and cassava are considered to be the most important ones.

A variety of vegetable crops is also grown and among them tomatoes, beans, cabbage, carrot, pumpkin, lettuce and vanilla are important. Peanuts, water-melon, pineapple are also important crops in the country, including bananas, papaya, coconut, breadfruit, mango, avocado and passion fruit.

The vegetation is rather scattered and not managed properly as to maximize land use and yields. However, all these features undoubtedly indicate that Tongan soils and climate have a great potential to provide sufficient food for consumption as well as for export.

Livestock

Poultry, pigs, goats, cattle and horses are domestically maintained in the country.

According to the census in 1980, the livestock population was as follows: chickens, 141 000; ducks, 5 000; pigs, 100 000; goats, 13 000; cattle, 2 000; horses, 1 650.

Cattle population is not significant and only 30% of whole milk consumption is produced in Tonga. This indicates that for self-sufficiency in milk, Tonga needs to have at least 6 700 head of cows.

Socio-economic Status

According to the census in 1976, only 23.8% of the total population within the range of ages of 15 and 65 years represented the total labour force (i.e., those employed and actively seek employment).

Of the total manpower (labour force) 51.2% was engaged in agriculture, forestry and fishing. The percentages of the level of education of the labour force in the primary industry (agriculture, forestry and fishery) was 99.3% of primary or secondary education and only 0.7% of tertiary level.

On the other hand, it was estimated that 70% of the total population depended primarily upon agriculture for their livelihood. At the end of 1979 approximately 87% of farm families were engaged in some form of farming activity and 58% of them were the heads of the family.

Analyzing the total labour force of 21 400, only 18 626 were employed which means 2 774 persons or almost 13% of total labour force was unemployed.

The importance of the agriculture sector is very striking when exports are considered. Agricultural and agro-based products consistently accounted for around 90% of total export earnings of which copra, desiccated coconut and coconut oil comprised over 70%.

Land Tenure

Most of the farmlands are divided into small-holdings typically of 8.25 acres and allocated to individual male of age 16 and over. One limitation of this system is its lack of flexibility. As a result, many farmers find this farm size insufficient for expanding farm activities (Lamipeti, 1990). This also limits the level of mechanization in Tonga.

Status of Mechanization in Agriculture

The male population between 16 and 65 years of age (which was 21 151), some 80% of them live in rural areas. The total farming area comprises of 139 603 acres. This means that about 83.5% of the whole area is under farming. A large portion of the land is suitable for cultivation.

Mirdha, 1986, calculated that one person working with animal-drawn implement and hand tools can cultivate only 1.0 ha per year. On the other hand, using the tractor and implement one person can

Table 1 Distribution of Traditional Tools and Cart

Name of island	No. of farmers	Type of traditional tools and carts					
		Bush knife	Fork	Spade	Hoe	Axe	Cart
Tongatapu	5 937	9 287	4 396	7 617	11 285	4 221	946
Vava'u	1 896	2 915	1 340	2 040	2 741	1 524	39
Ha'apai	1 225	1 688	733	1 243	1 806	915	163
'Eua	692	1 005	552	761	1 044	543	31
Niua's	371	658	131	366	500	294	28
Total (K.T)	10 121	15 553	7 152	12 027	17 376	7 497	1 207

Table 2 Some Elements of Mechanization

Name of island	No. of farms	Number of some elements of mechanization				
		Tractors	Sprayers	Copra dryer	Vanilla dryer	Vehicles
Tongatapu	5 937	77	534	300	11	1 279
Vava'u	1 896	16	35	348	18	181
Ha'apai	1 225	5	9	154	1	20
'Eua	692	13	26	55	0	37
Niua's	371	4	0	107	0	35
Total	10 121	115	604	964	30	1 552

cultivate in average 18 ha or 45 acres with one tractor of 85 Hp capacity.

According to the 1985 census, the total population over the age of 15 was 31 980 which maybe considered as total man-power and out of which only 20 000 are employed. This means about 12 000 people are available for agriculture (who are unemployed at present).

If this population is engaged in agriculture, using animal drawn implement, it is possible to cultivate only 30 000 acres or 12 000 ha or about 21.5% of the total farm areas. Each farmer with 8.25 acres will require in average of 7 horses or 7 cows or, a combination of 2 horses, 4 cows and one ox to carry out farming activities.

Now-a-days hardly any farmer uses animal power. But there exists great need for animal power for cheaper farm work.

Traditionally, most farmers perform farm activities with the use bush-knife, fork, spade, hoe and axe. For transportation of their products, they use cart (Langi, 1990). **Table 1** shows the distribution of traditional tools. (Statistics Department, 1987). Due to lack of appropriate technology in the production system, crop yields are low and most crops are late maturing. Moreover, during rainy days, a high percentage of harvested crops is damaged due to lack of proper processing and storage facilities.

The Government of Tonga, during the Third Five-Year Development Period (1980-1985) acquired 38 tractors and a wide range of implements. Some of the implements were found unsuitable. But still the application of power-drawn techniques started in the Tongan agriculture sector. **Table 2** indicates a few elements of mechanization (Langi, 1991).

The Machinery, Equipment and Vehicle Pool of the Ministry of Agriculture has acquired some implements like disc plough, disc harrow, or ridges slasher, digger, cultivators, liners, and rotary hoes.

Many farmers have shown interest in using tractors and implements because of the ease with which farming operations are done at short periods of time.

The acquisition of tractors and necessary implements is very costly and beyond the farmers' purchasing capacity. In addition, most farmers are not technically trained in the operation, care, maintenance and repair of highly technical, powerful and costly tractors, other machines and equipment.

With all these negative factors the Government of Tonga has taken a very daring measure to encourage farmers to use agricultural machinery so as to develop agriculture sector, through the application of new technology of production systems.

Although in the Fourth Five-Year Development Plan (1985-1990) the government gave more emphasis in acquiring more tractors and implements, still the number of tractors was not sufficient to meet the demand.

Tonga has now only 115 tractors of different sizes/power. This implies that it will take many years before a high level of agricultural mechanization can be attained. Tonga needs to train farmers in operating, care and maintenance, and repairing of those costly machines and equipments.

Irrigation and Yield

The climate in Tonga is favourable in most parts of the year except the drought period in June through September. During the rainy season, the run off water is not availed of due to poor drainage systems and lack of catchment areas.

Excess stagnant water damages some of the standing crops and when released, it mixes with the seawater. A great loss of fresh water is caused during the rainy season.

On the other hand, during the drought period the crops and even people suffer from the lack of fresh water. As a consequence, the crops are damaged and the yield is poor.

A high level of mechanization is profitable only when the necessary irrigation water supply is available. In order to attain that condition, profitable farming needs proper planning, construction of irrigation and drainage systems, reservoir and their management.

No irrigation and drainage system exist in Tonga. The underground water contains unsoluble salt which is not recommended in irrigating crops.

Conclusion

1. Tonga needs a good number of trained, skilled and professional personnel in agriculture, livestock, agricultural economics, agricultural engineering, fisheries and forestry so as to perform the task of planning, programming, management, administration and research.
2. A large number of technical personnel such as drivers, mechanics, extensionists, and service personnel are needed to be trained in appropriate organizations.
3. A comprehensive survey of agricultural productivity needs to be undertaken for use as benchmark in planning.
4. Demonstration farms in the use of tractors and implements, care of livestock and poultry and nursery for new crop varieties need to be established by the Government.
5. Demonstration farms or experiment stations on the desireability of proper use of farm animals as source of power should likewise be established by the government. This should include the use of mould-board plough.
6. On swamp or lower areas, water reservoirs should be constructed so as to keep fresh water for drinking as well as for irrigation purposes.
7. Appropriate storage facilities for keeping agricultural and livestock products should also be initiated by the Government.

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Infestation, Damage and Grading of Cocoyam

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Effect of Mechanical Shaking of Groundnut on Combining Losses in Heavy Clay Soils of the Sudan

by
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Abstract

Because of the nature of the heavy clay soil particles which make them adhere to groundnut pods, various problems are encountered during groundnut harvesting. An experiment was conducted for two seasons (1987/88-1988/89) to evaluate the effect of extra shaking of groundnut on combining losses. Treatments included zero, one, two, and three extra shakings.

Results showed that extra shaking reduced the combining losses by decreasing pre-combine and header losses. It is recommended that at least one extra shaking be performed.

Introduction

The total groundnut (*Arachis hypogae* L.) area cultivated in the Sudan is about 1.1 million ha. About 15% of the area is cultivated in the irrigated clay soils accounting for about 40% of the total production; this has a stabilizing effect on production not found in other groundnut producing areas of the world (Ishag and Said, 1985). Ishag (1982) reported that up to the 1960s there was an erroneous belief that the heavy clay soils of the Gezira were not suited for groundnut production. Detailed and intensive research showed that the potential pod yield of groundnut in irrigated Gezira is about 6.7 tones per ha.

At present, groundnut production is mechanized at varying levels in the agricultural projects at Rahad (27 000 ha), Gezira (90 000 ha), New Halfa (17 000 ha), and Suki (5 000 ha). The Rahad project has the highest percentage of mechanization with about 42% of the cultivated area being mechanically dug out and 62% of the total area being mechanically threshed (Ibrahim et al., 1986).

In heavy clay soils, various harvesting problems are encountered because of the nature of clay particles that adhere to groundnut pods. As high as 60% pod losses in the digging operation has been reported (Dafalla, 1982 and Dawelbeit, 1989). Slow direct combining operations causing low field capacities, low field efficiencies as well as high field losses are also a problem.

In groundnut producing areas in the United States some farmers practice the operation of lifting the groundnut plant which is performed after digging and before combining the crop. It involves passing a groundnut lifter, made of shakers without digger blades which fluffs the already built windrows. This operation is believed to have the following advantages for both wet and dry harvest seasons: removes excess soil from the vines, speeds up the upcoming combining operation, and helps vines at the bottom of windrows to dry faster. It also allows combining earlier in the morning and results in less foreign materials in the harvested crop.

In the Sudan, the commonly used digger-shaker-windrowers were designed for fairly light soils and the shaking done was enough to remove soil particles from the plants in these types of clay soils but not in heavy soils. However, it was thought that more shaking is needed for the dug out plants in heavy clay soils commonly found in the Sudan.

The objective of this research was to investigate the effect of extra shaking using the digger-shaker-windrower on threshing losses of the groundnut combine. The parameter used to compare these treatments is crop losses. This will indicate to the farmer how much money he is saving by utilizing the improved harvesting method.

Stokes and Reed (1950) reported that the purpose of peanut shaking equipment is to lift the peanuts out of the ground, shake off the soil, and place them in the desired type of windrow; windrows for curing and combining should be free from soil, loose, and of uniform size. This facilitates air circulation and enables controlling the rate at which the material is fed into the combine.

Materials and Methods

The experiment was conducted at Elfau-Rahad Research Station for two consecutive seasons (1987/88 and 1988/89). The soils are vertisolic with high clay content (50-60%), low organic matter (0.03%), and alkaline pH value of (8.78-9.4) (Fahal, 1984). The design of the experiment was randomized complete blocks with four replications. Treatments included: i) no extra shaking, as control; ii) one extra shaking; iii) two extra shakings; iv) three extra shakings.

The plot size was 30 × 1.6 m. All recommended cultural practices were conducted, including: ridge planting (80 cm wide), seed rate (90 kg/ha, sowing date (June), green ridging, and watering (10 waterings at fortnight intervals). The plots were kept weed-free. The groundnut seed variety MH383 was used. At optimum harvresting date (about 150 days from emergence) the plots were dug out. Shaking treatments were done immediately after digging at a soil moisture content of about 17% (D.B.).

The machines used in the experiment included a tractor-mounted Lilliston digger-shaker-windrower (model 850) and a Lilliston groundnut combine (model 1580).

Calculations were done according to the following parameters:

i) Total yield: the sum of digging losses, pre-combine losses, header losses, tail losses, and basket yield;

ii) Digging losses: pods left in the soil after digging operation.

iii) Pre-combine losses: pods that are on the ground before the combine header picks up the plants.
Percent pre-combine loss = (pre-combine loss)/(total yield) × 100

iv) Header losses: pods which are left on the surface of the ground after the combine header passes.
Percent header losses = (header losses)/(total yield) × 100

v) Tail losses: pods lost with the hay thrown at the back of the combine.
Percent tail losses = (tail losses)/(total yield) × 100

vi) Total threshing losses: sum of the pre-combine losses, header losses, and tail losses.
Percent total threshing losses = (total threshing losses)/(total yield) × 100

Results and Discussion

Data collected in this experiment was processed and the analysis of variance (using SAS 1985) was performed. The analysis of variance showed that none of the four treatments (one, two, three, and no extra shaking) has a statistically significant effect on pre-combine, header, and tail losses for the two seasons. However, trends of the losses are discussed as follows:

Pre-combine Losses

These are caused by natural and weather conditions. Because of the high temperatures the plants quickly dry up and the pods become crispy and vulnerable to shattering. Results of the first season (1987/88) showed that the pre-combine losses decreased with three shakings **(Fig. 1)**. Losses were almost identical in quantity for no shaking, for one, and for two extra shakings. However, in the second season the pre-combine losses decreased with extra shakings from zero to one and from one to two but increased with the third extra shaking. The decrease in the pre-combine losses in the second season could be due to the fact that extra shakings are helping the soil clods dislodge from the plants. The increase in the pre-combine losses in the third shaking may be due to the damage by shattering caused by excessive

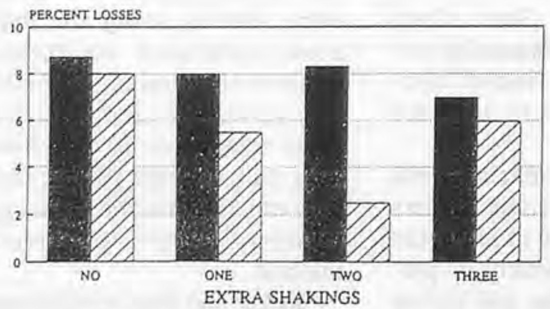

Fig. 1 Effect of shaking on groundnut pre-combine losses.

