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VOL.21, NO.2, SPRING 1990

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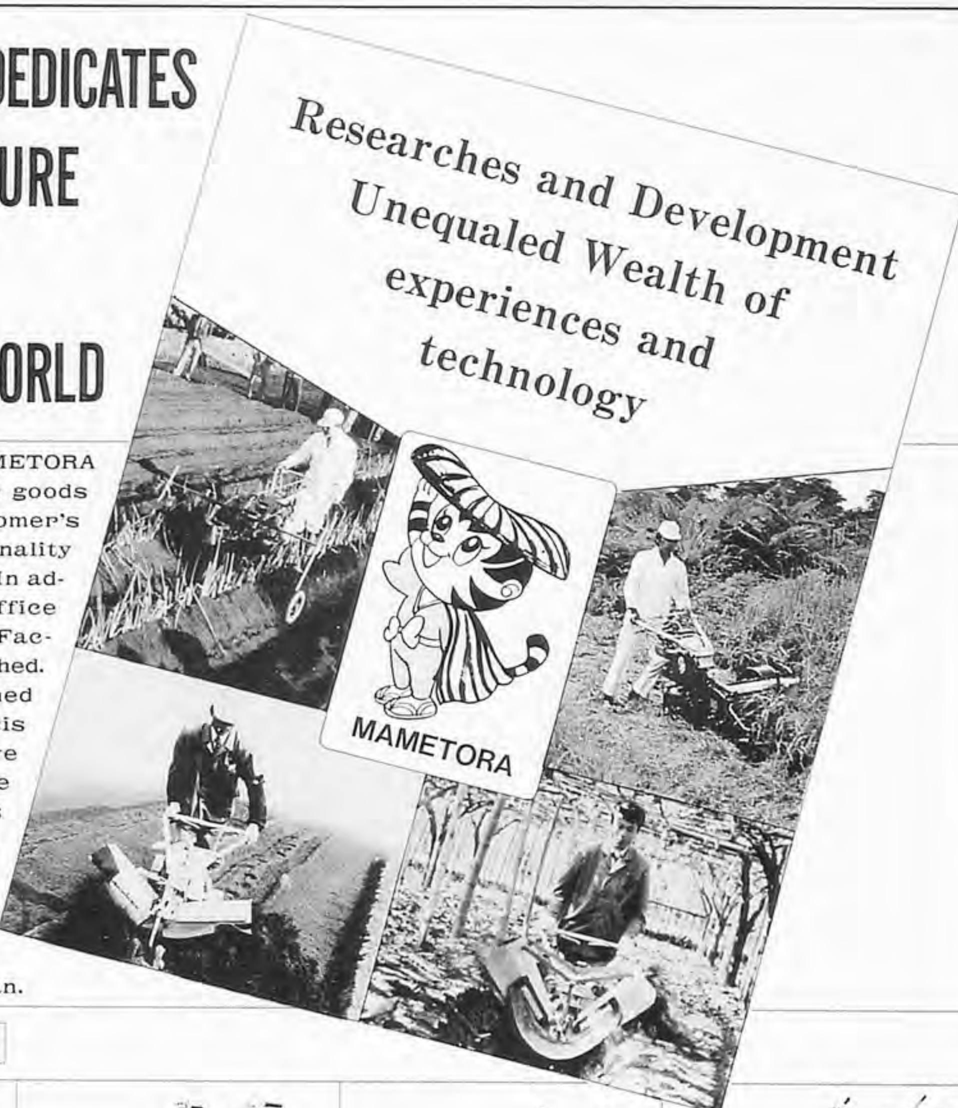

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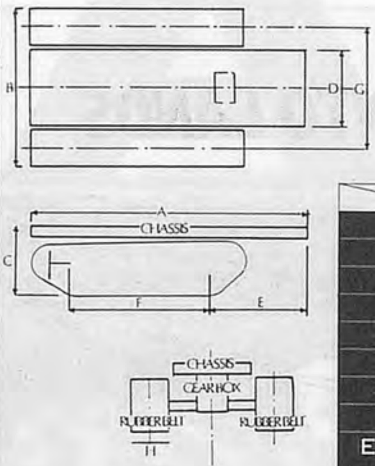

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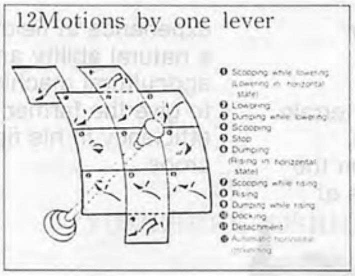

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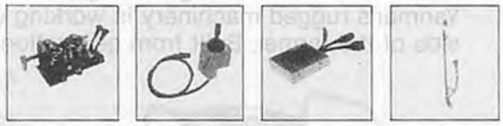

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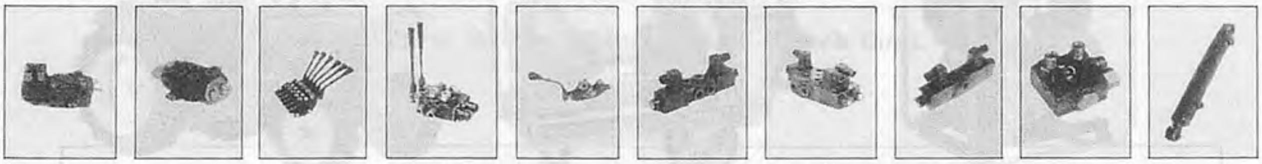

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EDITORIAL

A Question of Need Over Profit

I seldom fail to attend the annual agricultural machinery show-SIMA in Paris, France and other international exhibits on the same subject. The reason is obvious – agricultural machineries have since been part of me. And from the exhibits and shows, I almost always come away the wiser: with new innovations observed and useful lessons learned which I could share with others through the AMA and other media.

The most recent agricultural machinery show that I attended in early March, 1990 in Paris has left in me a very deep impression that I wish to share with AMA readers because it carries an important message, particularly for the manufacturers of agricultural machineries and equipment. This was a result of my observations of the exhibits at the 5th Pavillion, in particular, the booth of the Centre d'Etudes et d'Experimentation du Machinisme Agricole Tropical (CEEMAT).

In one section of the CEEMAT booth was a complete line of familiar-looking farm machineries and equipment that were evidently designed and developed for use in developing countries. The display overwhelmed me and I thought that it was a wonderful sight – for a change vis-á-vis the large and sophisticated exhibits in other booths. I could not recall having seen a similar display in many other international exhibits that I attend.

I could not contain my enthusiasm nor was I content in just appreciating the exhibit, hence I took time out to interview one of the exhibitors in order for me to fully reconcile why all of a sudden the manufacturers designed those machineries and implements and whether they would sell for a profit.

The response of the exhibitor was simple and straightforward when he intimated that those machineries for use in developing countries are not expected to sell for huge profit but that the manufacturers are acutely aware that THERE IS NEED for those machineries in developing countries.

The response was thought-provoking for a while and it struck me that the farm machinery manufacturers, big businessmen as they are, are not only casting their lot in the manufacture of models for use in developing countries but are also cognizant of the fact that indeed, there is need for those machineries in the Third World. Others will probably label this gesture of the machinery manufacturers as a kind of "loss leader". And even if this is the motive behind it, I still continue to pay great respect to those forward-looking entrepreneurs for understanding the needs of the time in developing countries.

The message of the response seems to address itself to governments in developing countries, to other farm machinery manufacturers and to aid givers that the needs in the developing countries must be met–for which those displays at the CEEMAT booth are intended to provide the lead.

May all others follow the lead! AMA, for one, will follow by playing up the message in this editorial and to promote the manufacture of farm machineries and implements for developing countries in subsequent issues.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
April, 1990

CONTENTS

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Effect of Implement and Soil Parameters on Penetration Depth of a Disc Plow

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Abstract

The effect of tilt angle and soil moisture content on the depth of penetration of a disc plow was determined in varying soil conditions. The experiment was conducted in three types of soils with five different moisture levels for four different tilt angles of the disc plow. It was observed that the depth of penetration decreased with the decrease in soil moisture content and increased with the decrease in tilt angle. At 16° tilt angle, the depth of cut was maximum at 9.3, 8.3 and 9.2% moisture content in clay-loam, sandy and sandy loam soils, respectively. The relationship among the depth of cut, soil moisture content and tilt angle was developed for each type of soil and it was found to be a power function with the depth of cut as dependent variable and moisture content of the soil and tilt angle of the plow as independent variables.

Introduction

Gordon (1941) studying the soil reaction on plough discs reported that the depth of cut of disc plough (66 cm diameter with 20° tilt angle) varied from 5 cm to 15 cm at a speed variation of 2.58 km/h to 9.8 km/h in a soil with a moisture content of 15.9%. McGreery and Nichols (1956) reported that the weight of the disc was the most important factor in penetration. Singh et al (1978) conducted a study to determine the effect of soil, implement and operating parameters on depth of penetration of a disc harrow. Considering the depth factor, operating factor and penetration factor they developed an equation for predicting the depth of penetration. Nakra (1987) described that the depth of penetration depends on the weight, disc angle and tilt angle of the plough disc. He reported a disc angle of 50° and tilt angle of 18° to be appropriate for average ploughing conditions.

Disc ploughs are now used increasingly for multi-purpose uses. A knowledge of tilt angle and soil moisture content is essential in deciding the depth of penetration as the former parameters greatly influence the later. The experiment reported here was undertaken to study the effect of soil moisture content and tilt angle on the depth of cut of a disc plough for three different types of soils and to establish a relation among them in the form of an equation for each type of soil.

Materials and Methods

The experiment was conducted in the Central Farm, OUAT, Bhubaneswar, India in 1985. Three types of soil (clay-loam, sandy and sandy-loam) were considered. The soil texture was determined by bouquous hydrometer method. Five plots each of 20 m x 40 m size were laid out in each type of soil to obtain five different moisture levels. The average moisture content of each plot was determined by gravimetric method by taking samples from different places. The

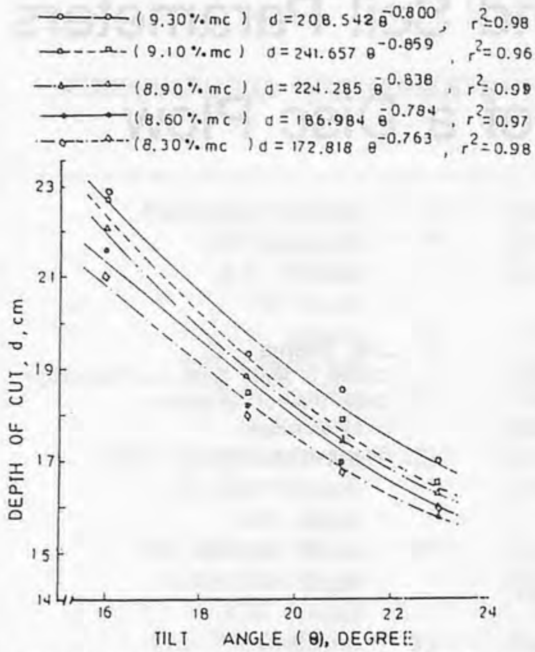

Fig. 1 Depth of cut and tilt angle of disk plough at 50° disc angle for different moisture contents (% dry weight) in clay loam soil.

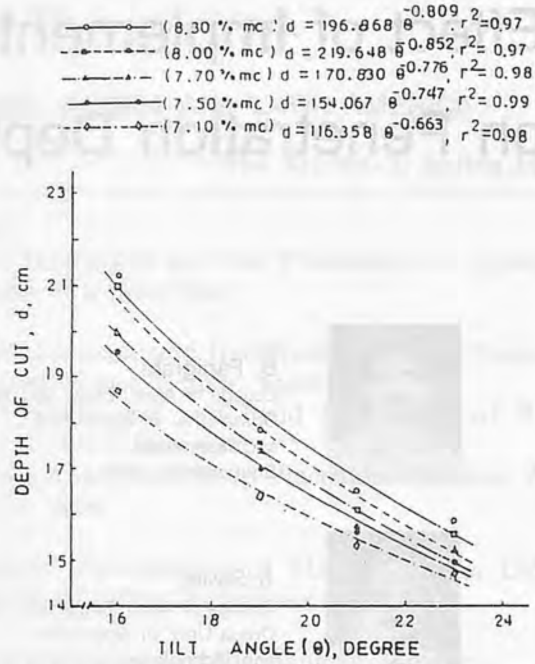

Fig. 2 Depth of cut and tilt angle of disc plough at 50° disc angle for different moisture contents (% dry weight) in sandy soil.