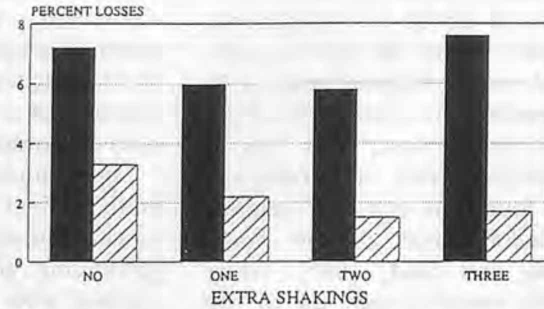

Fig. 2 Effect of shaking on groundnut header losses.

Fig. 3 Effect of shaking on groundnut tail losses.

Table 1 Effect of Shaking on Total Threshing Losses and Yield for Two Seasons

Treatment (extra shaking)	Percent Total Threshing Losses		Total Yield (kg/ha)	
	1987/88	1988/89	1987/88	1988/89
1. None	20.4	12.5	2 441	3 696
2. One	17.2	9.0	2 654	3 064
3. Two	22.0	5.8	3 094	3 284
4. Three	18.7	10.0	3 574	2 692
Mean	19.6	9.3	2 941	3 184

shaking.

Header Losses

Header losses are pods which have been missed or dropped by the header while picking the plants. In the first season, header losses were kept in a narrow range **(Fig. 2)**. There was a decreasing trend with one and two extra shakings while a third extra shaking caused an increase in the header losses. In the second season (1988/89) header losses decreased with the increase of extra shakings. The decreasing trend in header losses could be due to the fact that the pick up fingers were picking plants smoothly with less soil clods. The increase with the three shakings in the first season may be due to damage caused by shattering the plants.

Tail Losses

Tail losses are mainly cleaning and processing losses. They include pods which were not detached from the plants as well as those removed by the cleaning screen. Tail losses in the first season fluctuated between 3.3% and 5.1% **(Fig. 3)**. In the second season there was an increasing trend in tail losses with an increase of frequency of shaking. This could be due to the fact that the cleaning fan was set for the control (no extra shaking) condition. However, correction can be done by re-adjusting the air flow and/or the cleaning screens.

Total Losses

The total threshing losses for the two seasons are shown in **Table 1**. These ranged from 18.7% to 20.0% in the first season (1987/88) and from 5.8% to 12.5% in the second season. Minimum losses were observed at one extra shaking in the first season (17.2%) and with two extra shakings (5.8%) in the second season. From these results it could be seen that at least one extra shaking could benefit the farmer, i.e., reducing his losses by about 3% relative to no extra shaking for the two seasons under investigation. However, an economic analysis should be performed to actually evaluate the economic returns of this operation.

It is also observed from **Table 1** that the percentage total threshing losses for the first season were twice those of the second. This could be due to the variation in season or weather conditions.

Total yield (kg/ha) is also shown in **Table 1**. There were no significant differences in the total yield for the different treatments.

Conclusions

1. Extra shaking of dug out groundnut reduces pre-combine losses and header losses and increases tail losses in groundnut cultivated in heavy clay soils.

2. One extra shaking is recommended. This could reduce total combining losses by at least 3%.

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Planning Farmshops for Developing Agriculture

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Abstract

The establishment of farmshops in developing countries can promote realistic farm mechanization and general development of rural communities. This paper identifies shortage of capital for investment in production and service machinery as the most serious constraint limiting the development of such farmshops. A simple procedural approach is developed in the paper for establishing commercially viable farmshops through progressive investment in machinery.

Introduction

An effective way of promoting farm mechanization and rural development is through the establishment of farmshops by individuals or cooperatives. These farmshops can serve the following functions:

(a) The manufacture of simple farm implements such as cutlasses, hoes, shovels, etc. with progressive graduation to the manufacture of simple farm equipment and machines;
(b) The repair and maintenance of farm machinery and equipment such as tractors, tillers, threshers, harvesters, sprayers, dusters, etc.;
(c) A hiring or leasing centre for tractors and other agricultural equipment and implements, including transport facilities;
(d) A distribution centre for farm inputs;
(e) A trading outlet for farm products;
(f) An information centre for the dissemination of technological information which will be of benefit to agriculture and rural development.

A village or farm workshop can, therefore, be a very important catalyst for the promotion of farm mechanization not only through the provision of needed tools and technical services but as a visible agent for technical change among farmers.

A survey carried out in Ondo State of Nigeria by the author reveals the following reasons for the very low level of establishment of farmshops:

(a) Shortage of technically skilled entrepreneurs for establishing such farmshops;
(b) Lack of supporting infrastructural facilities such as electricity, motorable roads and water supply; and
(c) Shortage of lack of capital for investment in machinery and working capital.

Of the above reasons, the most important factor militating against the establishment of rural farmshops is the lack/shortage of capital for investment in production or service machinery. Many prospective shop owners have been frustrated due to their inability to secure enough capital for buying needed production and service farmshop machines. The present practice is for prospective farmshop operators to plan for all the machines they require over the planning horizon and seek finance through commercial banks or government loan organizations. Commercial banks are at best only willing to provide money for working capital. Most applications for loans for procuring machinery end up in failure.

The selection of workshop equipment must balance a desire for completeness with economic viability. Over investment creates an unnecessary debt burden while a lack of tools inhibits completion of vital work (Pothecary and Skarp, 1988).

It is, therefore, necessary to formulate an approach whereby farmshops can be developed gradually from initially low investment in machinery while taking into cognisance the functionality of such farmshops.

This paper describes a simple but effective procedure for gradual development of such farmshops. The procedure lends itself to easy implementation which can facilitate ready application for a developing agriculture.

A Systems Model for Progressive Planning of Farmshops

The following procedural steps are required for gradual establishment of farmshops from initially low capital base.

STEP 1: Choose a location for the farmshop.

STEP 2: Conduct market survey to determine possible farmshop activities within the location.

STEP 3: Conduct prefeasibility studies on the planned activities covering market analysis, technical and financial feasibility. If location is not promising, reject and go back to Step 1.

STEP 4: For each farmshop activity, determine the technical requirements in terms of:
- (i) the technical departments required;
- (ii) the type and cost of machinery and tools functionally needed in each of the technical departments;
- (iii) the requirement of each technical department in terms of space.

STEP 5: Layout the entire farmshop based on the planned activities over a long run.

STEP 6: Design the farmshop building in a modular form for gradual expansion through addition of new departments.

STEP 7: Establish the initial level of capital available for investment.

STEP 8: Sequence the activities for implementation on a periodic basis using the sequencing rule discussed in Section 3 until all activities are fully implemented.

Development of the Activity Sequencing Rule

The Investment Criterion

A farmshop activity may be considered most profitable for scheduling over a planning period if it can generate the highest periodic net returns per investment outlay in technical departments.

$$\text{i.e., Max } R_m(t)/I_m(t) \text{ or Min } I_m(t)/R_m(t) \quad \ldots\ldots\ (1)$$

where $I_m(t)$ is the capital investment over the planning period t and $R_m(t)$ is the corresponding net returns.

In order for capital to be available for any selected activity m at time t,

$$C(t) - I_m(t) \geqslant 0 \quad \ldots\ldots\ (2)$$

where C(t) is the available capital at time t.

The value of C(t) at any time this given as

$$C(t) = C(t-1) - I_m(t-1) + \Sigma 4R_m(t-1) \quad \ldots\ldots\ (3)$$

where $I_m(t-1)$ is the investment outlay for the selected activity at time $(t-1)$ and $\Sigma R_m(t-1)$ is the sum of periodic net returns on all ongoing activities (i.e., previously selected) from month $t-1$ and below.

This formulation is a classical dynamic programming model which can be solved by the usual standard methods (Wagner, 1982). A good rule for sequencing the implementation of the farmshop activities is derived by scheduling the activity with the lowest value of D_m where $D_m = I_m(t)/R_m(t)$ subject to Equation 2. In case of a tie in the value of D_m, an activity with the lowest value of I_m is ranked first. An illustrative example is given in next section.

Illustrative Example

Table 1 lists the relationship between identified shop activities and the required technical departments. **Table 2** gives the cost of setting up a functional technical

Table 1 Activity — Technical Department Matrix

Activity Code	Activity Description	Required Technical Departments									
		I	II	III	IV	V	VI	VII	VIII	IX	X
A	Fabrication of simple farm tools	*	*			*		*	*		
B	Routine servicing of farm engines and equipment	*								*	
C	Repair and maintenance of farm engines equipment and structures with bought parts	*	*			*		*	*	*	
D	Fabrication and machining of spare parts for repair and maintenance work	*	*	*	*	*	*	*	*	*	
E	Design and manufacture of powered farm equipment and machines	*	*	*	*	*	*	*	*		*

* Key to Required Technical Departments
I Bench Fitting
II Machining (Drilling)
III Machining (Turning)
IV Machining (Milling)
V Machining (Grinding)
VI Machining (Shaping)
VII Sheet Metal Fabrication
VIII Welding and Soldering
IX Maintenance and Servicing
X Design Room

Table 2 Cost of Setting Up the Technical Departments

Department Code	Department Description	Investment Cost ($)
I	Bench fitting	2 000
II	Machining (Drilling)	2 000
III	Machining (Turning)	40 000
IV	Machining (Milling)	40 000
V	Machining (Grinding)	2 000
VI	Machining (Shaping)	24 000
VII	Sheet Metal Fabrication	4 000
VIII	Welding and Soldering	4 000
IX	Maintenance and Servicing	4 000
X	Design Room	2 000

Table 3 Expected Net Returns on Every Activity per Quarter

Activity Code	Expected Net Return Per Quarter ($)
A	2 400
B	960
C	3 200
D	12 800
E	16 000

Table 4 Solution of the Illustrative Example

Table 4(i): Quarter 1: C(1) = $8 000

Active Code	Required Departments	I_m	R_m	Financial* Feasibility	Dm**	Activity Selected (Yes or No)
A	I+II+V+VII+VIII	14 000	2 400	NF	—	No
B	I+IX	6 000	960	N	—	Yes
C	I+II+VII+VIII+IX	18 000	3 200	NF	—	No
D	I+II+III+IV+V+VI+VII+VIII+IX	122 000	12 800	NF	—	No
E	I+II+III+IV+V+VI+VII+VIII+X	120 000	16 000	NF	—	No

*F = Financially feasible (Eqn. 2). NF = Not Financially feasible.
**Dm is only calculated for financially feasible activities.

Table 4(ii): Quarter 2: C(2) = $2 960

Active Code	Required Departments	I_m	R_m	Financial* Feasibility	Dm**	Activity Selected (Yes or No)
A	II+V+VII+VIII	12 000	2 400	NF		No
C	II+V+VII+VIII	12 000	3 200	NF		No
D	II+III+IV+V+VI+VII+VIII	116 000	12 800	NF		No
E	II+III+IV+V+VI+VII+VIII+X	118 000	16 000	NF		No

Continued interation reveals that activities A, C, D, E remain infeasible until the 12th quarter.

Table 4(iii): Quarter 12: C(12) = $12 560 (Step 1)

Active Code	Required Departments	I_m	R_m	Financial* Feasibility	Dm**	Activity Selected (Yes or No)
A	II+V+VII+VIII	12 000	2 400	F	5	No
C	II+V+VII+VIII	12 000	3 200	F	3.75	Yes
D	II+III+IV+V+VI+VII+VIII	116 000	12 800	NF	—	No
E	II+III+IV+V+VI+VII+VIII+X	118 000	16 000	NF	—	No

Table 4(iv): Quarter 12: C(12) = $560 (Step 2)

Active Code	Required Departments	I_m	R_m	Financial* Feasibility	Dm**	Activity Selected (Yes or No)
A	—	0	2 400	F	0	Yes
D	II+IV+VI	104 000	12 800	NF	—	No
E	II+IV+VI+X	106 000	16 000	NF	—	No

Hence activities C and A are selected in the 12th Quarter.
Activities D and E continue to be infeasible until the 28th Quarter.

Table 4(v): Quarter 28 C(28) = ₦ 105 520 (Step 1)

Active Code	Required Departments	I_m	R_m	Financial* Feasibility	Dm**	Activity Selected (Yes or No)
D	III+IV+VI	104 000	12 800	N	16.4	Yes
E	III+IV+VI+X	106 000	16 000	NF	—	No

Table 4(vi): Quarter 28 C(28) = $1 520 (Step 2)

Active Code	Required Departments	I_m	R_m	Financial* Feasibility	Dm**	Activity Selected (Yes or No)
E	X	2 000	16 000	NF	—	No

Table 4(vii): Quarter 29 C(29) = $20 880

Active Code	Required Departments	I_m	R_m	Financial* Feasibility	Dm**	Activity Selected (Yes or No)
E	X	2 000	16 000	F	0.13	Yes

Table 5 Results of the Sequenced Plan

Quarter	Activity implemented	Technical Department Established
1	B	I — Bench fitting
		IX — Maintenance and Servicing
12	C	II — Machining (Drilling)
	A	V — Machining (Grinding)
		VII — Sheet metal fabrication
		VIII — Welding and Soldering
28	D	III — Machining (Turning)
		IV — Machining (Milling)
		VI — Machining (Shaping)
29	E	X — Design Room

department while **Table 3** gives the expected net return for each activity for a quarter (i.e., 3 months). For an initial investment capital of $8 000, the iterative solution steps are given in **Table 4(i)-4(ix)**. A summary of the results of the sequenced plan is given in **Table 5**.

Underlying Model Assumption

The model as described is deterministic in estimating the expected net returns on each activity. This assumption does not limit its application since the model is dynamic and different data for expected costs and revenues can be used during actual implementation.

Conclusions

The above model which lends itself well to both manual and computerized implementation can be used satisfactorily in developing countries for progressive planning of farmshops. Its use will reduce the present investment problem arising out of lack/shortage of investment.