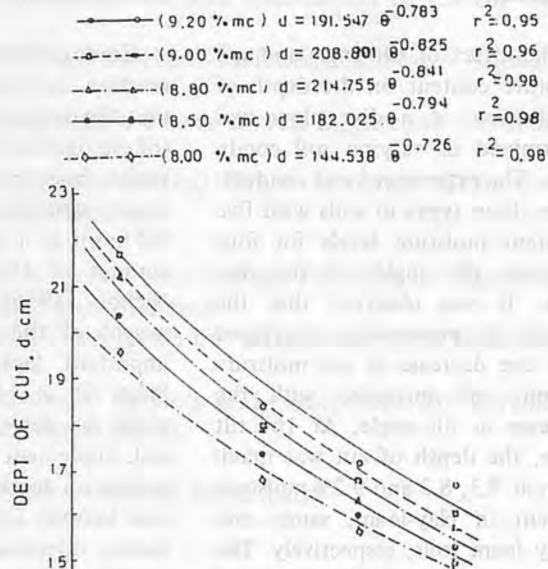

Fig. 3 Depth of cut and tilt angle of disc plough at 50° disc angle for different moisture contents (% dry weight) in sandy loam soil.

moisture content was expressed in dry weight basis.

A two-bottom tractor mounted disc plough with an International B-275 tractor was used for the experiment. The depth of penetration of the disc plough was measured in each plot for 4 different tilt angles (16°, 19°, 21°, and 23°) at 50° disc angle. The average depth of cut for each plot was obtained from 15 observations taken for each tilt angle. The effect of various parameters on depth of cut was tested by least square method (Hann, 1977).

Results and Discussion

The results of the experiment conducted in 3 different soil textural classes at five moisture levels and four tilt angles are presented in Figs. 1, 2 and 3.

The observations Figs. 1, 2 and 3 indicate that the relationship between the tilt angle and the depth of penetration is represented by a power function. The depth of cut decreases with increase in the tilt angle. Increasing the tilt angle, within the range of 15° of 25°, normally encountered in disc ploughs, increases the draft and the vertical upward force but reduces the measured side draft. Thus, penetration is reduced at higher tilt angles (Kepner et al, 1987). For a given tilt angle, the depth of penetration is lowest in sandy soil and exhibits higher value from sandy to sandy loam and clay loam in that order. The depth of penetration is greater at higher moisture content for each soil type. The relationship between the depth of cut and tilt angle has been found to be:

$$d = A\,\theta^{B} \qquad (1)$$

where,

d = depth of cut, cm
θ = tilt angle, degree
A and B = coefficients

The equations so developed for different soils and moisture contents are presented in Figs. 1, 2 and 3 along with their r^2 values. The large values of r^2 between the depth of cut and tilt angle (r being called as coefficient of correlation) indicate that the equations developed can satisfactorily predict the depth of cut for a given tilt angle, soil moisture and soil type.

It was observed from these equations for each type of soil at each moisture content that the value of the coefficient A increased with a decrease in soil moisture up to a certain extent and then exhibited a decreasing trend as the soil moisture decreased. The value of B showed a reverse pattern of behaviour as A along with the decrease in moisture content (Figs. 1 to 3). The values of A and B are affected by soil moisture content and, hence, are expected to be functions of the latter. The relationship between each of these two coefficients and soil moisture content are found to be non-linear in the form of power functions as given below:

$$A = a_1\, m^{a_2} \qquad (2)$$
$$B = b_1\, m^{b_2} \qquad (3)$$

where,

m = soil moisture content (% dry weight basis), and a_1, a_2, b_1 and b_2 are constant soil factors.

The results of the best fit curves

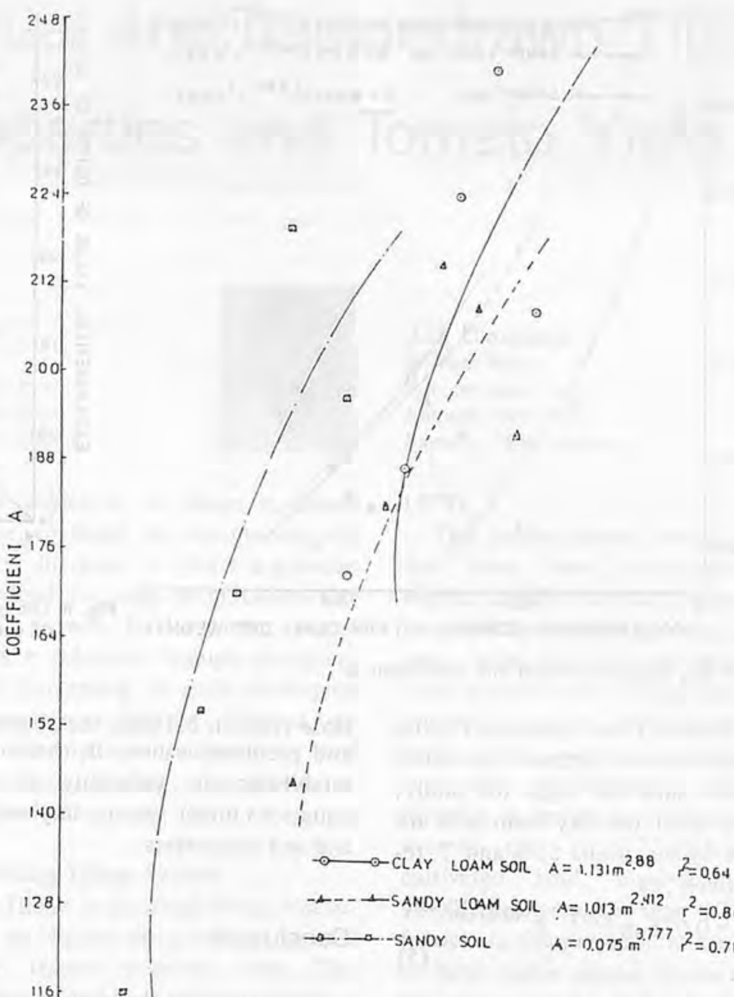

Fig. 4 Soil moisture content and coefficient A.

for A (Fig. 4) indicate that the value of the coefficient A increases with the increase in moisture content for all types of soils considered in the experiment. In the same soil moisture range, the coefficient A exhibits a higher value for clay loam than sandy loam soil. The values of the coefficient for sandy soil remains almost in the same range as that for the other two soils but for a lower range of soil moisture.

The values of the coefficient B are observed to be negative. It shows an increasing trend with a decrease in soil moisture content in all the three types of soils (Fig. 5). In the same moisture range the coefficient B shows a higher value in sandy loam soil than that obtained in clay loam soil. The nature of the power functions in these soils are more gradual than that in sandy soil.

The final general equation for the depth of cut in terms of moisture content and tilt angle is found to be:

$$d = (a_1\, m^{a_2})\, \theta^{-(b_1 m^{b_2})} \qquad (4)$$

Where,

a_1, a_2, b_1 and b_2 are constant

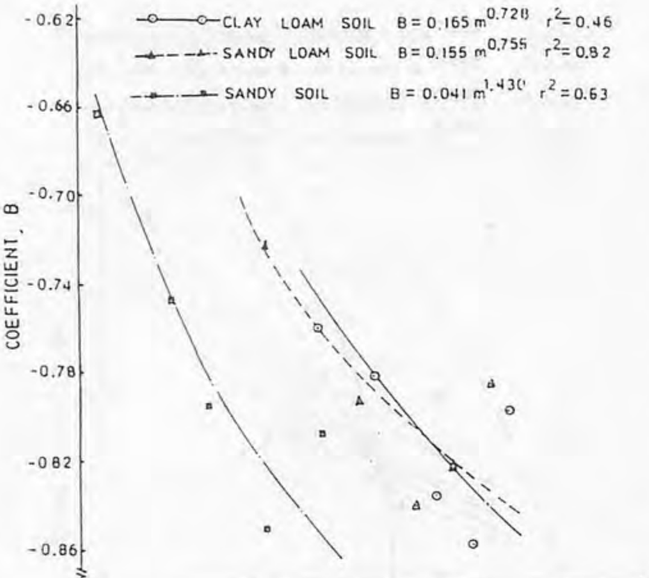

Fig. 5 Soil moisture content and coefficient B.

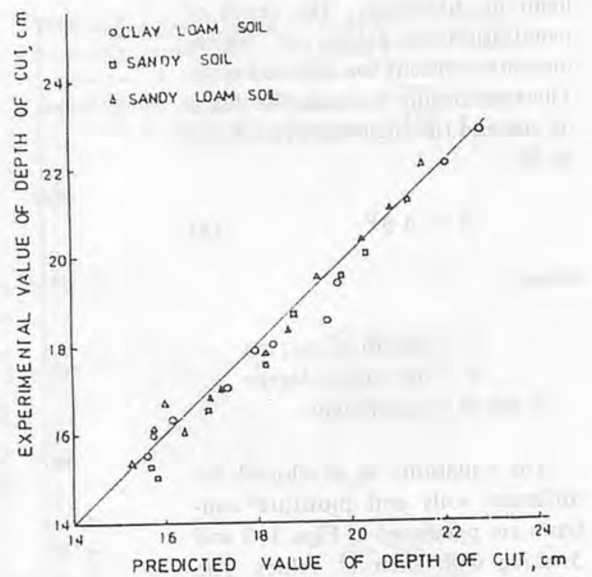

Fig. 6 The actual value of depth of cut and predicted value of depth of cut for verification test.

soil factors. Final equations for the depth of cut in terms of moisture content and tilt angle for sandy, sandy loam and clay loam soils are given by equations 5, 6 and 7, respectively, as

$$d = 0.075\ m^{3.777}\ \theta^{-(0.041\ m^{1.430})} \quad (5)$$

$$d = 1.013\ m^{2.412}\ \theta^{-(0.155\ m^{0.755})} \quad (6)$$

$$d = 1.131\ m^{2.388}\ \theta^{-(0.165\ m^{0.728})} \quad (7)$$

In all above equations 5 to 7, d = depth of cut in cm, m = moisture content (%) on dry weight basis, θ = tilt angle in degrees.

For verification of the general equations (4), field tests were conducted with a two bottom tractor mounted disc plough in different soils. The predicted values as well as the observed values are plotted in Fig. 6. The results indicate very close relation between the observed and predicted values. It, therefore, establishes the versatility of the equations under varying implement and soil parameters.

Conclusion

It is observed that a decrease in tilt angle, within the range normally available on disc ploughs, increases the depth of cut. The increase in soil moisture content increases the depth of penetration. For a given tilt angle and moisture condition, the depth of cut is highest in clay loam followed by sandy loam and sandy soil in that order. The effect of tilt angle and moisture content on the depth of cut of disc plough is expressed in the form of a power function. The close relation between the observed and predicted values establishes the versatility of the equation.

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Influence of Manual and Tractor-drawn Tillage Tools on Soil Properties and Tomato Yield

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Abstract

The influence of manual and tractor tillage tools on soil properties and yield performance of tomato were investigated on sandy-loamy soil. Three tillage treatments were compared: no-tillage (NT), manual tillage (MH) and tractor tillage (TD).

Both the manual and tractor tillage tools significantly influenced the soil dry bulk density and penetrometer pressure with the tractor tillage tools providing the deeper and better soil tilth.

The tomato on the tilled plots matured earlier than the untilled plots. The total fresh fruit yield in the manual and tractor plots were 67 and 157%, respectively, higher than on the untilled plots.

Introduction

Agricultural soils are constantly subjected to onerous pressure arising from vehicular traffic and climatic changes. Top soils generally lack sufficient strength to absorb these pressures which usually result in their compaction. Research has shown that compaction due to vehicular traffic or climatic changes on agricultural land results in low infiltration rate, soil erosion, restricted root growth and reduced crop yield (Dunham, 1982). One of the objectives of tillage is, therefore, to break the compacted soil layer in order to create a suitable seedbed for seed germination and crop growth. In the tractor system this is achieved through ploughing and harrowing. In such developing countries as Nigeria, tillage is one of the major labour-intensive and energy-demanding operations in agriculture.

Existing Tillage System

Tillage is currently being practised in Nigeria using manual, animal and tractor powered tools. The common manual tillage tool is a hand hoe. Hand hoes are constructed of curved wooden handles and soil shearing metal blades. The different types of hand hoes are ridging and bedding hoes (garma)* and wedding hoes (fartanya)*. The tillage hoes vary in size and shape from one geographical location to another (Musa 1979). The limitations of the manual tillage tools stem from man's limited power output (about 0.1 hp continuous) and the drudgery associated with them. Musa (1979) reported that the time involvement for manual tillage tools could be as high as 200 man-hours per hectare. Over 90% of the farmers in Nigeria are dependent on some type of hand hoes as the major tillage tool (Kaul, 1979).

The animal drawn tillage tools that have been introduced in Nigeria include Ariana, Unibar and Emcot-Ridger. Investigations, however, reveal that although most of these animal-drawn tillage tools are potentially useful, they have not been widely adopted for lack of availability and inadequate training of users. A survey in a project area showed that on 322 400 ha of cultivated land, involving over 80 000 farmers, less than 17% of farmers in the project area had one or more viable animal drawn tools (one pair of oxen and at least one plough) (Kaul, 1979). The cost of owning these animals as well as the prevalence of such animal killer diseases as tse-tse fly have limited the use of animal-power in some areas of the country.

The tractor powered tillage tools include disc and mould board ploughs, disc harrow, disc and mould board ridgers, rotary tillers, and other subsoilers of which only the disc and mould board ploughs, disc and mould board ridgers, and disc harrow are commercially avilable in Nigeria. An example of each system in operation is illustrated in **Fig. 1**.

The advantages of the tractor-drawn tools over the other two types, especially in terms of greater output, has been fully established (Kepner et al, 1977; Kaul, 1979;

*Local (Hausa) names for hand hoe.

Fig. 1 The three existing tillage system: a) Manual, b) Animal and c) Tractor

Musa, 1979). However, concern is growing over soil compaction due to excessive machinery traffic. With particular reference to developing countries, the cost of owning a tractor is beyond the financial means of majority of the farmers. In Nigeria where the government has introduced Tractor Hiring Unit (THU), other problems have emerged. Where the facilities were available, they were quite limited: it has offered services in land preparation only due to non-availability of essential tools for other operations. This leaves the farmers to handle the subsequent operations with traditional hand tools. Another glaring consequence of tractorization is the lack of appropriate implements to control weeds. This results in the farmer having to give up at least part of the ridged land at some stage of the production process.

In most developing countries, farmers producing such crops as cereals and legumes have largely adopted the use of tractors for their seedbed preparations where such facility is readily available. However, farmers of horticultural crops have been very reluctant to use the tractor system for their seedbed preparation. This is largely due to their preconceived idea that the tractor system will not provide the much needed good soil-tilth which is required for growing these crops. Tomato is one of the tender crops mostly grown by the peasant farmers. Its production has always, therefore, involved intensive seedbed preparation as well as subsequent weeding operation. In order to ensure a good tilth for tomato seedbed the farmers rely quite conservatively on hand hoe for seedbed preparation. As a result the tomato growers manage only small size farms, varying between 0.1 ha and 0.4 ha per farmer (Quinn, 1975). However, the advantage of mechanization, even for tomato production, has been fully established world-wide. Hence, each of the tillage systems has a place in tomato production in developing countries.

Several tillage studies conducted by Ofori and Nandy (1969); Kang and Yinusa (1977); Lal (1979) Agboola (1981); Dunham (1982); Oni and Adeoti (1986) and Ike (1986) have shown that crop yield varies with the location, environment, soil and crop types. Most tillage studies in Nigeria are on maize (Lal, 1979; Agboola, 1981).

The objectives of this investigation were to study the extent to which the manual and tractor tillage tools could loosen loamy soil and the resultant effect on the growth and yield of tomato.

Materials and Methods

The experiment was carried out under rainfed condition on a sandy-loam soil at Samaru, Zaria which is situated within the Northern Guinea Savanna Zone and lying within latitude 9°N and 13°15'N. The cropping season usually starts in the month of April and lasts until early October, a period of about 6 months.

The three tillage treatments consisted of No-Tillage (NT), Manual/ Hand Hoe Ploughted (MH) and Tractor Disc Ploughed disc Harrowed (TD), respectively (**Table 1**). A randomized complete block experimental design with three replications were used for the investigation.

The initial land preparation consisted of clearing of previous season crop remains and newly emerging weeds using hand hoe, with minimum top soil disturbance. This was followed by broadcasting of compound fertilizer (NPK) at a rate of 200 kg/ha. The randomized complete block design for the above treatment had a plot size of 20 m by 2 m. The plot seedbed were then prepared on the basis of the three tillage treatments. Immediately following these tillage treatments, tomato seedlings were transplanted by hand in the last week of July at 4 cm row spacing and 75 cm be-

Table 1 Tillage Treatments and Depths of Soil Disturbance

Tillage treatments and codes	Cultivation system	Description of operations	Mean depth of soil disturbance (cm)
No-tillage* (NT)	No-tillage	Seedling drilled into soil	5
Manual tillage (MH)	Hand hoeing	Old seed bed split with hoe and new seed bed made in same position	13
Tractor tillage (TD)	Tractor/disc ploughing/disc harrowing	Disc plough/disc harrowed	22

* Previous season crop residue and newly emerging weeds were removed by hand hoe.

tween rows, with 3 rows per plot. Subsequent treatments were in accordance with the normal cultural practices.

The soil values determined were soil bulk density and moisture content using core sampler. The penetrometer pressure was taken using a hand-held cone penetrometer adopting the guideline described in ASAE standards (Annonymous, 1983). These soil properties were taken before and after the tillage treatments. The plant growth was monitored and harvesting of matured tomato fruits commenced in the third week of September with subsequent harvesting conducted at weekly interval. Harvested fresh fruits from each plot were weighed.

Results and Discussions

Soil Properties

Figure 2 shows the plots of cone penetrometer pressure, soil dry bulk density, and soil moisture content against soil depth as determined immediately after the tillage operations. The No-Tillage (NT) plot is indicative of the condition of all plots before the tillage treatments. The treatment means of the measured parameters as well as the statistical analysis of the various variables are summarized in Tables 2 and 3. For each treatment the soil parameters did not show any appreciable difference with depth, except for the No-tillage treatment which showed slight increase of penetrometer pressure (Table 2). The tillage methods significantly influenced both the soil dry bulk density and the penetrometer pressure at P≦0.05 as shown on Table 3. Both the hand hoeing and tractor disc poughing - disc harrowing reduced compaction at each depth, with the tractor system indicating greater reduction (Table 2 and Fig. 2). Also, the tractor system indicated the greatest depth of

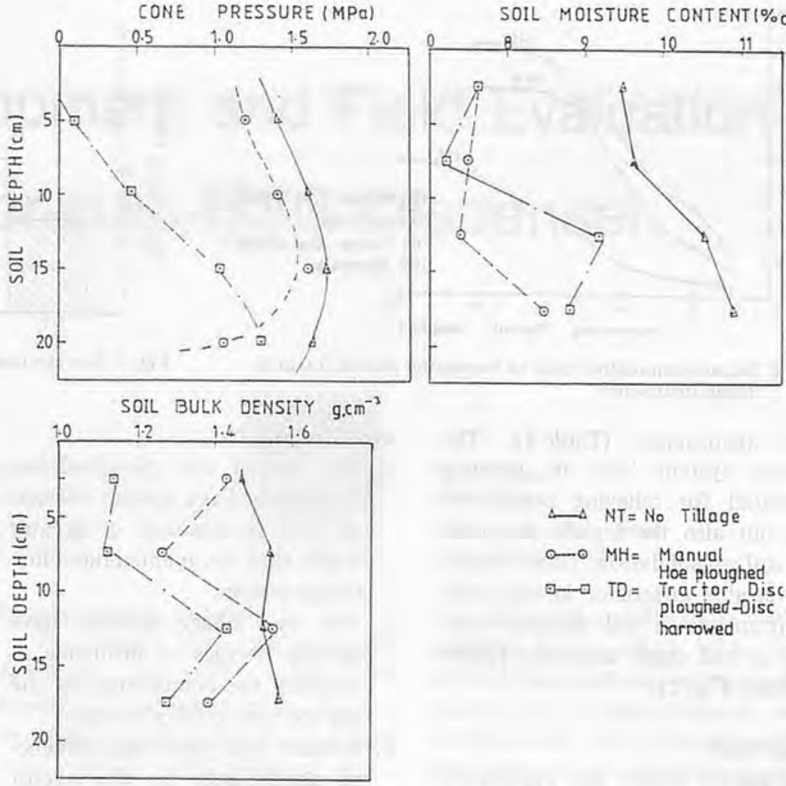

Fig. 2 Cone penetrometer, soil dry bulk density and soil moisture content vs soil depth for three tillage treatments

Table 2 Treatment Means for Measured Parameters of Soil and Tomato

Tillage treatment	Soil depth (cm)	Means of parameters: Penetration resistance (MPa)	Bulk density (g/cm^3)	Moisture content (db.%)	Yield (t/ha)
NT	5	1.40a	1.47a	9.53a	
	10	1.57ab	1.54a	9.60a	1.27a
	15	1.77bc	1.51a	10.46a	
	20	1.67ac	1.56a	10.93a	
MH	5	1.17a	1.43a	7.60a	
	10	1.4ab	1.26a	7.47a	2.13ab
	15	1.6b	1.53a	7.43a	
	20	1.06a	1.38a	8.57a	
TD	5	0.1a	1.14a	7.6a	
	10	0.47b	1.13a	7.23a	3.27b
	15	1.03c	1.43b	9.17a	
	20	1.30c	1.27a	8.77a	
S.E.D.		0.1705	0.0633	1.7801	0.5657

Note: a, b, c Means with the same letter are not significantly different at P≦5%.

Table 3 Summary of Statistical Analyses of Variance for Measured Parameters

Source of variation	D.F.	Mean squares of parameter: Penetration resist. (KPa)	Bulk density (g/cm^3)	Moisture content (%)	Yield per plot (kg)
Repetitions (R)	2	0.1526*	0.0216*	1.0486ns	2.54ns
Soil depth (SD)	3	0.5734*	0.0172ns	3.5788ns	
Tillage method (TM)	2	2.3812*	0.3784*	19.1036*	3.01ns
SD × TM	6	0.2781*	0.01918*	0.6177ns	
Residual	22	0.0436ns	0.006007ns	4.7528ns	0.48ns

Remarks: ns = Not significant at P≦5% * = Significant at P≦5%.

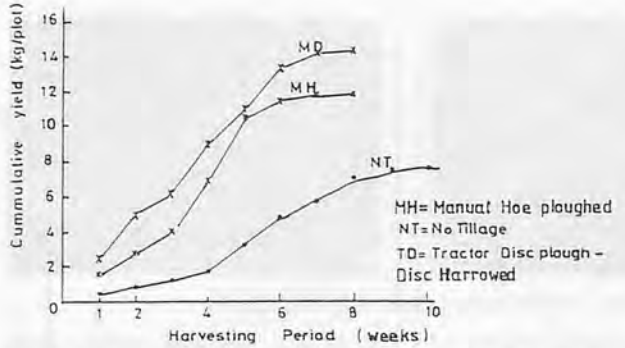

Fig. 3 Tomato cumulative yield vs harvesting period for three tillage treatments

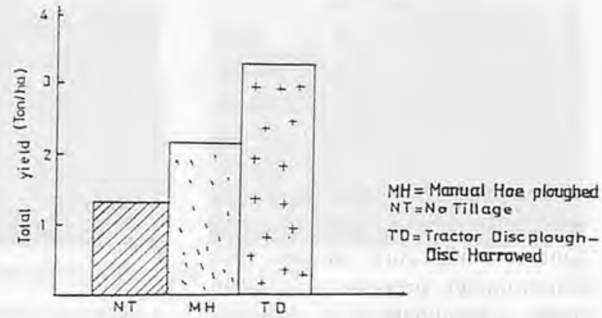

Fig. 4 Tomato total yield for three tillage treatments.

soil disturbance (**Table 1**). The tractor system had the greatest potential for relieving compacted soil but also the highest potential for soil consolidation. There was no appreciable difference in the treatment means in soil moisture content as soil depth increased (**Table 2, 3** and **Fig. 2**).

Crop Yield

Figure 3 shows the cumulative yield of tomato fruit for each tillage treatment. The tomato in the tilled plots matured earlier than the untilled plots, with tomatoes under the tractor system maturing earlier. This has an economic advantage since tomato fruit attracts higher price at the beginning of its harvesting seasons.

Figure 4 is the bar chart for the yield for each tillage treatment. The total fresh fruit yield in the manual and tractor tillage plots were 67 and 157%, respectively, higher than the No-Tillage plots. The tractor system gave higher yield than the manual system. The statistical analysis (**Tables 2** and **3**) shows that only the tractor tillage system had significant yield difference from the No-Tillage plot. This indicates that although tomato is classified as one of the shallow rooted crops according to Hussain (1986), it stands to benefit from ploughing as obtained from the tractor disc ploughed-disc harrowed tillage operation.

Conclusion

It can be concluded from this investigation that:

1. The tractor disc ploughed-disc harrowed tillage system alleviated soil compaction at greater depth than the manual-hand hoe tillage system.
2. The two tillage systems have varying degrees of influence in relieving the compaction of the top soil and yield of tomato.
3. Tomato fruit yield was influenced significantly by the tractor tillage system.
4. Tomato crops in the tilled plots matured earlier than the untilled plots. This is of economic importance since tomato attracts higher prices at the beginning of harvest season.

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Design Development and Field Evaluation of RPS Marker-cum-USG Dispenser

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Abstract

The Agricultural Engineering Research Centre, Pune, India has designed and developed a simple, low cost and high utility device to help to transplant wetland paddy with recommended plant geometry of 15 x 20 cm and to facilitate applying Urea Super Granules (USG) during transplanting at recommended rate without damaging the granules. The device is named as "RPS marker-cum-USG dispenser" (Row Plant Spacing marker-cum-Urea Super Granules dispenser).