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Performance Evaluation of A Medium-scale Cocoa Dehulling and Winnowing Machine

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Summary

A medium-scale cocoa dehulling and winnowing machine that was recently designed is described in this paper. There is also a report on the performance test of the machine. The machine is easy to operate. The only adjustment required on the machine is the roller clearance. The optimum roller clearance was determined. The machine was found to have high dehulling and winnowing efficiencies at the optimum roller clearance.

Introduction

Cacao is the plant that produces the crop called cocoa. The cacao seed is referred to as cocoa bean. The only cultivated specie of cacao is *Theobroma cacao* (Wood, 1980).

Cocoa is the raw material used for the production of many products. The different processes involved in the production of cocoa products are summarized in **Fig. 1**. After stones and dirts have been removed from the cocoa beans, they are dried to a moisture content of about 3.0%. The cocoa beans are then dehulled to expose the cocoa nibs out of the shells. The nibs are separated from the shells during the winnowing operation.

The cocoa nibs, which are the primary raw material for cocoa bean products, are ground while steaming to obtain cocoa liquor. The liquor is pressed to release cocoa brown oil, leaving behind cocoa cake. The brown oil is filtered to obtain cocoa yellow oil. The yellow oil is conveyed into a cold room where it is tempered to produce cocoa butter. The butter is then moulded into cocoa chocolate. The cocoa cake earlier obtained is milled to produce

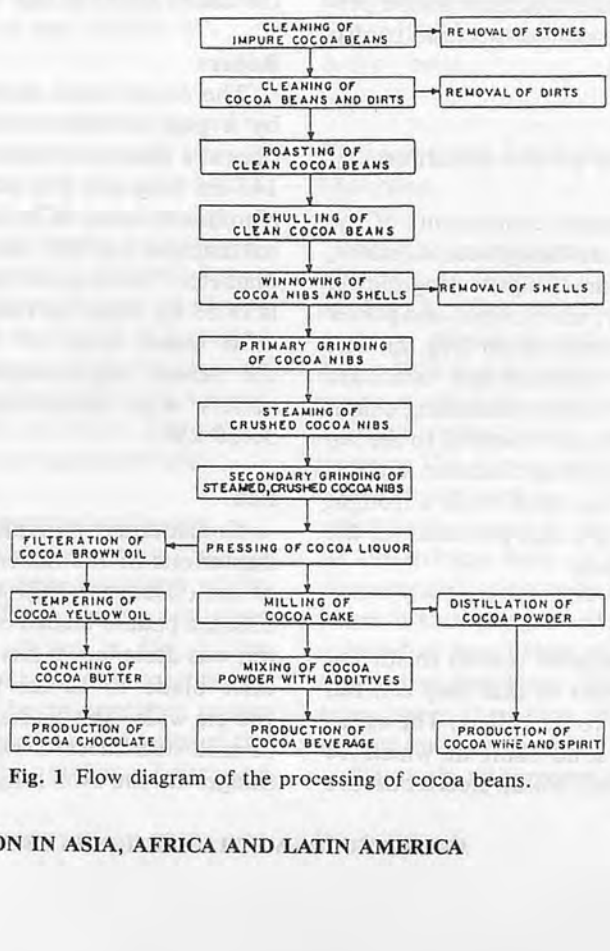

Fig. 1 Flow diagram of the processing of cocoa beans.

Acknowledgement: I am grateful to the Federal University of Technology, Akure for the use of its machine shop. I acknowledge the support of a professional colleague, Engr. A. Ajibade, who supplied materials for the fabrication of the machine. I also thank Mr. A. Adesina and Mr. R. Akinwale for their assistance during the performance test of the machine.

cocoa powder. Cocoa wine and spirit are manufactured from cocoa powder by distillation. alkalised cocoa powder is obtained by adding a basic chemical such as sodium carbonate. The cocoa powder is also converted to cocoa beverage by mixing with additive such as sugar and milk.

The major operations involved in the production of cocoa nibs are performed by the cocoa dehulling and winnowing machine developed. It is a medium-scale machine for dehulling and winnowing cocoa beans from a large cocoa plantation or from small cocoa farms within the same locality. The machine was designed for ease of operation so that the local farmer himself can operate it. The only adjustment to be made on the machine is the clearance between the pair of rollers. The determination of the optimum roller clearance that produces the most effective dehulling of the only cultivated specie of cacao is reported in this paper. The effect of varying the roller clearance on the performance of the machine is also discussed.

Features of the Machine

The major components of the machine are the agitator, aperture, rollers, fan, reciprocating plates, nib auger, nib elevator and power transmission system (**Fig. 2**). The agitator, aperture and rollers are installed inside a dehulling chamber. A hopper is welded to the top of the dehulling chamber. The nib auger is enclosed inside a trough. A housing is also provided for the nib elevator.

Agitator

The agitator rotates to stir the cocoa beans so that they can fall freely on to the rollers. The agitator is a solid shaft at which 14 cylindrical, solid, steel rods are welded. The 20 mm-diameter rods are 100 mm long and they are equally spaced round and along the shaft. The power required to drive the agitator was calculated to be 0.227 kW.

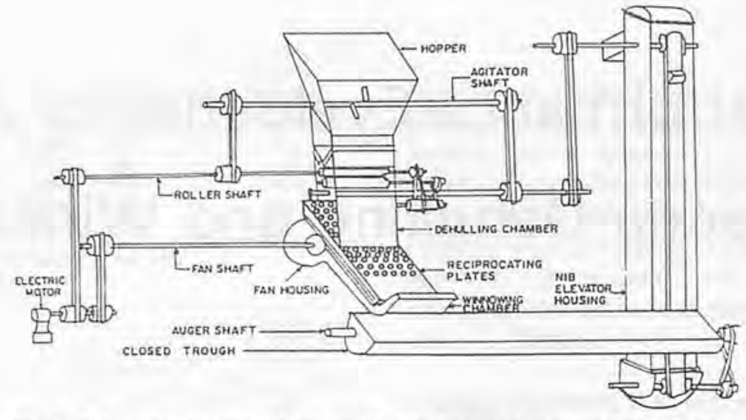

Fig. 2 Schematic diagram of the cocoa dehulling and winnowing machine.

Aperture

The aperture serves to direct the cocoa beans into the clearance between the rollers. The aperture consists of two rectangular plates which are hinged at the top to the dehulling chamber. The plates are equally inclined with an opening between them at the bottom for the cocoa beans to fall through.

Rollers

The cocoa beans are dehulled by a pair of rollers rotating in opposite direction. Each roller is 140 cm long and it is made from a hollow cylinder of 88 mm internal diameter and 100 mm external diameter. The mass of each roller is 19.83 kg. Since the rollers rotate at a mean speed of 700 rpm, the power requirement of the rollers was calculated to be 3,420 kW.

Fan

Considering the merits and limitations of the different types of fan (Osborne, 1979 and Balls, 1986), a paddle-bladed centrifugal fan was designed. It has 6 blades, each blade is 10 cm long and 140 cm wide. The blades are made of mild steel sheet, SWG 14. The flanges at the two long sides of each blade serve to keep the blade rigid. The three hangers, which join each blade to the rotating shaft, are made of flat iron bars. The fan housing has an involute shape and it is made of galvanised sheet, SWG 16.

The outlet of the fan housing was welded to the bottom of the winnowing chamber. The dehulled bean inlet is mid-way between the bottom and top of the winnowing chamber. There is a nib outlet near the bottom of the chamber for the discharge of the nibs into the nib trough while the shell outlet at the top of the chamber is for the release of the shells out of the chamber.

From pre-design experiments, the air velocity was determined such that it is less than the terminal velocity of cocoa nibs but higher than the terminal velocity of cocoa shells in order to achieve effective separation of the nibs from the shells (Leung and Wiles, 1976). The air velocity of 6.1 m sec^{-1} was measured at the top of the fan housing with a windmeter and the fan pressure of 600N m^{-2} was measured with a manometer. The power required to drive the fan was calculated to be 1.098 kW.

Receiprocating Plates

The reciprocating plates consist of three rectangular plates, 75 cm long and 140 cm wide, and one rectangular deflector, 65 cm long and 140 cm wide. They are made of galvanised sheet, SWG 14. The bottom plate and the deflector are not perforated. The top plate is a sieve of 8 mm diameter holes while the middle plate is a sieve of 3 mm diameter holes. The plates are inclined forward at an angle of about 3°. The deflector, which is installed between the top and middle plates, is inclined backward at an angle of about 10°. The backward and forward spacings between the top and middle plates are 21 cm and 18 cm, respectively. The backward and forward spacings between the middle and bottom plates are 11 cm and 9 cm, respectively. The plates are reinforced at their edges and at the spacings between two plates by 5.08 cm × 5.08 cm angle iron. The front of the middle plate coincides with the dehulled bean inlet of the winnowing chamber.

A rotating crank produces the reciprocating motion of the plates. The cocoa nibs, shells and any undehulled beans are discharged on the top plates. As the plates reciprocate, the cocoa nibs, shells and undehulled beans continue to move forward. At the same time, the few undehulled beans from a top layer while the cocoa nibs and shells fall through the sieve to the deflector. Any undehulled beans are discharged at the front of the top plate into a slanting channel. The deflector conveys the nibs and shells to the back of the middle plate. As the nibs and shells move forward again, the tiny nibs fall through the sieve on to the bottom plate. The nibs and shells are discharged at the front of the middle plate into the dehulled bean inlet of the winnowing chamber. The nibs fall through the chamber and they are discharged through the nib outlet of the chamber into the nib trough. The shells are carried upward by air current through the chamber and they are discharged at the shell outlet of the chamber. The tiny nibs are discharged at the front of the bottom plate through a slanting channel into the nib trough.

From pre-design experiments, it was found that a linear movement of 3.0 cm of the reciprocating plates is required to achieve complete separation of undehulled beans, nibs and shells. Hence, the crank was designed to have a radius of 1.5 cm. Since the mass of the reciprocating plates with cocoa beans is 90.29 kg and the speed of the crank is 182 rpm, the power requirement of the reciprocating plates was calculated to be 0.141 kW.

Nib Auger

The nib auger is enclosed inside a trough. The function of the auger is to convey the cocoa nibs from the trough to the bottom of the nib elevator. The auger was designed to have the capacity of conveying 845.4 kg cocoa nibs obtained from 1000 kg of cocoa beans per hour. The diameter of the 1.65 m-long auger was calculated to be 8.53 cm and the power requirement was 0.015 kW.

Nib Elevator

The nib elevator is required to lift the cocoa nibs through a height of 200 cm. The elevator belt is 10 cm wide. The cross section of each elevator bucket is a quadrant and its volume is 160 cm^3. It was calculated that 20 buckets should be rivetted to the belt at a spacing of 16.07 cm so that the elevator might be able to lift 845.4 kg of cocoa nibs per hour. The power requirement was 0.005 kW.

Power Transmission System

A 7 kW electric motor provides all the power requirement of the machine. The power transmission system is shown in **Fig. 2**. the maintenance of the machine is simplified by transmitting power to the various components of the machine by pulleys, belts and shafts. The pulleys, belts and shafts have been designed as in Ademosun (1990). All the pulleys were cast from aluminium in order to minimize their weight.

Two pulleys are installed on the electric motor. Power is transmitted through an open belt from the electric motor to one of the rollers, from the roller to the agitator, from the agitator to the crank of the reciprocating plates and from the crank to the nib elevator. Power is transmitted through a crossed belt from the elevator to the auger. The two rollers are required to rotate in opposite direction for the dehulling operation and they are too close to transmit power directly to each other. Therefore, power is first transmitted through an open belt from the first roller to an idler pulley from where power is transmitted through a crossed belt to the second roller. The fan receives its power supply directly from the electric motor through an open belt. The two belts transmitting power from the motor are B-type belts while the remaining belts are A-type belts.

Performance Test of the Machine

All the components of the machine are assembled as shown in **Fig. 3**. The machine was designed to dehull and winnow about 1000 kg of cocoa beans per hour. A feeding conveyor discharged cocoa beans into the hopper. The driving shaft of the conveyor rotated at 700 rpm, which is the speed of the rollers. As the driving shaft of the conveyor rotated, the conveyor passed below a stationary leveller which is installed at a height of 20 mm above the conveyor. The cocoa beans were, therefore, uniformly spread on the conveyor.

The only adjustment required

on the machine is the clearance between the rollers since all the other components of the machine were fabricated according to design specifications. The optimum roller clearance is the roller clearance at which the dehulling efficiency of machine is highest. The optimum roller clearance was, therefore, determined during the performance test of the machine.

The cocoa beans were dehulled at about 3.0% moisture content. The roller clearance was initially adjusted at 21.0 mm. The machine was switched on and 15 kg of cocoa beans were fed into the hopper. At the end of the dehulling and winnowing operation, which lasted about 60 sec, the undehulled and partially dehulled cocoa beans collected inside a basket at the side of the reciprocating plates, the cocoa nibs collected inside a bag tied to the outlet of the nib elevator and the cocoa shells collected on a mat at the front of the winnowing chamber. The undehulled and partially dehulled cocoa beans were manually separated. The quantities of undehulled cocoa beans, partially dehulled cocoa beans, cocoa nibs and cocoa shells were weighed. The experiment was repeated for different values of the roller clearance.

Results

The results obtained from the experiment on the variation of roller clearance are illustrated in **Fig. 4**.

As the roller clearance increased from 8.0 mm to 10.0 mm, both the quantities of the undehulled and partially dehulled beans increased. However, the quantity of the former was smaller than that of the latter within this low roller clearance because there was sufficient contact to cause most of the

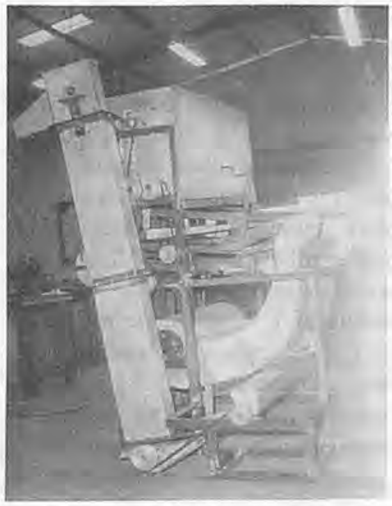

Fig. 3 The cocoa dehulling and winnowing machine.

cocoa beans to shear. Beyond a roller clearance of 10.0 mm, the quantity of the undehulled beans increased rapidly while that of the partialy dehulled beans decreased rapidly. The rate of change became slow between a roller clearance of 14.0 mm and 19.0 mm. At this high roller clearance, the rollers could scarcely be responsible for any shearing of the cocoa beans. No more cocoa bean was dehulled when the roller clearance exceeded 19.0 mm.