The feasibility trials of the device were conducted at different locations, with skilled labour and also with unskilled labour. The prevailing improved method of line transplanting with USG application after 8-10 days was used as local method for comparison. It was observed that: i) with skilled labour (who are accustomed to systematic transplanting methods) the Mh/ha required for the device are 230 as against 268.44 of local method, giving a labour saving of 38.44 Mh/ha; ii) when unskilled labour are used, the Mh/ha required with the device are 510.88 as against 553.10 of the local method, giving a labour saving of 42.22 Mh/ha; iii) in the case of farmers who would get accustomed to using the device, the Mh/ha required would be considerably reduced.

The device does the intended functions efficiently with the benefit of manpower saving. It can be fabricated by local artisans using local material with minimum skill. It involves minimum and easy repairs.

Introduction and Literature Review

Rice is one of the most important cereal foods on which depends about one fourth of the world's population (Kent, 1966). It is the most important food crop of India as well as of Asia. Nearly three-fourths of the people in India subsist on it.

In recent years, the use of nitrogenous fertilizers for rice has increased greatly. Urea, in the form of prills applied to wetland paddy by the conventional broadcasting method concentrates in the flood water and surface soil where the nitrogen is very likely to be lost through NH_3 volatilization, nitrification, denitrification process and runoff. The use of urea super granules for wetland rice has several definite advantages over surface application of prilled urea (Savant et al, 1983). It substantially reduces losses of fertilizer N due to ammonia volatilization and denitrification (Craswell and De Datta, 1980; Craswell et al, 1981). When N is applied through urea super granules, placed at 8-10 cm deep in well puddled soil, in a wetland paddy, very little of the urea finds its way into the flood water. Deep placed N in the form of USG is less subjected to algal immobilization (Vlek and Craswell, 1979, Craswell et al, 1981) and to uptake by aquatic weeds (Sawant et al, 1982) than is broadcast and/or incorporated urea. These factors contribute to the improved use efficiency of USG in the wetland paddy. In addition to providing these benefits, deep placed USG by not disturbing the natural algal N-fixing systems, provides a bonus of nitrogen to the wetland soil-rice plant ecosystem (Roger et al, 1980). With USG the recovery of deep-placed N in the tops of wetland rice is greater than the N recovery from surface applied and/or incorporated ordinary urea (Sawant et al, 1983).

Many of the field experiments conducted by INSFFER (International Network of Soil Fertility and Fertilizer Efficiency for Rice) INPUTS (Increasing Nitrogen Productivity Under Tight Supply), AICRP (All India Coordinated Rice Improvement Project), IFFCO (Indian Farmers Fertilizer Cooperative Ltd.), HFCL (Hindustan Fertilizer Corporation Ltd.) IARI

(Indian Agricultural Research Institute) have shown that the deep placement of USG gives significantly higher yield than those derived from split application of urea (Savant et al, 1983). In case of wetland rice it has been shown that for four hills (2-3 plants per hill) at a plant geometry of 15 x 20 cm (hill spacing 15 cm row spacing 20 cm) one USG of 1 to 2 grams and 11 to 14 mm diameter placed centrally at a depth of 8-10 cm giving N application rate of 30-80 kg/ha) during transplanting results in higher fertilizer efficiency and significantly higher rice yields. Keeping these distinct advantages of USG in mind, a low cost, less labour involving RPS marker-cum-USG Dispenser has been designed and developed in order facilitate deep placement of USG while transplanting rice at plant geometry.

Materials and Methods

The RPS marker-cum-USG dispenser consists of the following parts (Fig. 1):

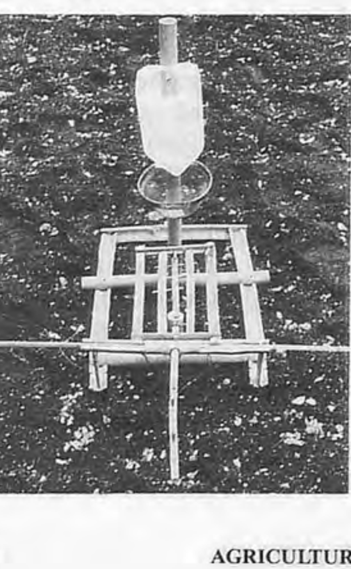
i) *Base frame with seedling tray* – A 65 x 43 cm base frame of bamboo halves provides floatation to the device on the puddle and supports the other parts. A tray, also of bamboo sticks, provided on this frame can be used for placing the bundles of seedlings during transplanting.

ii) *Markers* – The front cross support of the tray accommodated two detachable long thin bamboo sticks, named arms, each of cm length, graduated with 15 cm marks to indicate the plant/hill spacing of 15 cm.

The central member of the tray extended in the front along the length of tray to 40 cm to serve as a row spacing marker. The centre of the extended portion of 40 cm is marked with a bamboo pag. This marker helps placing rows at 20 cm spacing during transplanting.

iii) *Dispenser unit* – A dispenser unit on the handle of the device consists of a plastic box with a circular opening of 3.75 cm at the base. The opening is controlled by a circular plastic disc fixed at the end of a lever with the help of the bamboo peg. The plastic disc serves as a valve and the peg serves as an agitator, both operated by the same lever. The USG are dropped through the opening of the box into the receiver provided below and fixed on the same handle.

The RPS marker-cum-USG dispenser can be lifted or slid easily on the puddle during the transplanting operation with the help of the portion of the handle extending above the USG box. The box is covered with plastic cloth during transplanting operation for protecting the USG from getting wet due to rains.



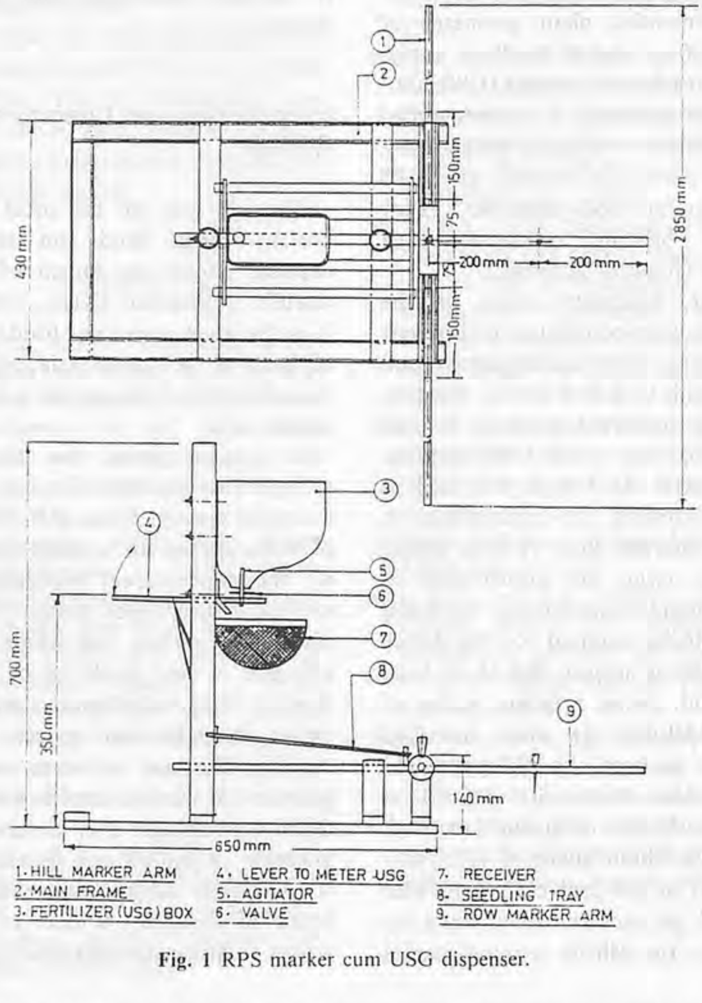


Fig. 1 RPS marker cum USG dispenser.

How to Use the Device

During rice transplanting one such device is shared by two workers, each standing on either side of the device. Each worker transplants 20 hills in 2 rows, spaced at 20 cm with a hill spacing of 15 cm. Then he gently taps the lever from below so that he receives 5 to 6 granules in a receiver. He needs 5 granules at a time for the 20 hills he has transplanted. Even with his wet and muddy hands he can pick up the granules from the receiver and can hand-place them at the rate of one granule in the centre of 4 hills. This combined operation of transplanting and deep placement of USG is continued, moving only backward and sliding the device only backwards, until the entire field is covered.

Results and Discussions

The RPS maker-cum-USG dispenser was field-evaluated in comparison with the prevailing improved practice of line transplanting at different locations, viz. Vadgaon Maval, Lonawala and Khopi. The labour at Vadgaon Maval were skilled labour whereas at Lonawala and Khopi they were unskilled. The observations are, therefore, recorded separately for skilled and unskilled labour through **Table 1** to 4. **Table 1** shows Mh/ha required for transplanting paddy and placing USG with the help of the device. If the labourers are skilled like those at Agricultural Research Station, Vadgaon Maval, who are accustomed to systematic transplanting methods, the Mh/ha required will average 230 when the device is used.

Table 2 shows Mh/ha required for transplanting rice and application of USG with the method which is prevalent in research stations and state farms, i.e., line transplanting of paddy with the help of marked rope and rod and application of USG after 8-10 days of transplanting.

When skilled labour use the RPS marker-cum-USG disapenser there was a labour saving of 38.44 Mh/ha.

Table 3 shows the Mh/ha required for transplanting rice and application of USG with the help of the device, when trials are taken on farmers fields. Here the farmers are not used to any improved methods of transplanting rice. Therefore, the Mh/ha requirements are high, i.e., average 510.88 with the help of the

Table 1 Mh/ha Requirement for Use of RPS Marker-cum-USG Dispenser (Skilled labour)

Plot size: 150 m^2 per trial

Year & place	Trial	Time (h)	Labour (men)	Mh/ha	Average Mh/ha
1985	I	0.86	4	229.33	
(ARS)	II	0.83	4	221.33	
Vadgaon	III	0.85	4	226.67	224.00
Maval	IV	0.82	4	218.67	
1986	I	0.83	4	221.33	
(ARS)	II	0.92	4	245.33	
Vadgaon	III	0.87	4	232.00	236.00
Maval	IV	0.92	4	245.33	

Table 2 Mh/ha Requirement for Line Transplanting + USG Application after 8-10 Days (Skilled labour)

Plot size: 150 m^2 per trial

Year & place	Trial	Transplanting		USG application		Mh/ha	Average Mh/ha
		Time (h)	Labour (men)	Time (h)	Labour (men)		
1985	I	0.43	6	0.75	2	272.00	
(ARS)	II	0.45	6	0.75	2	280.00	
Vadgaon	III	0.38	6	0.74	2	238.67	260.00
Maval	IV	0.37	6	0.70	2	249.33	
1986	I	0.54	5	0.70	2	273.33	
(ARS)	II	0.60	5	0.63	2	284.00	276.87
Vadgaon	III	0.66	5	0.57	2	253.33	
Maval	IV	0.66	5	0.57	2	296.00	

Table 3 Mh/ha Requirement for Use of RPS Marker-cum-USG Dispenser (Unskilled labour)

Date & place	Trial	Plot size (m^2)	Time (h)	Labour (men)	Mh/ha	Average (Mh/ha)
6.7.86	I	90	1.17	4	420.00	511.11
Lonawala	II	90	1.13	4	502.22	
22.7.86	I	150	1.83	4	488.00	510.66
Khopi	II	150	2.00	4	533.33	

Table 4 Mh/ha Requirement for Line Transplanting + USG Application after 8-10 Days (Unskilled labour)

Date & place	Trial	Plot size (m^2)	Trans-planting		USG application		Mh/ha	Average Mh/ha
			Time (h)	Labour (men)	Time (h)	Labour (men)		
6.7.86	I	90	1.10	4	0.25	3	572.22	569.2
Lonawala	II	310.5	1.35	11	0.91	3	566.18	
22.7.86	I	300	1.82	8	1.86	1	547.33	537.0
Khopl	II	300	1.75	8	0.90	2	526.67	

device. It is almost double that required under skilled labour, i.e., average 230 Mh/ha.

Table 4 shows the average Mh/ha required for transplanting paddy plus USG application after 8-10 days, on farmers fields. It is an average of 553.10 Mh/ha and is more than double compared to that required under skilled labour, i.e., average 268.44 Mh/ha.

Even when unskilled labour use the RPS marker-cum-USG dispenser, there is a labour saving of an average 42.22 Mh/ha.

Conclusions

The device does the following intended functions.

1) It facilitates transplanting of paddy in the puddled fields with 20 cm row spacing and 15 cm hill spacing.

2) It facilitates carrying and can very successfully meter out the required number of USG during paddy transplanting operation, protecting the granules from getting wet even during rains.

Besides the efficient performance of intended functions the device offers the following additional benefits:

1) Deep placement of USG in puddled soil is possible at the time of paddy transplanting and no separate deep placement operation is required (Normally done 7-10 days after transplanting requiring 36 Mh/ha).

2) The additional labour, additional disturbance and trampling of transplanted field is avoided.

3) The use of urea is economical (USG is 30-35% more efficient than prilled urea).

4) Since every hill is positively served with N, yield of rice is increased (established fact).

5) Lateral movement of workers while transplanting in puddled fields is eliminated, saving time and effort.

5) The device is very simple; light weight, 1.5 to 3 kg; prepared out of local materials; easy to fabricate requiring minimum skill; easy to repair and repairs are negligible; and can be made by village artisans.

5) The cost of the device is within reach of even marginal farmers.

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Drag Force Analysis of Deep Placement Fertilizer Applicator for Rice


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Abstract

The deep placement fertilizer applicator for rice developed by the International Rice Research Institute had been analysed for the drag force requirement. It was found that the existing method of force application, i.e., pushing is not an efficient one. For pull type, from various hitching combinations tried, the hitch point just below the centre of gravity of the applicator was optimum. Higher angles of pull caused large lift heights, hence it is suggested that the angle of pull be kept below 38 degrees. The force required to pull the applicator was twice as high under non-flooded conditions (170 N) than under flooded conditions (94 N), hence it is suggested to operate the applicator with a thin film of water in the field. Among the traction elements the skid absorbed the maximum amount of pull. It absorbed 40% of pull in flooded condition and 62% in non-flooded condition, followed by the other parts, namely; the furrow opener, 29% and 20%; cage wheel, 20% and 14%; and furrow closer, 10% and 4% in flooded and non-flooded conditions, respectively.

Introduction

Rice has always been the most important crop in the world (Khan, 1982). Paddy yields of 3 to 6 t/ha are quite common for Japan, Korea, Australia, U.S.A., and the countries of the Mediterranean area, whereas the normal crop yields in tropical Asia and Africa are seldom higher than a third of this. One of the major causes for this poor yield response is believed to be the inefficient use of the applied fertilizers by the plants. Also, the increase in cost of fertilizers makes it particularly important to use fertilizer nutrients as effectively as possible.

Surface broadcasting causes 20% waste of the applied fertilizer (Shioiri, 1941). Many reserach studies at the International Rice Research Institute (IRRI) and other institutions have consistently proved that deep placement of fertilizer results in 10 to 20% increase in yield over conventional practices (Shioiri, 1941; Khan, 1982).

The IRRI Agricultural Engineering Department has developed several types of manually operated, push type deep placement fertilizer applicators for rice as the researchers focus on improving the efficiency of placement, metering of fertilizer and reducing the losses of nitrogen to flood water. However, they paid little attention toward reducing the force requirements of the applicators (Khan, 1984). In addition to cost and efficiency of operation the wider acceptance of a machine, particularly the manually-operated one like the deep placement applicator, mainly depends on the ease of operation in which the man-machine interaction plays a major role.

The objective of this study was the force analysis of the IRRI developed deep placement fertilizer applicator as affected by the method and point of force application, angle of pull, soil condition and forward velocity.

Review of Literature

The use of urea as nitrogen fertilizer in the world agriculture has increased dramatically during the past 20 years (Engelstadt and Huack, 1974). Cohran et al (1982) reported that most farmers in South East Asia broadcast fertilizer by hand directly on to the flood water 2 to 3 weeks after transplanting rice which causes extensive losses of nitrogen to the atmosphere and in run-off water due to oxidation, denitrification and leaching. As much as 50% increase in yield can be obtained by placing fertilizer at a depth of 5 to 7 cm below the soil surface. Crasswell and De Datta (1980), based on their experiments on the efficiency of nitrogen fertilizers for rice, stated that broadcast application of urea causes losses of up to 50% whereas point placement of urea super granules 10 cm deep in the soil may result in negligible losses.

The IRRI has been developing deep placement fertilizer applicators for almost a decade now and many interesting machines have been designed and fabricated. Most of them can place fertilizer at 5 cm depth and can close the furrow. All the prototype models are manually-operated, push type and use long skids for getting flotation in the puddled clay soil (Khan, 1983, 1984).

The fertilizer applicator released for commercial use during the 1983 crop season was a spring auger applicator with the augers inclined at 40 degrees. The auger sprockets are driven from the bottom of the drive sprockets which are mounted directly on the wheel shaft. A drive ratio of 1:4 is used between the ground driven sprockets and the two augur sprockets. This machine was used in this study.

Passmore and Durvin (1955), while discussing the human energy expenditure, mentioned that many agricultural tasks involve working on soft uneven surfaces. They further stated that the power required to walk in a ploughed land is 35% more than that required on an asphalt road. Also, at slow speeds the rate of energy expenditure is low, but as the speed increases the power required increases.

Thai and Chancellor (1985) conducted experiments on boat tractor hull design to minimize drag forces. They observed that an increase in drag was accompanied by a decrease in hull pressure and vice versa. Shah (1980) stated that floats associated with machinery in wetland fields may improve their performance. From his experiments on different types of floats he concluded that long narrow floats give less coefficient of drag than short and wide ones for the same base area and the same load. The draft is reduced 35% when the point of application is shifted 1/4 of the float length back from centre. A substantial reduction in drag force resulted when the surface was covered with a thin film of water.

Materials and Methods

Experimental Site and Soil Preparation

A soil bin 18 m long, 2 m wide and filled with clay soil to a depth of 1 m at the Regional Experimental Centre of Asian Institute of Technology (AIT), Bangkok was used for conducting the experiments. Before each experiment the soil was puddled carefully using a rear mounted cultivator and was perfectly levelled using a scraper. The first set of experiments were conducted without flood water and the second set, with flood water. About 3 cm of water was allowed to stand on the prepared soil.

The Cone Index (CI) was considered to be the prime check to assure the same soil condition. Glen et al, (1983) defined the CI as a relative measure of soil strength expressed as the force per unit area of a 30 degree circular cone. A direct recording cone penetrometer of cone base area 3.22 cm^2 and apex angle 30 degree, was used for calculating the cone penetrometer resistance. All the experiments were conducted at a CI value of around 125 kPa as this is the typical range of penetration resistance of the puddled soil about 10 days after puddling (the actual range of CI value for all the experiments was 113.47 kPa to 140.48 kPa).

After every test run, samples from four different points of the soil bin were collected for moisture content determination. The moisture content of the sample was determined by drying the sample at 105°C for 24 h in an oven. The difference between the maximum and minimum moisture contents were between 49.76% and 54.83% for flooded condition and 40.80% and 49.45% for non-flooded condition.

For measuring the force, four strain gauges of 119.8 ohms resistance and gauge factor of 2.1 were fixed diametrically opposite on either side of a proving ring with a 10.8 cm inner diameter and 0.56 cm thick wall. The output was amplified using a strain amplifier and recorded on a 7-channel tape recorder for further analysis.

A real unwinding apparatus was used for measuring the forward speed. Two outputs were taken from the frequency to voltage converter, one was connected to a tape recorder for recording the speed and the other to a millivolt meter fixed on the control panel of the soil bin carriage which would facilitate the operator to control the velocity while increasing it in steps.

A linear variable differential transformer (LVDT) was used to measure the lift of the nose of the applicator in dynamic condition. The central iron rod of the LVDT was fixed over the skid at a distance of 8 cm from the nose and the transformer core was fixed permanently to a suitable frame so that any lift in the nose of the applicator will cause an output voltage proportional to the height of lift and was directly recorded.

Experimental Design

In the 18-m long soil bin a potential run of 15 m was possible. The experimental run was started at a low speed of about 0.5 km/h and after every 3.5 m of run the velocity was increased in steps of approximately 0.5 km/h so that the final velocity was 2.0 km/h. The velocity range was chosen with the assumption that a man can walk at a velocity of about 1 to 1.5 km/h over puddled clay soil.

Three points on the skid, one forward of the C.G. (22.5 cm from nose), one just below the C.G. (32.5 cm from nose), and the third point rearward of the C.G. (37.5 cm from nose), were selected for force application. At each point three angles of pull 34.1, 38.1 and 42.4 degrees were used for force application. Three replicates were conducted for each combination.

Further tests were conducted in two different soil conditions, with and without flood water, for the optimum hitching combination. In both soil conditions the force absorbed by each part of the applicator was measured by conducting the experiments without various parts of the applicator (furrow opener, furrow closer and the cage wheel).

Results and Discussion

The recorded data from the tape recorder was played back and plotted on an X-Y plotter. **Fig. 1** shows the typical X-Y plotter output. While reading these outputs the accelerating portions of the plot were omitted in order to avoid the additional drag force expected due to acceleration.

Force Application—Push Type

When the applicator was tried as push type, the nose of the applicator went down into the soil. The reason for this is that the horizontal component of the push created a net downward-acting moment. To overcome this downward moment, the operator has to always give a counter acting moment. This necessary additional force needed made it difficult to operate the applicator for long durations. Hence further experiments were conducted keeping the applicator as pull type only.

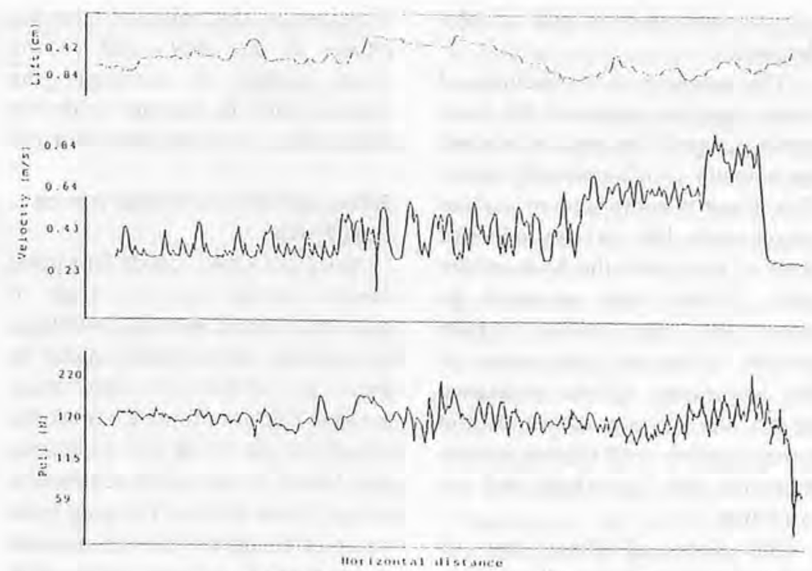

Fig. 1 A typical X-Y plotter output.

Dynamic Behaviour of Nose of Applicator

For each of the three replications the lift heights at four velocities were measured and it was found that the lift height did not depend upon the forward velocity. Hence all the lift heights for a particular hitching combination were pooled **(Table 1)**.

The lift height greatly varied with different hitching combinations. The lift height at hitch point forward of the C.G. is about 4 to 5 times that of the other hitch points at all angles of pull. The percentage of lift of the furrow opener is about 13% to 27.6% which supports the safe conclusion that the hitch point forward of C.G. of the applicator is difficult to control and does not serve the purpose of deep placement of fertilizer.

Analysis of Pull Data

The software package Curfit 2 for the Apple II computer was used to fit the pull data against forward velocity. Pull (N) was linearly related to the forward velocity (km/h), for all the hitching combinations. The SAS program was run to find the 95% confidence limits for this line. **Fig. 2** shows these lines at hitch point rearward

Table 1 Results of Life Characteristics of Applicator Nose

Hitch point on float	Remarks	Angle of pull (deg)		
		34.1	38.1	42.4
Forward of C.G. (22.5 cm fron nose)	Mean (cm)	2.31	3.05	4.72
	S.D.	0.73	0.84	0.61
	% FOH lifted	13.33	17.60	27.23
Rearward of C.G. (37.5 cm from nose)	Mean (cm)	0.56	0.60	1.42
	S.D.	0.09	0.10	0.29
	% FOH lifted	3.23	3.46	8.19
At C.G. (32.1 cm from nose)	Mean (cm)	0.60	0.79	1.36
	S.D.	0.24	0.23	0.18
	% FOH lifted	3.46	4.55	7.85

S.D. — Standard deviation of the mean in cm.
% FOH lifted — % of furrow opener height lifted.

of C.G. and angle of pull of 38.1 degrees.

The intercept at the ordinate of these equations represent the force needed to pull the applicator when the velocity is infinitesimally small. This force is comprised of various components like (a) the adhesive force of mud with the body of the skid; (b) the force required to move the cage wheel; (c) the inertial effect of the mass of the applicator; (d) the resistance against the cutting action of the furrow opener; and (e) the motion resistance due to sinkage and rut formation.