Above a roller clearance of 14.0 mm, only small quantities of cocoa nibs and shells were obtained because of the low frictional force attained. As the roller clearance decreased from 14.0 mm to 8.0 mm, the quantities of cocoa nibs and shells rapidly increased. However, when the roller clearance was less than 8.0 mm, the cocoa beans could not pass between the rollers. Therefore, the largest quantity of cocoa beans was dehulled at a roller clearance of 8.0 mm and the dehulling efficiency of the machine was calculated to be 98.36%.

There were three times that cocoa nibs were found with the cocoa shells after the winnowing operation. When the values of the

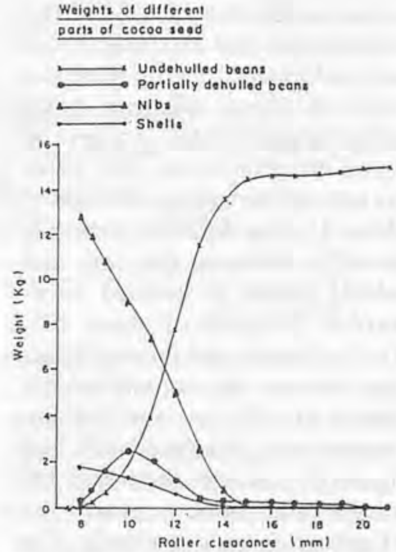

Fig. 4 Effect of roller clearance on the performance of cocoa dehulling and winnowing machine.

roller found with the shells were 0.053 kg, 0.063 kg and 0.070 kg, respectively, these quantities of cocoa nibs found with the shells were 0.498%, 0.503% and 0.450%, respectively, of the total weights of the cocoa nibs and shells. Therefore, the winnowing efficiency of the machine was about 95.5%.

Conclusion

A medium-scale cocoa dehulling and winnowing machine has been developed. The machine is rugged and it is easy to operate and maintain.

The only adjustment required on the machine is the roller clearance. The quantity of cocoa nibs dehulled increase rapidly as the roller clearance decreased from 14.0 mm to 8.0 mm. The dehulling efficiency of the machine is 98.36% and the winnowing efficiency is about 95.5%.

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(Continued on page 64)

Application of Abrasive and Lye Peeling of Ginger at Individual Farmer's Level

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Abstract

A small, manually-operated ginger peeling machine for application at individual farmer's level was developed. The machine utilizes locally available material and can be fabricated and repaired by local village artisans. It operates on the principle of abrasive peeling. Its performance was evaluated in view of peeling efficiency and ginger meat loss. The effect of presoaking the ginger in mild lye solution was also determined.

Introduction

The need for an effective mechanical peeling system for ginger to alleviate the problems associated with the indigenous manual operation was realized by Agrawal et al (1983). They developed an abrasive brush type ginger peeling machine consisting of essentially two continuous brush belts being driven in opposite directions with a downward relative velocity by an electric motor. The operation of the machine was later optimized by Agrawal et al (1987). The machine had a capacity of 160 kg/day (based on 8 h/day operation) under optimum operating condition and was found suitable for application at medium-large farmer's level and at the cooperatives' level. It was, however, felt that this machine may not be suitable for small farmers for two reasons: one, the cost of the machine would be approximately US$1500 (including motor) which is beyond the reach of small farmers in India, two, the machine consists of specially cast pulleys and specially built brush belt lending it suitable for commercial manufacturing only.

This work was, therefore, undertaken to develop a low cost manually operated ginger peeling machine which can be built and repaired by village artisans using locally available materials. The application of lye pretreatment in conjunction with this machine to facilitate peeling was also investigated.

Acknowledgement: The authors acknowledge the assistance of Messrs, M. Trivedi and N.K. Dave, and former BE students at the College of Technology and Agricultural Engineering, Udaipur in the testing of the machine.

Special Features

In order to make this machine simple in construction, one of the abrasive surfaces was kept stationary with a sufficient inclination to facilitate the downward movement of ginger. Locally available materials were adopted in the construction. A manual drive was provided the machine in order to minimize cost. Brushes made of coconut fibres were used as abrasive surface. The hardness of coconut fibre results in better abrasive action while the flexibility helps in cleaning the grooves or irregular surface of epidermic layer.

Constructional Details

The developed machine has the following components: moving

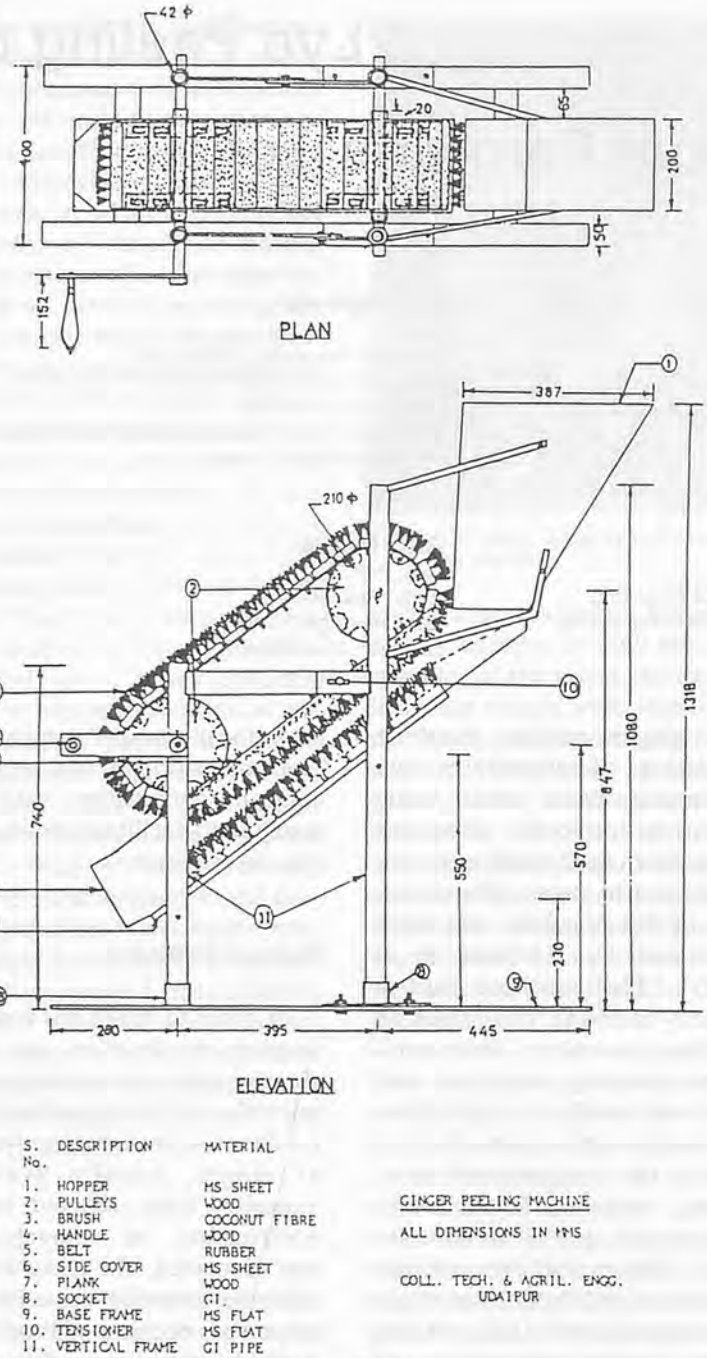

Fig. 1 Abrasive type ginger peeling machine.

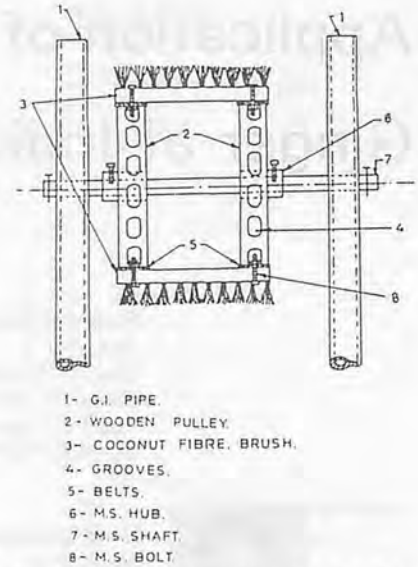

Fig. 2 Sectional view of brush and pulley assembly.

abrasive surface; stationary abrasive surface; frame and hopper; and driving mechanism (**Fig. 1**).

The moving abrasive surface was made of coconut fibre (30 mm length) brushes mounted on two endless canvas belts of 40 mm width and 5 mm thick with the help of 2.5″ × 0.25″ bolts and nuts. The canvas belt has enough strength and flexibility for trouble-free operation of the machine. This belt is readily available in local markets, and the ends can easily be joined together and mounted on the pulleys by a semi-skilled man. Readily available coconut fibre brushes (size 200 mm × 55 mm) in local market were used for this abrasive surface. These brushes can also be manufactured locally. The flexibility of the fibres helps in minimizing the loss of ginger meat along with the proper cleaning of grooves on irregular surface of the ginger pawn. Wooden pulleys were selected to provide the movement to the abrasion surface since it costs less considerably as compared to other conventional pulleys. It requires no special skilled labour in manufacturing. Pulleys of 210 mm diameter and 30 mm width were used in the machine. To ensure the positive drive to the moving abrasion surface, the peripheral surface of these pulleys were grooved, spacing 60 mm, to get in the extra long bolt, used for mounting the brushes on the belts (**Fig. 2**). Pulleys were mounted on 20 mm diameter M.S. shaft keeping them 160 mm apart.

The stationary abrasion surface was also developed with the same brushes arranging them side by side on a wooden plank of 780 mm × 240 × 15 × size. A uniform gap of 15 mm was maintained between the moving and stationary surfaces so as to accommodate ginger pawn between them. The sides of the surfaces were covered with the help of 22 gage M.S. sheet in order to restrict the side throw of ginger pawns and to advance the pawns downward towards the discharging end.

A rectangular base of 1 120 mm × 400 × size was made with 50 mm × 5 mm M.S. first to erect a tubular frame over it. Four GI pipes of 38 mm diameter were used in the frame to mount the complete abrasion peeling unit. GI pipes were supported on the base with the help of four threaded GI sockets welded on the base to facilitate assembly and dismentling by the farmer during transportation. The belts could be tightened with the help of grooved M.S. flats welded on the tubular frame for maintaining a uniform gap between the abrasive surfaces (**Fig. 2**).

A hopper of 10 kg capacity was made with 20 gage M.S. sheet and mounted at the driven end of the machine to feed the unpeeled ginger between the abrasive surfaces. Its one side was kept slanting to avoid any backflow of ginger.

The provision of manual drive was provided at the discharge end of the machine to drive the moving abrasion surface. A wooden handle, free on its axis, was provided for the purpose.

An isometric view of the machine so constructed is shown in **Fig. 3**.

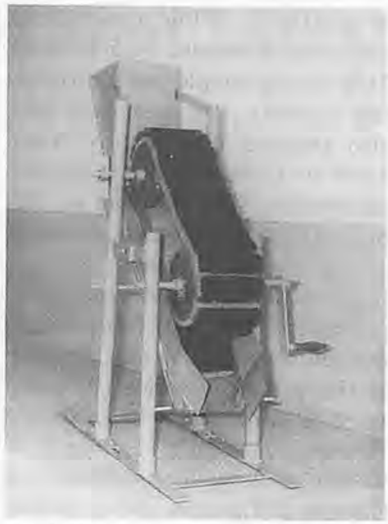

Fig. 3 The ginger peeling machine developed in the study.

Testing Procedure

The procedure developed by Agrawal et al (1987) was adopted for testing this machine in terms of peeling efficiency and ginger meat loss. Fresh ginger was procured from local market. The testing was conducted for one to five passes by maintaining a fairly constant belt speed during the experiment. The number of replications for each experiment were three. The machine was further tested using ginger pretreated with 7.5% lye (NaOH) solution for five min. at room temperature to determine the effect of lye treatment on peeling efficiency and ginger meat loss. After the lye treatment, ginger was washed in fresh water.

Results and Discussion

The average peel weight per unit weight of raw ginger was 0.059 g/g. The weight of peel on individual pawns varied from 3.5 to 8.0%. The experimental data on testing of the machine with untreated ginger are reported in **Table 1** along with the calculated peeling efficiency and ginger meat loss. The average values as affected by the number of passes are shown in **Fig. 4**. The peeling efficiency increased almost linearly with the increase in number of passes. The meat loss increased sharply in the third pass after which the increase in loss was relatively low but linear with increasing number of passes. On average, peeling efficiency of the machine was about 60, 64, 73, 75 and 81% in 1, 2, 3, 4 and 5 — pass operation, respectively, while the corresponding meat loss was about 0.8, 1.4, 3.3, 3.8 and 4.2%. High peeling efficiency and

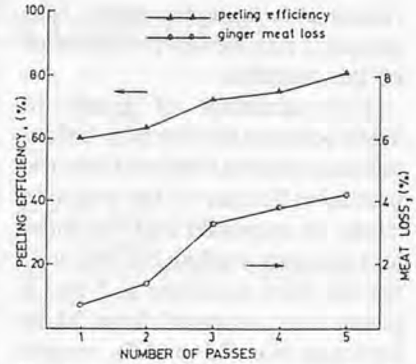

Fig. 4 Average peeling efficiency and ginger meat loss.