The slope of these best fit lines indicate that the pull increases linearly with velocity. This increase is due to two factors: (a) the shear force needed to cut the clay soil increases as the velocity increases (Rowe et al, 1961) and (b) the force needed to accelerate the viscous mud in contact with the skid surface increases with velocity.

Effect of Different Parameters on Drag Force

Since the pull is dependent upon various factors like the angle of pull, hitch point and soil condition, a common factor was sought to show the effect of these parameters. The net moment about the centre of gravity of the applicator was found to be better representative of these effects. The drag force was plotted against the net moment about the C.G. A linear relationship with correlation coefficient of 0.98 and above (for all the cases) was found. The drag force for each angle of pull at different hitch points and for each hitch point at different angles of pull was plotted to show the effect of hitch point and angle of pull on drag force. **Fig. 3** shows the effect of hitch point on drag force at angle of pull 38.1 degrees and **Fig. 4** shows the effect of angle of pull on drag force at hitch point 32.1 cm from nose. **Fig. 5** shows the effect of flood water on drag force.

Even though the drag force was less at hitch point forward of C.G. (**Table 2**) this hitch point was not considered to be optimum since the percentage of furrow opener height lifted is about 20%. The hitch point rearward of C.G. was not considered to be an optimum one either, because of the higher values of drag force even at lower

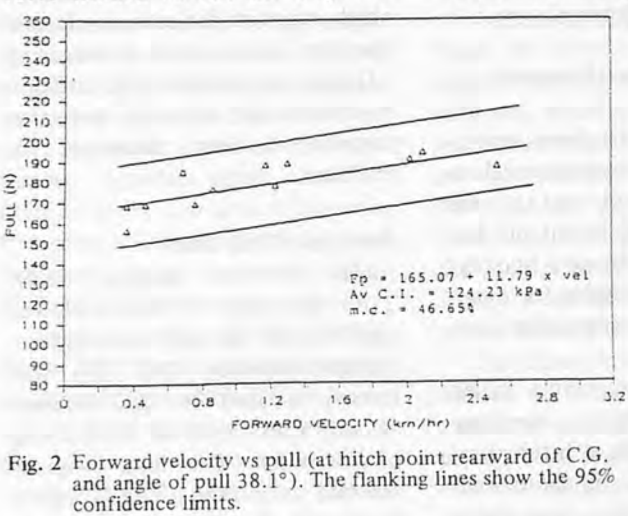

Fig. 2 Forward velocity vs pull (at hitch point rearward of C.G. and angle of pull 38.1°). The flanking lines show the 95% confidence limits.

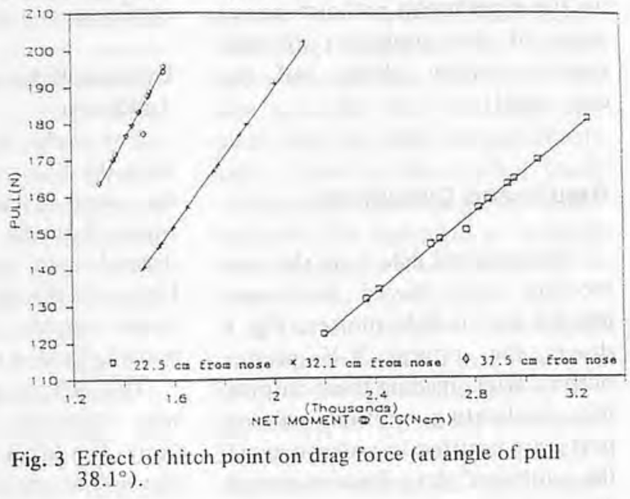

Fig. 3 Effect of hitch point on drag force (at angle of pull 38.1°).

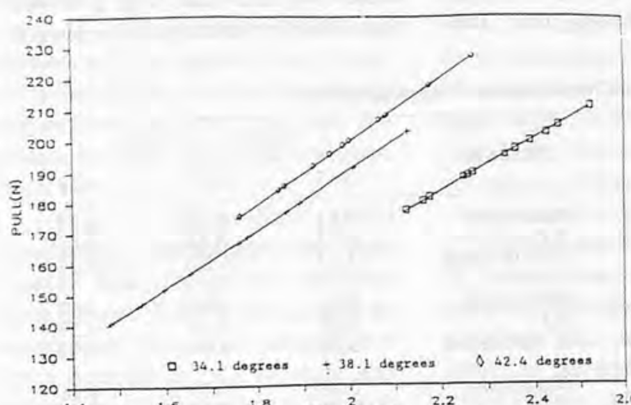

Fig. 4 Effect of angle of pull on drag force (at hitch point 32.1 cm from nose).

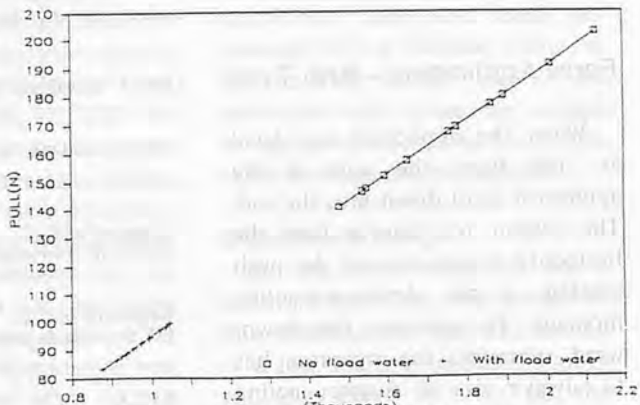

Fig. 5 Effect of flood water on drag force (at hitch point 32.1 cm from nose and angle of pull 34.1°).

Table 2 Average Force (N) Needed to Pull the Applicator at Different Combinations of Hitch Point and Angles of Pull

Hitch point	Forward of C.G.			At C.G.			Rearward of C.G.		
Angle of pull (degrees)	34.1	38.1	42.4	34.1	38.1	42.4	34.1	38.1	42.4
Velocity (km/h)									
0.5	97.8	134.7	53.2	179.4	154.8	186.4	157.8	170.8	173.8
1.0	105.1	146.4	58.2	188.2	161.4	195.5	172.4	177.6	185.0
1.5	112.3	158.2	67.6	196.9	170.2	204.5	179.7	184.3	196.3
2.0	119.7	169.9	74.91	205.7	179.1	213.7	185.7	190.9	207.5

values of net moment. The hitch point just below C.G. is an optimum one because at this hitch point there is neither more drag force required to operate the applicator nor is the furrow opener lifted much.

Among the three angles of pull tried, 42.4 degrees gave lower values of drag force but not advisable because of the high percentage of furrow opener height lifted. Angle of pull of 34.1 degrees is not considered optimum because of the high drag force requirement. When the third angle was tried, 38.1 degrees was considered optimum for better operating conditions and minimum drag force. A thin film of water causes a significant reduction in pull (Fig. 5).

Force Absorbed by Different Parts of Applicator

The force absorbed by a particular part of the applicator was calculated by subtracting the force needed to pull the applicator without that part from the force needed with that part. From the average pull needed to pull each part, the percentage of pull absorbed by each part was calculated and is given in Tables 3 and 4. The part that absorbed much of the pull was the skid which absorbed about 40% of the pull for flooded condition and 60% for non-flooded condition at all velocities. Also, it was noted that the percentage of force did not vary much with velocity. The percentage of force needed to pull the other parts of the applicator were, furrow opener 30% and 20%, furrow closer 10% and 4% and cage wheel 20% and 15% in flooded and non-flooded conditions, respectively. The drag coefficient for flooded condition at forward velocity of 1.5 km/h (normal walking speed of a man over puddled clay) was 0.85 and for non-flooded condition it was 1.54. The major recommendation from this analysis is that in future design the skid should be given attention for reducing the drag force.

To statistically determine the effect of the parameters on the drag force, a three factor analysis of variance was performed. The results show that the force needed to pull the applicator varies significantly with the position of hitch point on the skid and angle of pull. Forward velocity does not have much influence on the force needed to pull the applicator. The analysis of variance performed between flooded and non-flooded conditions showed that the flood water has a significant effect on drag force.

At walking speed (1.5 km/h), a man of 60 kg weight and 3000 calories per day input diet can exert a pull of 110 N continuously in puddled clay (Stout, 1979; Passmore et al, 1955). From the experiments it was found that at walking speed the pull type force application needed 94 N in flooded condition and 170 N in non-flooded condition. The conclusion from these considerations is that it is possible for a man to operate the applicator continuously for 10 hours with a thin film of water in

Table 3 Force (N) Needed to Pull the Applicator with Some of the Traction Elements Removed in Two Soil Conditions

Soil condition	Velocity (km/h)	Applicator			
		Full	CWR	CWFOR	CWFORCR
With flood water	0.5	86.5	64.1	41.1	33.0
	1.0	89.4	70.5	45.2	36.1
	1.5	93.9	76.8	49.4	39.1
	2.0	98.6	83.3	55.6	43.1
Without flood water	0.5	152.5	126.8	100.9	94.15
	1.0	161.4	136.6	106.5	99.4
	1.5	170.2	146.5	111.7	104.9
	2.0	179.1	156.0	117.0	110.39

Full – Full applicator
CWR – Cage wheel removed
CWFOR – Cage wheel and furrow opener removed
CWFOFCR – Cage wheel, furrow opener and furrow closer removed

Table 4 Percentage of Drag Force Absorbed by Different Parts of the Applicator

Velocity (km/h)	By skid	By cage wheel	By furrow opener	By furrow closer
With flood water				
0.5	40.48	24.46	27.24	7.80
1.0	41.41	21.41	28.10	9.08
1.5	42.25	18.65	29.03	10.07
2.0	43.00	16.14	29.60	11.26
Without flood water				
0.5	62.36	16.04	16.97	4.63
1.0	61.72	15.30	18.74	4.24
1.5	61.15	14.67	20.28	3.90
2.0	60.65	14.09	21.60	3.60

the field but not possible under non-flooded conditions.

Summary and Conclusion

On the basis of the work reported herein, the following conclusions can be drawn;

1. Pushing is not an advisable method of force application as it creates a net moment which will push the nose of the applicator down into the soil, and hence increases the force required to operate it.

2. The hitch point just below the C.G. is favourable for operating the applicator at optimum working conditions. Of the other two hitch points tried, the one forward of the C.G. caused a lift of about 25% of the furrow opener which does not serve the purpose of deep placement. For the one rearward of the C.G., the vertical component of pull pushed the nose of the applicator down into the soil.

3. Of the three angles tried, it was found that at 42.4 degrees the lift height of the furrow opener was large. Lower values of angles of pull (34.1 degree and 38.1 degree) are better for optimum operating conditions.

4. The standing water caused a reduction in pull by 80 N and drag coefficient by a factor of 2. Under flooded conditions the average pull required (90 N) is possible for human labour to exert continuously but the force required (170 N) is not possible under non-flooded conditions. Hence, it is recommended that the applicator be operated with a thin film of standing water in the field.

5. Skid should be given careful consideration in reducing drag force as it absorbs about 40% of the total force under flooded condition and 60% under non-flooded condition.

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Comparative Performance of Hand Sprayers Using Different Application Techniques

by

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Abstract

Four hand-held sprayers, namely; hand pressure (HP) sprayer, lever operated (LO) sprayer, ultra low volume (ULV) sprayer and electro-dynamic (ED) sprayer were tested using a laboratory experimental setup. Experiments were conducted to measure the variation in spray deposition efficiency and spray pattern over a width of 3 m in the walking speed range (0.8 to 2.0 km/h) and application height 20 to 60 cm. The deposition of spray discharge on artificial targets representing paddy plants was measured using a photo spectrometer.

It was observed that the average droplet size for ULV sprayers using atomization and ED sprayers using electrostatic charge varied from 70 to 90 microns while for pressure-operated sprayers using pressurization of liquid, it varied from 150 to 190 microns. The highest deposition efficiency was observed with ED sprayer (64-76%) followed by ULV sprayer (49-60%) and the lowest deposition efficiency for pressure operated sprayers (20-50%). Charging and atomization covered an effective width of 1.8 to 1.9 m compared to 0.7 to 0.9 m width covered using pressurization technique. The variation in deposition due to speed was up to 20% for pressure operated sprayers while it was only 5-7% for electrodynamic and ultra low volume sprayer.

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Introduction

In order to maximize the farm output, a farmer should choose affordable equipment with high efficiency. Since the quantity of chemicals consumed for agriculture is very high, it is important for farmers to realize the influence of excessive chemical usage for agricultural operations and to select a suitable sprayer for more effective spraying of chemicals.

The selection of suitable sprayer is based on the following factors; operational cost, uniformity of deposition, area of coverage and health hazard which are functions of methods of application (charging/atomization/pressurization) and operational parameters (speed of operation and height of application).