Table 1 Peeling Efficiency and Ginger Meat Loss

No. of Passes	Weight of ginger (g) before peeling	after mechanical peeling	after hand trimming	Peeling efficiency (%)	Average peeling efficiency (%)	Material loss (%)	Average material loss (%)
1.	117.30	111.82	109.14	61.20	60.13	1.05	0.76
	144.82	139.10	135.60	59.03		0.46	
	225.90	216.15	210.84	60.16		0.76	
2.	126.68	120.16	117.44	63.60	63.60	1.39	1.39
	160.75	152.55	149.10	63.62		1.34	
	187.17	177.42	173.40	63.59		1.45	
3.	146.96	135.56	133.32	74.16	72.80	3.38	3.31
	162.77	150.37	147.77	72.92		3.31	
	170.22	157.56	154.68	71.32		3.23	
4.	113.18	103.90	102.32	76.34	75.22	3.69	3.80
	152.37	139.75	137.42	74.14		3.91	
	176.31	161.76	159.18	75.19		3.81	
5.	145.98	132.60	131.12	82.81	81.10	4.28	4.21
	136.00	124.02	122.35	79.12		4.13	
	191.07	173.85	171.75	81.37		4.21	

reasonable ginger meat loss indicated satisfactory performance of the machine.

Lye treatment of ginger in 7.5% solution for five min. before machine peeling indicated that the peeling efficiency of the machine could be increased and the meat loss reduced. Peeling efficiency of the machine operating in 3 and 4 passes was increased from 73 to 83% and from 75 to 86%, respectively, by the lye pretreatment whereas the corresponding meat loss was reduced from 3.3 to 1.9% and 3.8 to 2.4%. A detailed study on optimization of lye pretreatment parameters — concentration, dip time, and temperature of solution — and on the number of washes required to remove the residual lye on ginger would, however, be required before its application in large scale in the rural areas.

One hopper — full untreated ginger, 10 kg, required about 25 min. to be peeled in 5 passes. The capacity of the machine was thus about 24 kg/h. The peeling efficiency and the meat loss in full capacity trial were 71% and 1.3%, respectively, which are comparable to those obtained by Agrawal et al (1987). While the peeling efficiency decreased from 81% to 71% during sample peeling trial at full capacity, the meat loss was also reduced significantly from 4.2% to 1.3% which is a certain advantage. This was due to the bulk effect and was also observed by Agrawal et al (1987).

The total cost of the machine, including the cost of fabrication, was about US$60.00 (Rs. 1000/-) at the prevailing prices in June 1989 in India.

Conclusions

The small, manually-operated ginger peeling machine developed in this study for application at individual farmer's level operated satisfactorily with high peeling efficiency and reasonably low meat loss. The peeling efficiency could be increased and the meat loss reduced by lye treatment of the ginger before peeling. The capacity of the machine was about 24 kg/h for 5 — pass peeling operation. At full capacity operation, the machine had a peeling efficiency of 71% with 1.3% ginger meat loss.

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(Continued from page 60)

Performance Evaluation of A Medium-scale Cocoa Dehulling and Winnowing Machine

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Studies on Thor Latex Extraction

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Abstract

In the present investigation, extraction of Thor latex was studied. Various parameters related to plant and cut, like cut location, cut spacing, depth of cut, cut interval and latex collection time were studied in order to optimize operating parameters of latex collection. The horizontal type of cut with 5 mm depth on the main stem at a collection interval of one week gave satisfactory results. A 25 mm cut was found acceptable. For optimum latex yield, cut spacing of 150 mm is recommended. A collection duration of 15 seconds is recommended in order to recover around 90% of latex and also to tap as many plants as possible. The latex yield per cut is around 1 ml.

The hammer-shaped cutting tool was modified to give proper cut without much exertion on the part of the worker. A two-vessel collection system was designed. The instant latex collection vessel is of 250 ml capacity and of cuboid shape with handle. A commonly used galvanised iron bucket with a lid was selected as a storage vessel. The overall performance of the improved latex collection system was superior over the traditional method.

Introduction

India imports substantial quantities of natural and synthetic rubber — spending approximately Rs. 1.5 billion on import of rubber goods alone. The present growth rate of natural rubber in the country is not sufficient to meet the demand of consumers. Thus, there is an urgent need to look for other alternative/additional sources, preferably from renewable natural resources, to meet the shortage of Havea rubber. Further, natural rubber plant can be cultivated only in a limited tropical zone. Therefore, any political, economic or biological changes in tropical zone could endanger the supply of natural rubber. Heavy rainfall is a must for this plant. To overcome this problem, there is a need to explore the availability of rubber from other plants to supplement natural rubber.

In India there are wild plants which produce sufficient amount of latex. For example, *Euphorbia caducifolia* (Thor), which is available in desert areas of India, yields good amount of latex. Dried Thor latex contains about 16% rubber and 74% acetone extract which is indicative of resin. Both rubber and resin from this plant are comparable with commercial rubber and resin. For some applications, dry latex can be used in place of natural and synthetic rubber.

The latex yield can be increased many times over through research efforts in breeding, agronomy and tapping techniques. Therefore, the present study was carried out on Thor plant characteristics in relation to the extraction of latex. This study will be helpful in developing efficient tapping techniques for Thor latex extraction.

Materials and Methods

Thor plant is found in abundance in many parts of the country. The plant contains latex in every bit of shrub. Latex can be discharged from any part of the shrub by making an incision. The rate of flow decreases with time. The duration of flow is very short. The cessation of latex flow is the typical character of the plant. The quantity of latex received from one cut is about 1 ml which is too low to measure and study. Being a new plant, details regarding latex discharge are not available. Therefore, the present study of plant in relation to latex availability was carried out and efforts were made to get maximum latex yield.

Selection of Thor Plant Set

A preliminary study was done to decide the experimental procedures to be adopted for the study of latex yield. It was observed that latex received from one cut was quite low and in unmeasurable quantity. Therefore, five plants were taken in each set and latex from one set was considered as one observation for this study.

The plants selected were of average size and of similar appearance. After the selection of plant set, the plants were labelled so as to identify the treatments. These selected plants were protected with wire fencing in order to avoid unforeseen disturbances during the investigations.

Selection of Parameters Affecting Latex Yield

On the basis of the available information on latex yielding plants, the following parameters were selected in the present study:

i) Cut portion: main, sub-main and lateral;
ii) Type of cut: horizontal and vertical;
iii) Depth of cut: 1, 2, 3, 4, 5 and 6 mm;
iv) Spacing between cut: 10, 20, 37.5, 75, 150 and 300 mm;
v) Cut internal: 1, 2, 3, 4, 5, 6 and 7 days; and
vi) Duration of latex collection: 5, 15 and 45 sec.

An experimental cutting tool with a very sharp edge of 2.5 cm width was used for this study. Everyday observations were taken in the morning hours at 8.30 o'clock. Latex yield from one plant set was collected. A graduated measuring cylinder of 10 ml capacity was used to measure the quantity of latex. A shallow cup shaped container with handle was used for collecting in the latex discharge from the plants.

Development of a Cutting Tool

If the cutting tool is efficient and easy to operate, a worker can make cuts on more plants in a given time without much exertion. Therefore, a cutting tool was developed. In order to develop an efficient cutting tool, various types of tools like chisel, scissor and hammer-shaped tools were tried. On the basis of preliminary trials, the type of cutting tool was decided. Subsequently, the selected tool was further improved. The improved hammer-shaped cutting tool was found to be efficient and safe to operate.

Development of Latex Collector

For Thor plants latex is discharged within a few seconds after a cut is made. Further, latex obtained from a cut is very scanty. Therefore, the worker has to move from plant to plant in the field, keeping a collector in one hand and a cutting tool in another. Thor plants are grown on the field boundary as fence. Taking into account the above facts, a collection vessel was developed which can be handled by a worker conveniently and is efficient in collection of latex from Thor fencing. Various types of latex collecting vessels were tried before finalizing the design of the container for collecting latex. The developed container is a cuboid with a square base and is provided with a handle. The capacity of the vessel is 250 ml which is convenient to handle and is able to cover sufficient area for collecting latex.

Results and Discussion

Effect of Cut Location and Type of Cut on Latex Yield

Experiments were carried out to study the effect of cut location and type of cut on latex yield. Main and sub-main stems and lateral branches of plants were tapped to make a comparative study on latex yield. Horizontal and vertical cuts were selected on the basis of preliminary study. The data on the effect of cut location on latex yield are given in **Table 1**. The results indicate that the main stem gives maximum yield of latex. From this study an inference can be drawn that in the case of Thor plant also, larger size latex veins lie in main stem which is a fact in the case of other latex bearing plants. It can be concluded, therefore, that the main stem should be tapped for maximum latex yield. It is also observed **(Table 1)** that there is a significant difference in latex yield of individual plants. This may be due to variation in phosiology of different plants. This indicates that there is a vast scope for the development of new high latex yielding Thor varieties.

Table 1 Effect of Cut Location on Latex Yield

Plant set	Main stem yield, ml	Sub-main yield, ml	Lateral yield, ml
1.	7.6	2.5	3.2
2.	10.3	2.7	3.0
3.	5.2	2.2	2.2
4.	4.5	3.1	2.1
5.	10.2	4.2	3.2
6.	3.0	1.6	2.1
7.	7.5	2.5	2.1
Average	6.90	2.69	2.56

Table 2 Effect of Type of Cut on Latex Yield

Cut portion	Latex yield, ml	
	Horizontal cut	Vertical cut
Main	4.5	3.0
Sub main	3.1	2.1
Lateral	2.1	1.6

The data on the effect of type of cut on latex yield are given in **Table 2**. Horizontal cuts gave higher latex yield than vertical cut which may be due to the arrangement of veins around the stem. Therefore, for Thor plant, horizontal cuts should be made in order to get maximum latex yield.

Effect of Depth of Cut on Latex Yield

The effect of depth of cut on latex yield is shown in **Fig. 1**. It has been observed that the latex yield increased with the depth of cut to a certain depth. Beyond a certain point there was no increase in latex yield. Deeper cuts required comparatively larger force and are injurious to the plant. The optimum depth of cut is 5 mm.

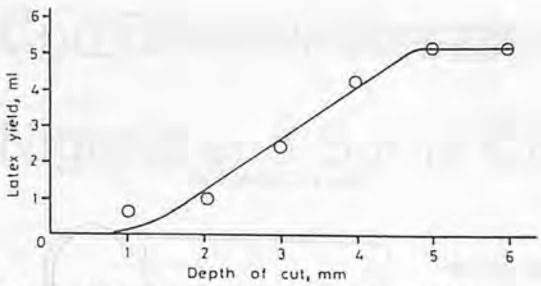

Fig. 1 Effect of depth of cut on Thor latex yield.

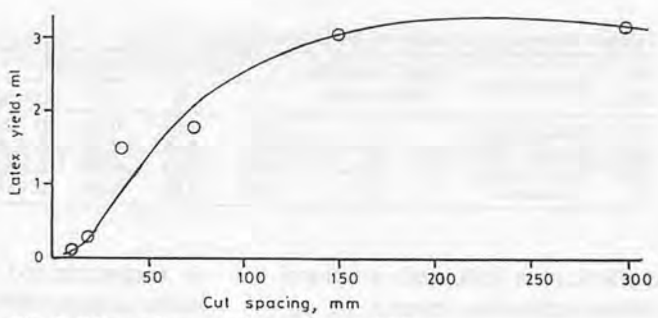

Fig. 2 Effect of cut spacing on latex yield.

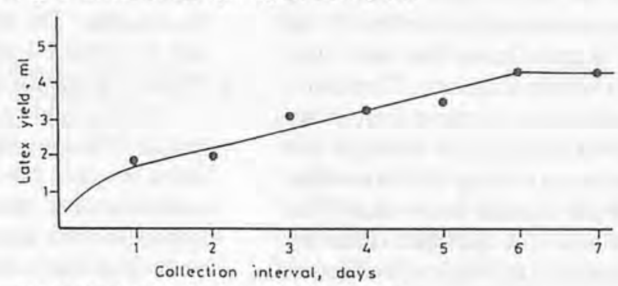

Fig. 3 Collection interval vs average yield.

Effect of Cut Spacing on Latex Yield

Cut spacing is one of the important factors which effect latex yield. The variation of latex yield with cut spacing is shown in **Fig. 2**. The latex yield increased with an increase in spacing between successive cuts initially and remained constant, subsequently. If the cuts are made closer and closer, the latex yield decreased appreciably. As the cut injures the plant, the shrub should be subjected to a minimum number of cuts. The study indicates that the optimum cut spacing was 150 mm.

Effect of Collection Interval on Latex Yield

Fig. 3 shows the effect of collection interval on latex yield. The study indicates that the average latex yield per tap increased with an increase in tapping interval. The decrease in latex yield with the decrease in collection interval may be due to lack of replenishment capacity of the plant. It is also possible that the plant portion may not have recovered fully from the stress and strain of previous cuts. The study indicates that the plant requires at least 6 to 7 days to replenish so as to maintain constant latex yield. Also, with an increase in collection interval, the number of cuts will decrease and the plant will be subjected to less stress and strain. Therefore, the collection interval of six days is recommended.

Effect of Duration of Collection on Latex Yield

In order to design a latex collection system, the effect of duration of collection on latex yield was studied. Durations of 0-5 sec, 5-15 sec and 15-45 sec were selected on the basis of preliminary investigations. It is evident from **Table 3** that latex yield is very high at the onset of the cut. In the first 5 sec duration, 75% of total latex is received while in the subsequent 10 sec only 15.87% is received. In the last phase of 30 sec only 9.13% latex is extracted. Latex collection is a continuous process. If the duration of collection is long, the number of plants covered by a worker will be less. In the first 15 sec duration, more than 90% latex was harvested. Therefore, optimum collection interval is 15 sec.

Development of a Cutting Tool

Based on the findings in the study, it was decided that a cut should be a horizontal type with 5 mm depth and should be made on the main stem. A 25-mm width of cut was selected to have uniform cut on stems of various sizes. A cutting tool meeting the above requirements was developed. Various cutting tools of different shapes were compared and data are presented in **Table 4**.