Researchers have mainly concentrated their efforts on the improvement of methods of application in order to attain maximum and uniform deposition using power-driven sprayers. But the variation in performance for different hand-held sprayers using different application techniques has been analyzed to a limited extent. The present study compares the relative performance of four hand-held sprayers.

Objectives

1. To compare the performance of sprayers employing three different application techniques, namely; pressurization, atomization and electrostatic charging of

spraying liquids.
2. To study the effect of height of application and speed of operation on spray pattern, spray droplet spectrum and deposition efficiency for four hand-held sprayers.
3. To select the optimum height and speed of operation corresponding to maximum deposition and to compare the cost of operation under these conditions.
4. To recommend a suitable sprayer based on performance and cost of operation.

Literature Review

Spray Deposition Studies

Law and Lane (1979) found that charging increased the deposition by 1.9 to 7 times depending upon the surface area-morphology relationship of the targets. Yates and Smith (1982) reported that the spray deposition was not only a function of method of application of chemicals but also depended on the parameters like surface area, forward velocity of sprayer and nozzle orientation. Hussain (1984) observed deposition in the case of electrostatic sprayer to be four times better than knapsack sprayer. Giles (1985) obtained a ratio of charged to uncharged spray deposition ranging from 1.5 to 2.0, depending upon the diameter, spacing and sampling elevation of target arrays.

Methods to Measure Spray Deposition

The percentage of transmittance and absorption of coloured tracer liquid are the direct measure of spray deposition. The fluorometer and photospectrometer employ these principles. Carlton and Bouse (1981) improved the accuracy of deposition measurements by employing 35 mm photo film as target. However, the special washing method complicated the extraction process. Sistler et al (1982) developed a digital image analyzer to measure the percent area covered by the sprayer for a given height of application. Patel (1981) developed a table-graph method to determine droplet size based on the droplet density.

Selection of Target

Maybank and Yoshida (1973) used aspirated filter paper as targets for collecting the sprayed volume. The extraction was observed to be better as compared to the ordinary filter paper. Roskamp (1973) reported that extraction of sprayed liquid was better in the case of stainless steel targets as compared filter paper. However, the chemical reaction of the sprayed liquid was a serious problem.

Bouse and Merke (1975) and Butler and Goering (1975) observed that extraction of spray deposition was better and easier with Mylar sheets than with filter papers. Goering et al (1976) reported that the size of the target had less influence in the measurement of spray deposition in comparison to orientation of target.

Anatheswaran and Law (1981) observed that deposition is a direct function of foliage leaf area. Giles (1985) found that depoistion increased 5 to 10 times when the diameter of cylindrical targets increased from 12.7 to 51 mm.

Methodology

Experimental Sprayers

The cross-sectional view of the hand pressure (HP) sprayer used in the experiment is shown in Fig. 1. The liquid is pressurized by the reciprocating motion of the piston to a preset level and discharged through a nozzle after travelling through a hose line. The discharge rate of sprayer is 4.3 to 4.5 ml/s at maximum pressure, when the pres-

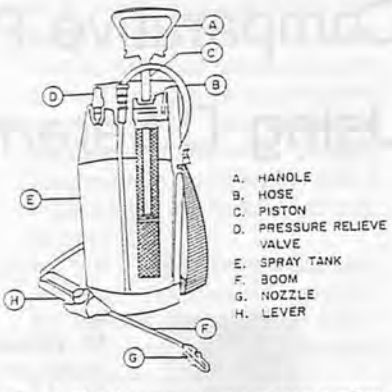

Fig. 1 Hand pressure sprayer cross-section.

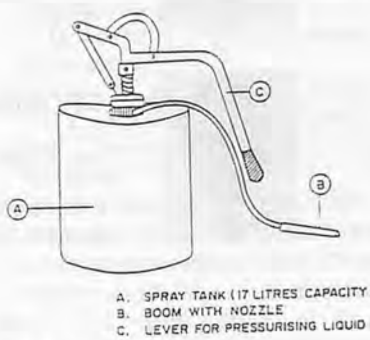

Fig. 2 A lever-operated sprayer.

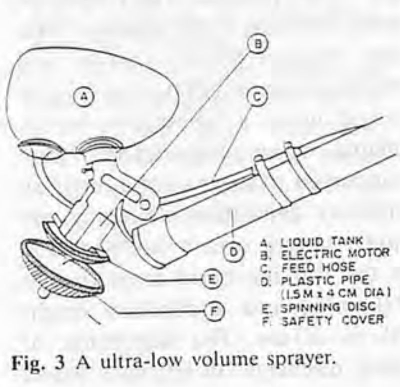

Fig. 3 A ultra-low volume sprayer.

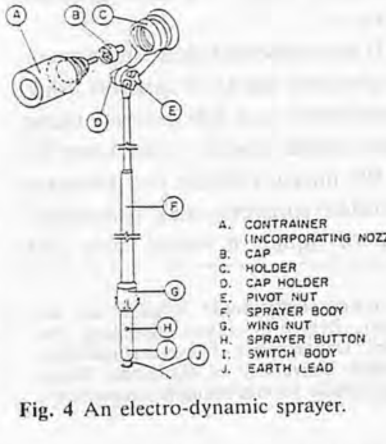

Fig. 4 An electro-dynamic sprayer.

sure relief valve just starts functioning.

Unlike the hand pressure sprayer, the liquid in the lever-operated (LO) knapsack type sprayer (**Fig. 2**) is continuously pressurized and delivered through a nozzle. The sprayer is supplied with two types of nozzles. One nozzle (N1) ejects the liquid perpendicular to the direction of motion and the other, (N2), discharges the liquid parallel to the direction of motion.

Ultra low volume sprayer (**Fig. 3**) has a long plastic pipe of 1.5 m long and 4 cm diameter which carries a 8.7 cm diameter disc rotary atmizer, rotating at 2 500 rpm powered by a 6 volt DC motor. The power to the DC motor is supplied by means of four 1.5-volt batteries. The spray droplets are atomized and discharged with momentum created by the rotary motion of the disc atomizer. For uniformity of discharge, an air inlet is provided in the liquid container to maintain a constant head of gravity pressure.

Electrodynamic sprayer (**Fig. 4**) has a long plastic pipe (1.5 m long and 4.5 cm diameter) which carries a high voltage generator, a pesticide container and batteries. The liquid is charged initially by means of electrodes surrounding the neck of the bottle and discharged by gravity pressure. A battery of four cells supplies the current and directs it to the voltage generator, whose voltage output at high voltage end is 22-25 kV. Earthen leads are provided at the other end of the plastic pipe to minimize health hazards. The sprayer is suitable for oil-based formulations only.

Experimental Set-up

The main components of the experimental set-up (**Fig. 5**) were spray tool carrying frame, motor and cable operating switches, target table, targets and wind barrier.

The height of application was varied from 20 to 60 cm by sliding the sprayer holding frame in the slots of the main spray tool carrying frame. This height corresponds to the elevation difference between nozzle centre line and top of the target surface.

The purpose of the motor and cable arrangement was to vary the speed of operation from 0.8 km/h to 2.0 km/h in steps of 0.4 km/h. Cables were provided through three pulleys and a drum to have forward and reverse motion of the spray tool carrying frame.

The forward, reverse and top switches were used to control the motion of spray tool carrying frame. The length of run was fixed by sliding the cut-off switches in a slider adjacent to main rails.

A 4.3 m x 2.15 m target table (made of water-proof boards) provided a base for fixing the targets.

The shape of the target is shown in **Fig. 6**. The selected target surface area and target height were 24 m and 0.6 m, respectively. These values are based on data collected for age, leaf area, height and approximate shape of the paddy (RD-23) plants starting from 7 days after transplanting until the harvesting stage.

The windbarrier (**Fig. 7**) controlled the speed of wind within the limit of 0.5 m/s. In the bottom half of the barrier, transparent polythene sheets were provided to view the performance of sprayer from outside.

Fig. 5 Experimental setup.

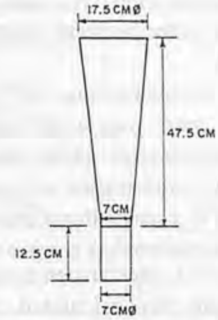

Fig. 6 Shape and dimensions of a selected target.

Fig. 7 Wind barrier.

Instruments and Measurements

The following parameters were measured during the experiment:

1. Forward speed of sprayer in km/h.
2. Height of application over the top of the plants.
3. Temperature of spray atmosphere.
4. Humidity in the spray atmosphere.
5. Average wind velocity over the target in m/s.
6. Deposition on the targets over a width of 3 m.

The experiments were carried out at four different forward speeds, namely; 0.9, 1.2, 1.6 and 2.0 km/h which are in the region of normal walking speed of human beings. The height of application of spray nozzle was varied from 20 cm to 60 cm over the top of simulated target, equivalent to 80 to 120 cm from the ground surface. This range of height was selected based on average knee-height as well as application range recommended by the manufacturers. A thermohygrometer was used to measure temperature and humidity. A cup type anemometer was used to measure wind velocity over the top of the target.

Potassium permanganate ($KMnO_4$) and Fluoroscin nitrium geopulvert were used as liquid ingredients. The concentration of the mixture was 10 g in 2 500 ml of water. The targets and target table were covered with coated polyethylene sheets.

The liquid deposited on the targets and spilled on the target table was collected in different containers by washing with 2% methanol solution. The samples of extracted solution were transferred to a flask.

The concentration of these samples was measured using a photospectrometer which gives the percentage absorption of samples collected at a particular wavelength. From the calibration chart or from equation (7), the concentration of the sample was calculated. From the ratio of concentration of liquid sprayed and collected on the targets and the volume of samples collected, the actual deposition on the targets was calculated using the following formulae.

Concentration = 0.0012 x Absorption (640 nm wavelength) ..... (7)

$$\text{Deposition} = \frac{CAVc}{Y\,Vs} \quad \ldots\ldots (8)$$

where A = absorption reading
C = colour factor = 0.12 for purple colour
Vc = volume of the sample collected
Vs = volume of liquid discharged at that speed
Y = concentration of the sprayed liquid

To measure droplet size, 25 g of vaseline was mixed with 10 ml of liquid paraffin and the mixture was placed in a petri dish of 10 cm diameter. The average droplet size in microns was measured by spraying the liquid over the mixture. The droplet spectrum was analyzed using a microscope.

The analysis of the experimental data was performed by finding the general relationship between any two parameters of observation at a particular condition. The types of analysis are:

1. The variation in spray deposition efficiency for different speeds of operation for a sprayer. This analysis was designated as performance of the sprayer.
2. The comparison of performance for different methods of application.
3. Spray pattern over a width of 3 m for different methods of application at different speeds and heights of application by measuring the average percentage deposition on the targets at equal distance from the nozzle centre line.

Results and Discussion

Droplet Comparison for Different Sprayers

Fig. 8 represents the comparative droplet distribution histogram. It is observed that the average droplet size in ULV and ED sprayers in the region of 70 to 90 microns. The droplet size in pressurized sprayers was observed to be 150-190 microns.

The measured average droplet diameters were used to calculate the forces responsible for spray deposition. From **Table 1**, it can be assumed that forces due to gravitation and buoyancy are negligible compared to application force in all the sprayers. However, the magnitude of application force was observed to be high in ED and ULV sprayers.

Figs. 9-13 shows the variation of deposition efficiency with reference to height and speed of sprayer carrying tool for experimental sprayers.

A higher deposition efficiency (64-76%) was observed in electrodynamic sprayer, followed by ultra low volume sprayer (49-66%) then by the sprayers that operate on the principle of pressurization of liquids. Considering sprayers operating on the principle of pressurization, the locally available lever operated sprayer was observed to perform better than hand-pressure sprayer with regard to deposition efficiency. However the discharge

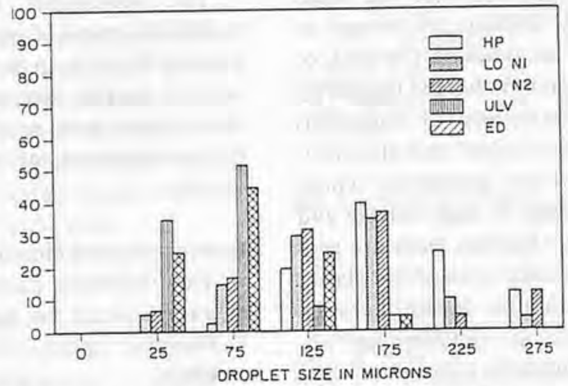

Fig. 8 Comparison of droplet distribution for diggerent sprayers.