Table 3 Variation in Latex Yield (ml) with Duration of Collection

Sr. No.	Duration of collection (in sec)		
	0-5	5-15	15-45
1.	2.1	0.5	0.3
2.	2.4	0.0	0.0
3.	1.6	0.2	0.0
4.	2.2	0.8	0.8
5.	1.3	0.3	0.0
6.	1.8	0.6	0.3
Ave. yield	1.89 ml	0.40 ml	0.23 ml
Latex collection	75.00%	15.87%	9.13%

The quantity of latex collected by using a hammer-shaped tool was greater compared to other tools shapes. Therefore, a hammer-shaped tool was selected and further improved. The size and weight of the tool were decided on the basis of latex yield per hour and ease of operation. The improved cutting tool is shown in **Fig. 4**.

Development of Latex Collection System

Traditional methods of latex

Table 4 Comparative Study of Different Cutting Tools

Sr. No.	Type of tool	Latex collection duration (h)	Latex collected (liters)			
			I	II	III	Average
1.	Sickle shape	3	0.72	0.81	0.81	0.780
2.	Scissor shape	3	0.62	0.68	0.66	0.653
3.	Chisel shape	3	0.81	0.84	0.85	0.833
4.	Hammer	3	0.93	0.98	0.96	0.953

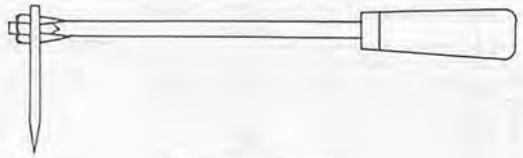

Fig. 4 Cutting tool.

Fig. 5 Latex collection system.

collection as followed in natural rubber collection cannot be applied as 90% latex from Thor plant is extracted in the first 15 sec and in most cases the latex flow stops within a minute. Therefore, a worker has to move from plant to plant holding the vessel in one hand and a cutting tool in another hand to collect latex. As Thor latex is to be collected from the main stem, the shape of collection device should be effective and handy so as to collect the latex efficiently.

It was observed that a worker can cover about 80 m fencing in a half day. As this distance is quite small, a two vessel system was adopted, that is, one vessel for instant collection and another vessel to store the latex collected in half day.

The square shaped vessel for latex collection from a plant was found superior over other shapes. The square shaped vessel was further modified to have proper capacity and ease of operation. The developed vessel is shown in **Fig. 5**. The size of this vessel is 250 ml. A common galvanised bucket of 2.5 litre capacity with a lid was chosen as the storage container on the basis of ease of operation and availability.

Conclusions

1. For optimum Thor latex yield, a horizontal cut of 5 mm depth and 25 mm width on main stem at a collection interval of one week with 150 mm cut spacing are recommended.
2. A collection duration of 15 sec is recommended so as to recover around 90% of the latex and also to tap as many plants as possible. The latex yield per cut is around 1 ml.
3. There is a significant difference in latex yield of individual plant. This may be due to variation in plant physiology. This indicates that there is a vast scope for the development of new high latex yielding Thor varieties.
4. A hammer-shaped cutting tool provides higher latex collection efficiency which may be due to its ability to make proper cuts with ease of operation.
5. A two-vessel collection system, that is, one vessel for instant collection and another vessel to store the latex collected in half day is recommended.
6. The improved method consisting of the developed cutting tool and two-vessel collection system extracted and collected 80% more latex as compared to traditional methods.

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Comparative Assessment of Grain Structures in Nigeria and Some Countries in Africa and Asia

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Abstract

Grains comprising maize, rice, millet and sorghum are very important agricultural products in the economy of Nigeria. Their roles as food for the citizens, raw materials for agro-allied industries and livestock feed are highlighted. The extent of losses occuring during storage and their causes are dealt with. The types of storage structures available for grain storage are discussed. The traditional storage structures include the native underground storage pits in places such as Bornu and Kano, plinths in the open; the rumbus as the most common method by which farmers store grains in Northern Nigeria; and the crib that is extensively used for grain, especially maize storage, in Southern Nigeria.

The deficiencies of these traditional storage structures and efforts made to solve the problems associated with them leading to the evaluation of improved traditional structures are discussed. The use of 200-litre drums for hermetic storage of grains is mentioned. The modern storage structures used in Nigeria and their effectiveness in enhancing the quality of the agricultural products stored in them are critically examined. Such modern storage structures include well-built standard warehouses or stores on medium to large scale levels, metal silos both in public and private sectors, concrete and timer silos, including the newly designed multi-produce silo by he Post-Harvest Technology Programme in the Federal University of Technology, Akure.

Rubber silos, particularly butyl rubber, had been tested in Nigeria with unfavourable results, so also are air-houses. Recommendations are made on strategies for improving the efficiency of the promising storage structures in Nigeria.

Introduction

In 1985 Nigeria produced 11.5 million metric tons of grains made up of maize, millet, sorghum and rice (F.A.O. 1985). Because of poor storage methods, up to 25% loss occurs in stores due to insects rodents and microorganisms (Adesuyi, 1982).

The problem of losses of stored food in developing countries is world-wide concern which led the seventh special session of the United Nations General Assembly in September 1975 to pass a resolution setting a target of 50% reduction in post-harvest food losses in developing countries by 1985.

Food grains play very important roles in the economy Nigeria. They form a staple in the diet of the people and constitute major raw materials in agro-allied industries. Grains are used in animal feed production, production of flour, semolina and grits. Oils, glucose and cornflakes are derived from grains. It is, therefore, essential to store grains very well so as to save both physical and quality losses of the crops from the agents of deterioration which are very active, especially under tropical conditions, ensure a steady supply of good quality grain to the consumers all the year round, make more food available, reduce seasonal fluctuations in price, enable primary producers to take advantage of any seasonal rise in price, ensure steady supply of raw materials to agro-allied industries, in case of exportation, and earn more foreign exchange and reduce or eliminate the need for importation of food.

The structure in which grain is stored has a lot to do with the final product at the end of storage. The structure must be such that it will protect the grain from agents of deterioration, e.g., insects, moulds or microorganisms, rodents and birds, and maintain the original quality for the period of storage.

Types of Grain Storage Structures

The structures available for grain storage in Nigeria can be discussed in three broad divisions: i) small scale storage structures comprising mainly of traditional structures; ii) medium-scale storage structure; and iii) large-scale storage structures.

Small Scale Storage Structures

These cover structures whose capacities are about 5 tons or less. They are mainly traditional structures.

Underground storage pits—The native underground storage pits are used in the far Northern parts of Nigeria such as Bornu. The suitability of this type of structure depends on the water table of the area which should be low. It is a hidden storage structure used to reduce pilferage of stored crops.

They are circular pits sealed with a dried earth cap. They are lined with woven grass matting and the gap between the matting and the earth filled with millet chaff and the opening is covered with grass thatch and thorns. Pits can be located in enclosed areas where cattle are kept since such areas are dry and free of termites.

Prevett (1962) reporting on the underground pit constructed in Kano in 1957-58 and filled with sorghum in mid June 1958 to October 1962 made reference to problems of air and moisture leakages supporting insect survial, especially at the manhole covers. The viability of the grain was reduced drastically after two years of storage and up to 3% in the third year. The grain was in excellent condition after four years storage but there was a reduction in nutritive value and viability. Some cracks were observed beneath the roof leading to slight leakages. Structures of this type are used also in India, North Africa and Latin America. Similar underground structures have been improved in other parts of the world and are known as Cyprus bin. It is extensively used in Kenya. As of 1975, there were 70 Cyprus bins in Kenya located in Nakuru and Kitale each having a capacity of 1400 tons of maize stored in bulk (Taylo and Adesuyi, 1975). The Cyprus bins are large underground pits with permanent concrete roofs designed in the form of large domes to increase the above ground storage capacity. Every section, both under and above ground is moisture-proof and strongly reinforced. The design of the pit and roof makes the structure hermetic. The bottom of the pit is elliptical. Maize stored in it is at 12% moisture content. No pest control is carried out since it is hermetic except occasionally at the hatches where there may be insect infestation.

The Cyprus bin has the following problems.

1. Loading and unloading of the bins are very tedious and difficult.
2. The elliptical bottom creates a problem in emptying.
3. There are frequent cracks at the joints in the above-ground roof and this permits entry of moisture into the bins resulting in mouldy grains. Condensation at the top of the bins also causes mouldiness.
4. The hatches at the side and top of the bin are square rather than being round and, therefore, difficult to make airtight.
5. There are no facilities for turning the grain in the bin. It is capable of storing grains for 3 years with an average loss of 2.5%. It is relatively cheaper than vertical concrete silos.

Rumbus—The most common method by which farmers store their grains in northern Nigeria is by the use of rumbus. There are containers with capacities which vary from 250 kg to 2 tons or more of grain (sorghum or millet), generally, on the head. They are usually constructed of mud or of woven zana grass. Rumbus may be flask-shaped with a relatively small aperture, or roughly cylindrical. The containers are raised from the ground on short legs or on a crude base of logs, while the apertures are closed with a thatched cover. The building material, shape and size depend on local soil conditions and tradition. In the more extreme north, zana rumbus are more commonly made than mud rumbus. They are cheap and easily portable but more permeable to insects. A lot of work has been done over the years in Nigeria to improve this structure and the pest control measures required.

Others—Other structures available for use on small scale or domestic scale are the 200 litre drums and polythene bags that should be properly sealed to provide hermetic condition. The sealed drums have been used to store dry grain for up to 2 years without any live insects or damage.

Medium to Large-scale Storage Structures

Crib—Farmers in southern Nigeria use traditional cribs of various types for storing grains, especially maize on cobs. There are different designs, some are round, some square, some use thatch materials while some are built of mud, some are on raised platforms while some are on the ground unraised, etc. They very from locality to locality. A common feature among the farmers is that they store their maize with the sheath on and the spices of the cobs turned inwards for protection against insects (**Figs. 1, 2**). There are several problems associated with this traditional method resulting in substantial losses of stored maize.

The traditional crib lacks adequate facilities for quick drying of maize (**Fig. 3**). Leaving the sheath on during storage slows down any further drying and does not allow the farmer to see the condition of the maize which is usually infested by insects from the field and continues in store. The farmer does not practice any control measure against insects, rodents and mould in the crib resulting in losses of about 25%.

To solve the problems enumerated above, an improved storage structure, the modern crib, has been designed for use to offer facilities for effective natural drying and storage of maize on the cob (Adesuyi and Cornes, 1978) (**Fig. 4**). In about 4 to 6 weeks maize stored in the crib dries from 25% moisture content to 13% depending on the relative humidity and temperature of the environment of storage. The crib also simultaneously serves as a storage structure for one year or longer. The inspects are controlled by applying persistent insecticide, mould controlled by adequate drying and rodents controlled with rodent guards. The modern crib has been widely adopted in southern to Central Nigeria by government and private farmers. The capacity could be from less than 15 tons to 40 tons of maize on the cob with the sheath removed.

Storage in the Open—Grains and groundnuts in bags are stored in the open in the northern part of Nigeria for long periods. This is used to store the pyramid-shaped stacks. It is covered with water-prrof sheets during the rains. The pyramids are constructed on square, raised plinths to minimize direct water damage by flooding. The plinths are built with considerable convexity to facilitate the run-off of any adventitious water. Water-proof sheet is used on the plinth to prevent moisture damage to basal sacks of produce of bottom layer. Adesuyi (1966) reported that there were 310 plinths in Kano City storage site alone with each holding 800 tons of produce (Anon, 1956) (**Fig. 5**).

Storage in the open is also used in other countries of Africa such as in Kenya where it is used only when the Maize and Produce Board is short of space in other stores. The bags are then stacked on wooden dunnage and covered with tarpaulin to prevent wetting by rain. This method of storage is also widely used in Zambia by the National Agricultural Marketing Board.

Each plinth, referred to as "hardstanding" takes 2000-2500 tons of maize and covered with gas-proof fumigation sheet for pest control. They remain outside on these hardstandings throughout the season and are protected by tarpaulins during rainy days. It is used to store maize for 1-3 years. The problems, however, include accidental wetting through leakages of tarpaulins or carelessness, insect reinfestation of grain, moisture migration and condensation at the top of stacks causing grain discolouration. Therefore, it would be worth the effort to encourage storage in the open in the northern parts of Nigeria and solve the problem of moisture seepage, migration and condensation. It is much cheaper than other storage structures of its capacity. The rodent problem has been investigated and solved (Adesuyi, 1966).

Warehouses or stores—Different types of warehouses have been in use by farmers and traders for a long time in Nigeria but most of them lack the planning and structural requirements to make them effective. Some traditional warehouses are built of mud, cor-

Fig. 1 A traditional storage structure for maize on the cob with apices turned inwards, Nigeria.

Fig. 2 A traditional storage structure with stored maize on the cob having the sheath on, Nigeria.

Fig. 3 Nigerian local storage structure with inadequate facilities or provision for quick drying.

Fig. 4 The improved modern maize crib.

Fig. 5 Storage of products in Pyramid-shaped stacks covered with waterproof sheets in the open in northern Nigeria.

Fig. 6 A warehouse in Nigeria.

Fig. 7 A row of warehouse in the Food Corporation of India, Borovli, Bombay, India.

Fig. 8 Aluminium silos for storing grains in Western Nigeria.

rugated iron sheets, planks, etc. However, the construction of modern warehouses has been improved to the extent that it is moisture proof by preventing leakages from roofs faulty doors or seepage from the floor that can cause mouldiness of stored produce. Insect and rodent infestation can also be prevented or controlled. Such a modern store fulfils the following conditions (Adesuyi, 1975):

1. It is accessible and never likely to be flooded.
2. The required capacity of 1.7 m^3/t of bagged grain and extra space for weighing and performing other duties are adequately provided.
3. Floor is designed to bear the load of stored grain and raised well above the ground level. A moisture-proof barrier is also incorporated.
4. The wall is either mud, cement, or timber material which is made waterproof else the sacks are placed on wooden dunnage or pallets or on plastic sheet stacked away from the wall.
5. All doors and windows are made tight-fitting to prevent flying insects and rodents and improve the effectiveness of insecticidal smokers and fumigants.
6. The roof is constructed of corrugated iron sheet or asbestos and made leak-proof. It is firmly held down so that it is not blown away by rainstorm. It is completely sealed up with no roof supporting pillars.
7. Adequate ventilation and drainage are provided.
8. In some cases, a special provision of a fan and heater unit for aeration and in-store-drying is made. This is essential under very humid conditions such as in southern Nigeria.

Some modern warehouses are of framed construction with the spaces between the stanchions filled with non-load bearing walling material such as cement blocks. The frame buildings are prefabricated at the factory, delivered as components and erected on the site on previously prepared foundations. They are, therefore, erected easily and quickly.

If a warehouse is properly built as described above, the stored products are initially dry to the safe moisture content level and no insect infestation, it is possible, contrary to the belief of many people, to store grains and pulses in bags for 3 to 4 years in such warehouses. Suitable handling machines such as bag trolleys, other handling facilities etc. should be provided to reduce drudgery. Several modern warehouses built to specification (Report of Federal Grain Storage Consultation, 1976) and located in most States of the Federation are owned by the defunct Nigerian Grains Board. The Cocoa Warehouse with a storage capacity of 15000 tons divided in six subsections and completely airtight (Adesuyi, 1976) located at Tkeja, Lagos, are owned by the defunct Nigerian Cocoa Board. The State government, commercial companies, other government bodies, groups and individuals all own modern warehouses (**Fig. 6**).

Grains, such as maize, sorghum, millet and rice are stored in well-built warehouses for 2 to 3 years in northern Nigeria and up to 18 months in Southern Nigeria. The 'godowns' or warehouses in Kenya are very large buildings of high spans with each holding from 6600 to 18000 tons of maize. The bags are stacked neatly to a height of about 30-36 bags (about 10 m). Bag conveyors are used for stacking and facilities for air circulation and cooling are provided at the eaves and ridges of the buildings. Zambia and India store the great majority of their grains in bags in warehouses (**Fig. 7**).

Storage in the warehouses is, therefore, a popular method all over the world. It is simple, versatile and people have been used to its operation over the years.

Air house—Another type of warehouse is the "air house". The fabric of the air house and other components, including the door are prefabricated. They are supplied and assembled. Two powerful fans are supplied with it. The air house is entirely supported by the air pressure from the two fans. The structure is fairly airtight. It has the advantage of being mobile and can be used for storage in temporarily congested areas. It can be used as a fumigation sheet but presents a high security risk, requires electricity and the depreciation cost is high. It was not, therefore, used beyond experimental stage in Nigeria. (Cornes, 1965).

Silos—Silos are storage structures commonly used for storing grain in bulk. They may be either rectangular or round. A circular or round silo is cheaper than the rectangular because it is ideal for resisting lateral thrust outwards, although they take up more space. The "dead" space between round silos in a given rectangular area is about one-fifth of the total floor area.

Silos are made of several materials. Choice of materials depends on capital cost, cost of maintenance, availability, suitability to environment, ease and speed of erection, proneness to insect or rodent infestation. The materials are:

Metal silos—These are mainly steel and aluminium alloy galvanised steel made up in panels or troughed sections are used to make prefabricated square silos. They are easy to erect and cheap. Corrugated curved sheets are used for round steel silos. Separate roofing can be provided. Round corrugated aluminium silos are very common and intended for outdoor use with a provision of a conical roof (**Fig. 8**).

Concrete—These silos may be of mass reinforced concrete poured into shuttering, or of concrete staves, or of concrete blocks. All types need adequate reinforcement. Concrete is generally more expensive than steel or timber.

Timber—Prefabricated silos can be made from timber, or timber used to construct small silos on the farm. They must be well seasoned wood to be suitable for making silos. Timber is relatively cheap but it deteriorates fast and sometimes liable to attack by pests.

A multi-produce silo that is capable of storing four different crops simultaneously has been designed and fabricated with timber in the Post-Harvest Technology Programme of the Federal University of Technology, Akure. This silo is useful to the housewives, small/medium to large-scale farmers, traders of raw foodstuff in markets, seed multiplication centres and feedmillers (**Fig. 9**).

The use of bulk storage has been tried on a number of occasions in Nigeria without success (Anon, 1958, Anon, 1959 a, b, Anon, 1960, Prevett, 1961, Caswell, 1962, (a, b), Uptoh 1962, Cornes and Adeyemi, 1964, Adesuyi, 1969).

The reasons for the failure are:

1. Poor standard of workmanship in erection of silos, the basal plinths and the walls leading to leakages and other structural weaknesses.
2. Incessant breakdowns of handling equipment or in some cases the equipment had never been in a working condition since installation.
3. Inadequate drying of produce before storage. Dryers are not operated correctly or they breakdown when most needed. Moisture meters when available are frequently not in working order or often not just used.
4. Inadequate trained staff, e.g., agricultural engineers, probably specialising in storage engineering and well-trained storage personnel are not available. Where they are available, they soon perform creditably, they are promoted and replaced by less competent hands. There is, therefore, a lack of adequate engineering backing.
5. There is also a lack of spare parts for maintenance of the mechanical systems.
6. In large storage sites, there is usually no sufficient grain stock to fill a silo at once, as it is required, because of the method of collecting grains through contractors and middlemen.
7. The inherent properties of the materials used for constructing silos which lead to condensation, mouldy, cakey grains and heavy insect infestation. Adesuyi (1972) reported that between 1.25 and 3.00 percent of the maize in the metal silos he investigated were damaged by moulds.
8. Lack of understandiang of the urgency and critical nature of bulk storage by administrators

Fig. 9 The wooden multi-produce silo, designed and fabricated at the Federal University of Technology, Akre, Nigeria.

Fig. 10 Dome-shaped reinforced cement concrete silo in the Food Corporation of India, Borovli, India.

and financial controllers who are to release funds for storage operations such as purchase of pesticides, pest control spare parts for maintenance, etc.

Despite these myriads of problems with silos in the tropics, Nigerian authorities still continue to import more metal silos. Recently over 1.5 million tons capacity of metal silos have been imported and erected. Except those installed and used as holding bins by the private sector, over 90% of the silo capacity in Nigeria are unused and yet more are being installed. This is sad but there is the need for the agricultural engineers to find solutions to these problems and at the same time exert pressure on the authorities to heed advice from indigenous experts.

In Kenya, maize is a controlled crop and the Maize and Produce Board as of 1975 had facilities for storing 0.5 million tons of maize. Eighty percent of these are handled in bags in warehouses. In Zambia, as in Kenya, maize is a controlled crop under the National Agricultural Marketing Board. As at 1975, Zambia has permanent storage facilities for 600000 t of maize and 90% of the grain is handled and stored in bags. The remaining 10% are handled in bulk in fully automated concrete silos with suitable conveyor systems and built-in methyl bromide fumigation facilities.

India, as of 1981, has total grain storage capacity of 23 million tons. About 60-65% of the grain is stored in bags in standard warehouses while the remaining 40% is stored in reinforced dome-shaped concrete silo (**Figs. 7** and **10**). Storage in the warehouse in bags is for 6 months to 2 years while it is for 3-5 years in the concrete silos. The silos and warehouses are well maintained. Each warehouse holds between 3000-5000 tons (Adesuyi, 1981).

From the above experiences and the Nigerian experiences, more emphasis should be placed on storage in bags in standard well-constructed warehouses in Nigeria. Bag handling equipment and other facilities should be provided to facilitate storage operations and remove drudgery. The aim should be to provide facilities for handling 95% of our stored grains in bags in warehouses and the remaining 5% in bulk in either concrete silos or timber silos. Grain delivered in bags may be handled manually, the government and private pest control staff are familiar with disinfestation of grain by fumigation under gas proof sheets. When not needed for grain, such warehouses can be used for other purposes.

Recommendations

Research for the improvement of storage structures should start with a study and improvement of the local structure for the small-scale farmers as they produce 80-90% of Nigerian foodstuff and store 90-95% of food in storage. The small-scale farmer should be the target for assistance. Simple, handy, versatile, robust and locally produced structures should be develoOped for him, e.g., the multi-produce wooden silo of the Federal University of Technology, Akure.

Well-built standard warehouses to specification and recommendation should be encouraged and used rather than metal silos. Some 95% of Nigerian grains should be stored in warehouses. Grain stores in good condition in warehouses for 2-3 years in some parts of northern Nigeria using the techniques developed and taught them by local storage experts.

Other storage structures that are found to be suitable to particular zones of the country should be developed and encouraged for use, e.g., storage in the open on plinths which is cheaper than silos, native underground pits in the far Northern parts of Nigeria but the problems encountered with the Cyprus bins in Kenya should be avoided.

The design and fabrication of storage structures should not be regarded as an engineering problem alone but should involved other relevant disciplines such as, biology, pest management and agriculture.

Administrators and financial controllers should be made to appreciate the importance of releasing sufficient funds and quickly to carry out critical operations in storage.

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EuroTier '93
The International DLG Exhibition for Livestock and Poultry Production and Management
June 22-25, 1993
Hanover, Germany

The exhibition reports excellent registration figures. Some 800 exhibitors from all over the world will be presenting their innovations and further developments on a net floor space of approx. 47,000 m^2. The German Agricultural Society (DLG) as organizer considers this result to be a confirmation for its new concept of combining pig and poultry production with milk and beef production.

Visitors to "EuroTier" will thus enjoy the opportunity, unique in Europe, of obtaining comprehensive information about the trends in these branches. All the leading manufacturers of inputs and technologies for these sectors will be represented at "EuroTier '93".

AGRITECHNICA '93
World Market of Agricultural Technology
Frankfurt am Main Germany
November 30-December 4, 1993

Excellent registration figures-Crucial test market for future sales developments

Shortly after the closing date for stand applications the International DLG Exhibition for Plant Production "AGRITECHNICA '93" already reports excellent participation by manufaturers of agricultural machinery from all over the world. According to the information supplied by the organizer, the German Agricultural Society (DLG), the global market leaders in the branch will be presenting their innovations and further developments.

Alongside large community participation from France, Italy and Netherlands, direct exhibitors from Greece, Portugal, Slovenia and the Ukraine will be facing the chalenge of international competition with their exhibits for the first time. "AGRITECHNICA '93" thus impressively underlines its leading position as world market for agricultural technology.

Europe's crucial event for the market in 1994/95

The registration figures to date also show that the agricultural machinery industry and the suppliers of accessories and spare parts are placing their expectations on highly qualified, international visitors to "AGRITECHNICA". The resolutions passed on agricultural reform in the EC have set clear signals. The farmers now know that they have to orient their production more strongly to the conditions of the free market. Rationalization measures will play a dominant role in the farms.

In order to be able to implement these activities, however, as well as to conform with the growing demands in connection with environmental issues, farmers are now more than ever in need of the innovation potential of the agricultural machinery industry. The manufacturers will be presenting their latest technical solutions in Frankfurt am Main. "AGRITECHNICA '93" will concentrate the demand of the world's largest market and, against the background of an investment backlog which has built up in years of uncertainty, will provide essential information about sales developments in 1994 and 1995. This further enhances the exhibition's status as Europe's crucial event for the market.

Innovation market for plant production technology

"AGRITECHNICA '93" shows the complete programme of technology for modern plant production. The bandwidth ranges from technology for cultivation of the soil to sowing, fertilizing and plant protection, from overhead irrigation to harvesting technology, harvest conditioning and processing. Special sectors such as "SILVATECHNICA" for forestry technology and the fields of landscape care, the environment and municipal applications complete the picture. In addition forum sessions and discussion panels on topical themes will be in the eye of the international visitors to "AGRITECHNICA".

Further information on "AGRITECHNICA '93" is available from the German Agricultural Society (DLG), Eschborner Landstrasse 122, D-6000 Frankfurt am Main 90, Germany, telephone (0) 69/24788-0 or telefax (0) 69/24788-110.

Australian International Farm Machinery Exhibition
Sydney Convention and Exhibition Centre
May 18-22, 1994

The Exhibition will be focused at the markets of the Asia-Pacific nations, which at this time feature improvement of living standards and economic growth above world averages, and it is realistic to consider this region as a positive and potential market for all types of agricultural machinery and equipment and services appropriate to agricultural production.

It is planned the number of exhibitors will be near to four (4) hundred and will represent product and services covering all aspects of agricultural production including all Farm Machinery Manufacturers, Distribu-

(Continued on page 80)

NEW PRODUCTS

The mission of the Committee to Encourage Technical Research is to show the advantages of the technical achievements of French and foreign manufacturers which are exhibited at the SIMA, offering a character of novelty or original improvements which can be considered as progress in the field of agricultural mechanization.

No. 1 Gold Medal
Starch Meter for the Control of Maturity
by Copa Informatique S.A.

This new device, based on the "iodine method test" method, replaces visual interpretation by a system of automatic measuring by means of a small portable box in which is integrated the computer and the image sensor. The non-subjective measuring of the coloured surface in relation to the total surface of a half apple, gives a very reliable indication of the maturity and of the quality.

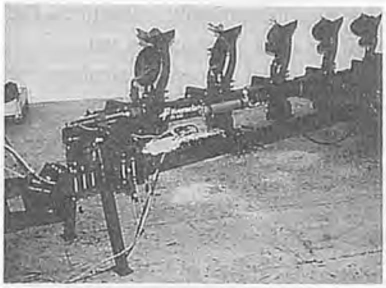
The CCD camera of the "AM92" replaces the eye of the specialist. Its presentation in the form of a small box makes for easy use.

No. 2 Gold Medal
Milking Robot for Cows
by Diabolo Manus S.A.

In order to reduce the burden of twice daily milking, this, the first milking robot developed by several research teams and european industrialists (French and Dutch), milks the cows as a "self service", at the same time distributing their ration of concentrates.

A double stall can milk 80 to 100 cows, 3 times a day, without any manual assistance both improving the productivity of the herd and reducing stress.

No. 3 Gold Medal
Electronic Management for Ploughs
by Kverneland Blanchot S.A.



Available on the market for the first time, a control and check panel manages all the functions of the plough and its settings.

Within this general concept, the principal invention consists of a labour saving electronic adjustment of the plough shares. The plough is equipped with "Non Stop" hydraulic safety devices. The pressure in the hydraulic circuit comes from the tractor hydraulic system using a control valve (a displacement controlled electro-valve).

The potentiometric control of the first share registers, in real time, the resistance of the soil. The signal from the potentiometer is digitalized and transmitted to the microprocessor. If the displacement of the beam of the plough is greater than the programmed value, the processor orders an increase in pressure by means of the electrovalve. In the opposite case, the system always tries to reduce the pressure.

No. 4 Silver Medal
Programmable Robot for the Management of Top Dressing
by Agram S.A.

The object of this on-board electronic device is to improve the application of fertilizers. The control system of the spreader regulates the delivery of fertilizer in proportion to the speed in order to ensure the pre-programmed coverage rate.

The ease of use of the control panel permits an electrical control of opening and closing of the delivery gates as well as a display of the principal spreading parameters (forward speed, area, programmed coverage/hectare, corrected coverage/hectare). In fact, a precision tool for fertilizing.

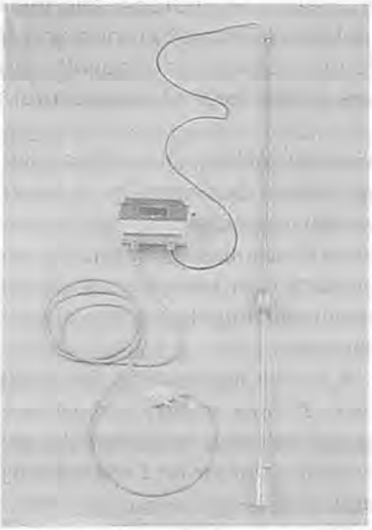
No. 5 Silver Medal
Folding Cutter Table
by Claas France S.A.

In order to reduce the size of a combine harvester to the limits authorized allowed for traffic on public highway, a new automatic folding cutter table is now available.

No. 6 Silver Medal
Pneumatic Sowing Drill Mounted on a Combine Harvester
by Horsch (SBM-Meunier Bruno)

Fitted to a combine harvester and mounted just behind the cutter table, the "SBM" pneumatic drill has a variable delivery sowing system controlled by a friction driven tilting wheel. Seeds are placed without working the soil. The straw and cuttings ensure a homogeneous cover retaining the humidity and ensuring germination and a good start to the plant.

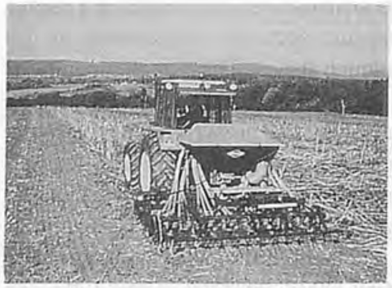
No. 7 Silver Medal
Device for Measuring the Volume of Milk Contained in a Cooler
by Ste Hugonnet (JAPY)



In order to remove the inconveniences of measuring volume using a graduated gauge in storage valts, the interpretation of the measure and its transmission, this magnetostrictive sensor automatically measures the position of a float in the vat.

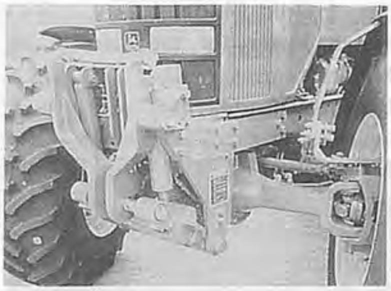
The central processor calculates the milk volume in real time. This information is displayed on a screen but can, if necessary, be stored in memory or transferred to a portable terminal, as well as printing out a ticket.

No. 8 Silver Medal
Device for Drilling in the Presence of Vegetable Residus
by Kuhn S.A.



The "Flexidrill" is a drill little attached by residus. It is fitted to in-line grain drills to give accurate placement of the seed in the soil.

No. 9 Silver Medal
Front 3-Point Linkage with Integrated Electronic Control
by Laforge S.A.R.L



This three point linkage has been developed to be compatible with the linkage of front loaders together with the use of a front power take-off. Amongst other advantages it has a sideways float movement, so avoiding problems with torsion.

No. 10 Silver Medal
Multi-purpose Precision Drill
by Nodet-Gougis S.A.

This multi-purpose precision drill is adapted to the sowing of cereals and brings to in-line drills the quality of precision necessary to all good drilling, that is to say, regular spacing between seeds and uniform depth.

With three rows of ploughshares the minimum distance is 12.5 cm between the rows. This distance is amongst the smallest available on machines today. ■■

Mechanized Annual Cropping on Low Fertility Acid Soils in the Humid Tropics—A Case Study of the Zanderij Soils in Suriname

(Netherland)

Edited by B.H. Janssen; J.F. Wienk

This report is based on research carried out jointly by the Faculty of Natural Resources of the University of Suriname and Wageningen Agricultural University, the Netherlands. The project, entitled 'The permanent cultivation of rainfed annual crops on the loamy soils of the Zanderij formation', was formulated within the context of a formal agreement for research cooperation between the two universities. Its justification was found in the interest the Suriname Government had in the future agricultural developments of these low fertility acid soils.

Although the project officially started in 1977, the research was a continuation of investigations initiated five years earlier by the Centre for Agricultural Research (CELOS) and the Agricultural Experiment Station. The project was discontinued at the end of 1983 when circumstances beyond the partners' control prevented the agreement from being renewed.

CELOS served as the project headquarters and supplied laboratory, technical and administrative facilities, and personnel. Its director was the official project administrator.

The field work was carried out partly on the project's own experimental farm at Kabo, and partly on the Coebiti farm of the Experimental Farms Foundation (STIPRIS). STIPRIS provided support for this work at Coebiti by making personnel, land and equipment available.

The research was monitored by the 'Begeleidings Commissie Suriname projecten' (Technical Steering Committee) consisting of members representing both universities and the Suriname Ministry of Agriculture. General matters regarding the cooperation between the two institutes were the responsibility of the bipartite 'Samenwerkings Overeenkomst Commissie' (Cooperation Agreement Committee).

The publication in its present from is the edited version of an interim report prepared in 1982 by the project staff under the supervision of the teamleader Dr. J.F. Wienk. Dr. B.H. Janssen of the Department of Soil Science and Plant Nutrition of Wageningen Agricultural University, who was involved in the supervision of part of the research, rewrote some chapter and edited the final report. In the last stages of this work he was assisted by Dr. J.F. Wienk.

The study shows that mechanized annual cropping in this ecologically problematic part of the tropics presents a number of problems which so far had not come to light and therefore had not been taken into account. The results provide a useful contribution to the existing information on the management of low fertility acid soils when used for annual cropping.

Size: 24cm × 17cm, Pp 230, Softcover Published by Wageningen Agricultural University, P.O. Box 9100 6700 HA Wageningen, Netherlands.

Small Sprayer Standards, Sofety and Future Directions for Asia

(Philippines)

By J.J. Hastings and G.R. Quick

The use of pesticides has been and for the foreseeable future will remain to be, both necessary and essential to help us meet the ever-increasing need to provide enough food of sufficient quality to feed the world burgeoning population. However, pesticide use must be resticted to a "need-based" application and always be applied in a safe and effective manner. Similarly, pesticides must be used only as a complimentary measure with other crop protection methods such as varietal resistance, cultural control, biological and physical control, in an integrated pest management approach. If not, pest populations may escalate at the expense of crop yields, increased production cots, food quality and environmental contamination.

More than 5 million small sprayers are sold annually, the majority of which are sold in Asia. The individual investment in lever operated knapsack sprayers typically range from $10-$120. The quality of a number of these sprayers, and their ability to be used to apply pesticides accurately and efficiently, is a concern.

The November 1991 Workshop on Small Sprayer Standards, Safety and Future Directions, with experts drawn from various Organizations from eleven countries, having experience in a wide range of fields was initiated by IRRI, under the auspices of an ADB-funded technical assistance grant (TA #5349), to establish practical and effective solutions to the problems of small sprayer use in Asia.

The intensive three day workshop proved extremely successful, meeting all four objectives. Clear recommendations on each objective were drafted. The country reports provided clear accounts of the current state of small sprayers in each of the Asian countries represented. This information will be used as part of a data base, needed in each target country, to full implement the workshop recommendation.

The working group sessions provided an excellent opportunity for delegates to plan and develop strategies and recommendations on each of eight key areas. The first four concerning spray equipment, in order to assist with the development of a set of minimum standard specifications for level-operated knapsack sprayers. They included improving aspects concerning sprayer quality, safety and ergonomics and intermanufacturer component compartibility. The other four areas related to strategies which would allow the practical and effective implementation of new sprayer standards throughout the Asian region. Specifically these were, developing training strategies for the various target groups, developing training network across Asia, implementation of the minimum standard specifications for LOK sprayers and ensuring overall program continuity.

As a direct output of the workshop, a set of draft minimum standard specifications for lever operated knapsack sprayers (LOKS) was developed. This is to be registered with the International Standards Organization (ISO). It will serve as the basis for an Asian regional implementation program aimed at providing solutions to more efficient pesticide application using small sprayers. The introduction of this program will specifically result in improved application efficiency, less operator exposure and less environmental contamination, in both rural and non-rural sectors.

To follow through on this workshop, coordination between policy makers, NGO personnel, manufacturers, training institutions, farmer groups and farmers will be essential. The planned implementation program will help foster this coordination. The results of this workshop have provided clear directions from which fresh approaches to safe and effective pest management can be manifested to enhance sustainable crop production.

Size: 27 cm × 21 cm, Pp 185, Softcover. Published by International Rice Research Institute, P.O. Box 933, Manila 1099, Philippines

New Books from the American Society of Agricultural Engineers 2950 Niles Road, St. Joseph, MI 49085-6959, U.S.A.

Drainage and Water Table Control: Proceedings of the Six International Drainage Symposium. 501 pp., 6 × 9 in., softbound, $54.00 List.

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(News *continued from page 76)*

tors, Farmers, their Families and End Users. All Rural Influentials, including Political Parties/Companies, Organizations with an interest in Rural Products and Affairs and Media Groups.

For information contact: Jessica Godfrey, Director Co-ordinator Australian International Farm Machinery Exhibition Pty. Ltd. 3 Cosgrove Road, Enfield, NSW 2136. GPO Box 4513, Sydney, NSW 2001 Australia. Phone: (02) 642 6444, Fax: (02) 642 8241

ASAE Adopts Standard to Classify Agricultural Cabs for Environmental Air Quality

Criteria for defining agricultural tractor and self-propelled vehicle cabs offering dermal and/or dermal and inhalation protection against pesticides is now available in ASAE Standard S525, Agricultural Cabs—Environmental Air Quality—Definitions, Test Methods and Safety Practices.

S525 is the first ASAE standard written using the International Organization for Standardization (ISO) format. The ASAE subcommittee (PM-03/16) that developed the standard included ASAE members and representation from the Environmental Protection Agency (EPA), the National Agricultural Chemical Association, state environmental departments, plus cab and filter manufacturers.

Further research work is required to identify types of cab filters and the length of time protection is provided when operating in areas where specific pesticides exist so that a standard addressing filter types and breakthrough identification/warning can be developed. Anyone wishing to participate in the development of breakthrough technology for cab filter systems is invited to contact ASAE Standards Director Russ Hahn for further information.

Companies and organizations who are current constituent supporters of the ASAE Cooperative Standards Program (CSP) may obtain free copies of S525 through the ASAE Order Department at 616-429-0300, Ext. 41 (Eastern Time Zone) or FAX 616-419-3852. ■■

INSTRUCTIONS TO AMA CONTRIBUTORS

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

Criteria for Article Selection

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

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

Rejected/Accepted Articles

a. As a rule, articles that are not chosen for AMA publication are not returned unless the writer(s) asks for their return and are covered with adequate postage stamps. At the earliest time possible, the writer(s) is advised whether the article is rejected or accepted.
b. When an article is accepted but requires revision/modification, the details will be indicated in the return reply from the AMA Chief Editor in which case such revision/modification must be completed and returned to AMA within three months from the date of receipt from the Editorial Staff.
c. "The AMA does not pay for articles published. However, the writers are given collectively 5 free copies (one copy air-mailed and 4 copies sent by surface/sea mail) of the AMA issue wherein their articles are published. In addition, a single writer is given 25 off-prints of the article and plural writers are given 35 off-prints (also sent by surface/sea mail)"
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Procedure

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b. Contributors of articles for the AMA for the first time are required to attach a passport-size ID photograph (black and white print preferred) to the article. The same applies to those who have contributed articles three years earlier. In either case, ID photographs taken within the last 6 months are preferred.
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Format/Style Guidance

a. Whether the article is a technical or popular contribution, lecture, research result, thesis or special report, the format must contain the following features :
   i) a brief and appropriate title ;
   ii) the writer(s) name, designation/title, office/organization ; and mailing address ;
   iii) an abstract following ii) above ;
   iv) body proper (text/discussion) ;
   v) conclusion/recommendation ; and a
   vi) bibliography
b. The pages must be numbered (Arabic numeral) successively at the top center. Tables, graphs and diagrams must likewise be numbered. Table numbers must precede table titles, e.g., "Table 1. Rate of Seeding per Hectare". Such table number and title must be typed at the top center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e.g., "Figure 1. View of the Farm Buildings".
c. Tables and figures must be preceded by texts or discussions. Inclusion of such tables and figures not otherwise referred to in the text/discussion must be avoided.
d. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
e. Express measurements in the metric system and crop yields in metric tons per hectare (t/ha) and smaller units in kilogram or gram (kg/plot or g/row).
f. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
g. Convert national currencies in US dollars and use the later consistently.
h. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
i. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers..., or Five tractors..." instead of 45 workers..., or, 5 tractors.

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