Table 1 Forces on Droplets for Different Sprayers

Sprayer type	Average particle size (microns)	Force due to gravity (10^{-16} N)	Force due to buoyancy (10^{-11} N)	Force due to appln. technique (10^{-8} N)
HP	186	1.320	3.305	1.18
LO N1	156	0.720	1.950	1.10
LO N2	150	0.693	1.730	1.00
ULV	70	0.070	0.176	23.58
ED	80	0.105	0.262	30.20

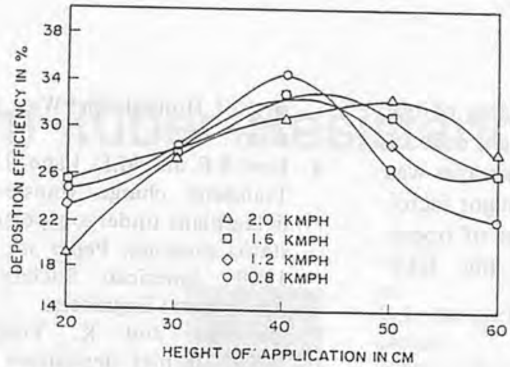

Fig. 9 Hand-pressure sprayer performance curves.

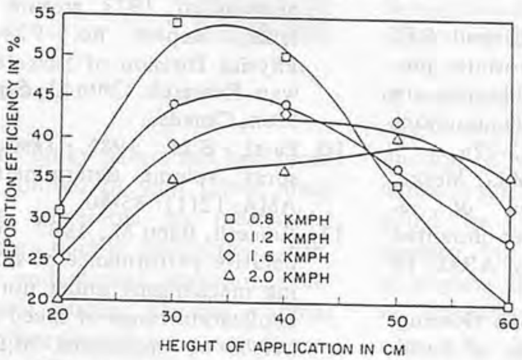

Fig. 10 Performance curve of level-operated sprayer Nozzle 1.

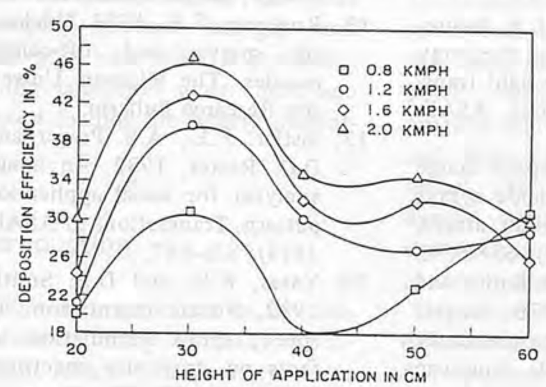

Fig. 11 Performance curve of level-operated sprayer Nozzle 2.

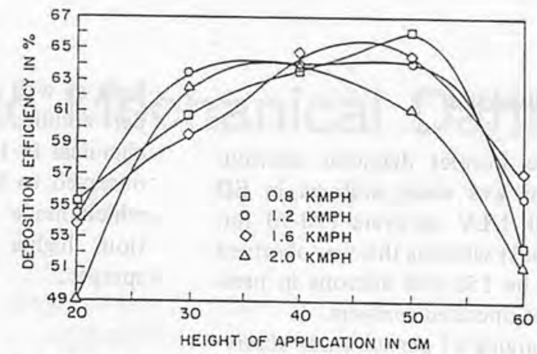

Fig. 12 Performance curve of ultra-low volume sprayer.

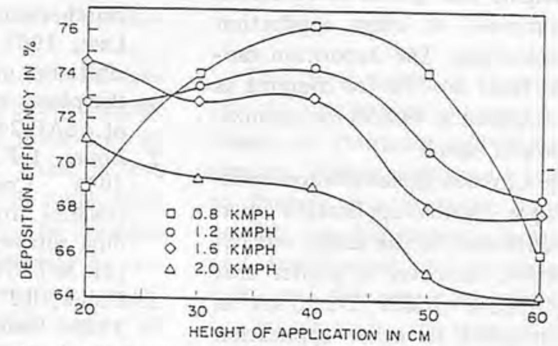

Fig. 13 Performance curve of electro-dynamic sprayer.

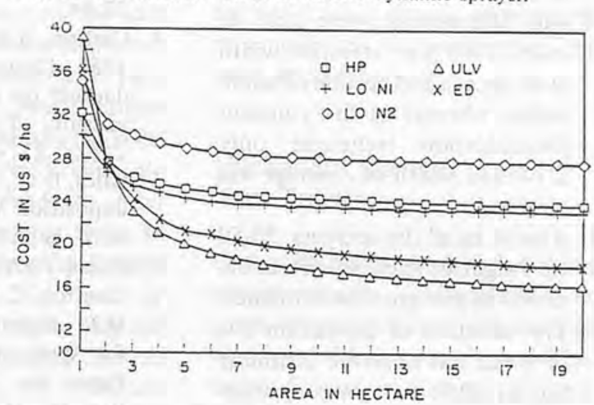

Fig. 14 Cost comparison curve.

of the lever-operated sprayer was observed to be twice that of hand-pressure sprayer.

Proportion of Deposition and Wastage of Spray Liquids

The spray liquid deposited on the targets and spilled over the table were measured at 40 cm height of application with 1.2 km/h speed. The values are listed in Table 2. Minimum losses were observed in electrodynamic (ED) sprayer followed by ULV sprayer. The other losses include evaporation and drifting losses.

Table 2 Proportion of Deposition and Wastage

Sprayer type	% Target deposit	% Spilled on table	% Other losses	Temp °C	Humidity %	Wind velocity m/s
HP	30	20	50	30	68	1.2
LO N1	45	20	35	30	68	2.0
LO N2	40	25	35	31	64	1.5
ULV	64	13	23	31	64	0.9
ED	75	7	18	32	62	1.0

Comparison of Cost of Operation of Sprayers

Fig. 14 shows the variation in cost of operation of different sprayers. The cost of operation was calculated to be less in ED and ULV sprayers at the high as well as low area of use per annum. High chemical cost (1 Baht/ml) in ED sprayer was observed to be the major factor which made the cost of operation higher than ULV sprayer. The operational cost of lever-operated sprayer using nozzle one (LO N1) was found to be cheaper than the other two pressure application sprayers.

Conclusions

1. The droplet diameter distribution was more uniform in ED and ULV sprayers (70-90 microns) whereas this was observed to be 150-190 microns in pressure-operated sprayers.
2. Charging of particles was observed to be the best technique at all heights and speeds of operation compared to other application techniques. The deposition varied from 64-77% for charging as compared to 49-65% for atomization of liquid.
3. Continuous pressurization technique with application perpendicular to the target was observed to cover a greater area (effective width 2-2.20 m) as compared to other application techniques. However, charging and atomization were able to cover 1.8-1.9 m effective width at all speeds and heights of application whereas in the constant pressurization technique only 0.7-0.9 m width of coverage was observed.
4. Almost in all the sprayers, 30-50 cm height of application was observed to give good performance.
5. The variation in deposition due to speed was observed distinctly (up to 20%) only in pressurization technique. The variation was only 5-7% in electrodynamic sprayer and ultra low volume sprayer.
6. The cost of operation was less in ED and ULV sprayers at the high as well as low area of use per annum. The high cost of chemical in the ED sprayer was observed to be the major factor which made the cost of operation higher than the ULV sprayer.

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Yam Tuber Resistance to Mechanical Damage

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Abstract

The bulky nature and high moisture content of yam tubers make them vulnerable to mechanical damage during production, handling and storage operations. Mechanical damage on any material is a function of its physical properties. The contribution of modulus of deformability, bioyield strength, rupture strength and density of yam tuber in predicting failure condition under dead and impact loading are briefly presented.

Introduction

Yam is a major source of cabohydrate to many especially in sub-Sahara Africa. This area represents 96% of the worlds yam production, and the level of consumption per caput is about 36.8 kg. In some areas of West and East Africa, the consumption was as high as 72.4 kg in 1983 (FAO, 1986). But yam production is decreasing at an annual rate of about 1% (Okigbo, 1986).

Ene (1986), and Okigbo (1986) recognized disease attack and lack of mechanized production as some of the constraints to increased production of root and tuber crop of which yam is one. These factors could be related to mechanical damage. For instance, the presence of physical injury increases the rate of physiological reaction which eventually affects the degree of pathological degradation. Also, mechanization of any of the unit operations of production may bring the tuber into contact with rigid body. Such will easily inflict physical injury to the tuber. Ezeike and Nwandikom (1987) have observed that the produce, after harvest, passes through a series of unit operations before it finally gets to the consumer.

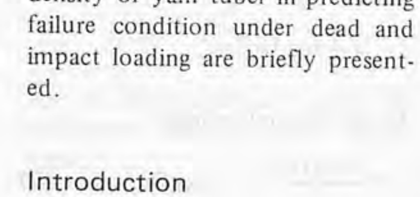

Fig. 1 Network diagram of post harvest activity of agricultural products

At each of these stages, they are exposed to physical damage. In the farm or market store, the tubers are packed, one on top of the other or tied on sticks. The heaps may be cubical, rhombic or pyramidal with square, rectangular or circular base and about 2 m high. During transportation in trucks they are again packed closely. In all of these some of the tubers suffer under dead load. These facts emphasize the point that mechanical damage is a major factor militating against increased production of yam.

Mechanical or physical damage could be seen on produce as bruises, slip, crack or abrasion depending on the mode and intensity of loading. Generally, the loading may be static, impact or fluctuating, in nature, all acting singly or in combination.

This paper is aimed at pointing out the methods of estimating the degree of resistance of tubers to damage. Higher resistance of tuber to damage is a guarantee to successful mechanization. Breeding and development of new varieties yam, and the degree of resistance to damage under the type of loading to which the produce will be subjected when in use, would serve as a guide for the selection of the most suitable variety.

Mechanical Damage on Yam Tubers

A solid material has failed when non-recoverable deformation or actual rupture occurs due to conversion of strain energy into other forms. Failure is a function of force applied, geometry of the surfaces in contact and the physical properties of the material.

In simple direct stress condition the yield point of a material is associated with a certain value of the normal stress. But under natural condition, the stress system is not simple. Parameters like the shear stress and strain energy also attains definite values by the time the material attains its yield point. Any one of these may cause damage. Having decided the actual value of the particular factor which corresponds to the onset of permanent deformation is usually taken to be the value reached in simple tension or compression at the elastic limit.

The amount of damage done is related to the amount of energy dissipated or absorbed.

The main failure modes in yam tubers and such other produce that have high moisture content in storage or during transportation are bruise, slip, crack or cleavage (Diehl et al. 1979; School and Holt 1982, Parke, 1963).

Bruise

Bruising is cell rupture or membrane disruption. It is caused by the shear stress components of the normal stress applied to the yam tuber. This distorts the cells leading to cell extension and eventual breakage. As pointed earlier, the normal stress value reached in simple direct loading is taken as the limiting stress. For yam and other viscoelastic products the limiting stress is referred to as bio-yield stress (Nwandikom, 1984; Igbeka, 1984 Mohsenin 1970). Bruising usually occurs under slow compression or tension, where the rate of strain energy build-up is low.

Slip and Crack

Slip is separation of tissue along shear surface while crack or cleavage is discontinuity of tissue membrane. Slip is a result of shear stress but crack is brought about by normal stress. If the tuber is loaded such that the maximum shear stress exceeds its slip strength before the maximum normal stress reaches the crack strength, then slip damage occurs. On the other hand, if the maximum normal stress exceeds the cleavage strength crack or cleavage damage will occur. Any of the failure may occur first then followed by others immediately after. There is a high tendency of slip occuring first if there is a slow build-up of strain energy in the tuber, i.e., if it is subjected to dead or slowly fluctuating load. But a crack is favoured by dynamic loading where the strain energy build-up is rapid or slow compression loading with already stored energy. The rupture strength of the material is the limiting normal stress that determines when either slip or crack is about to occur.

Resistance of Tuber to Damage

Mechanical damage is brought about by over-stressing a body under load. The behaviour of the body can be evaluated in terms of resistance to failure under the specified load. Mechanical damage involves energy transformation, stress state, and magnitude and strength of the material. Employing the strain energy theory which assumes that energy absorbed by a material is single valued function at failure, independent of the stress systems causing it (Ryder, 1973; Timoshenko and Young, 1968), the strain energy per unit volume causing failure is therefore equal to the strain energy at the limiting point is simple tension or compression. At bio-yield point, the strain energy per unit volume is equivalent to the modulus of resilience and at rupture point, it is equivalent to toughness.

The strain energy per unit volume, U, is expressed mathematically as equation below.

$$U = \frac{6^2}{2E} \qquad (1)$$

Tubers Under Dead Load

Yam tubers are generally arranged in square or triangular form shown in Fig 2 (a, b).

Considering the square arrangement, assuming uniform sized tubers, the potential energy,

PE of $T1_1$ on TO_1 = 1 mgr
PE of $T2_1$ on TO_1 = 3 mgr
PE of $T3_1$ on TO_1 = 5 mgr
PE on Ti_1 on TO_1 = (2n − 1) mgr
Total PE on TO_1

$$= \text{mgr} \; [1 + 3 + 5 + \ldots + (2n - 1)]$$

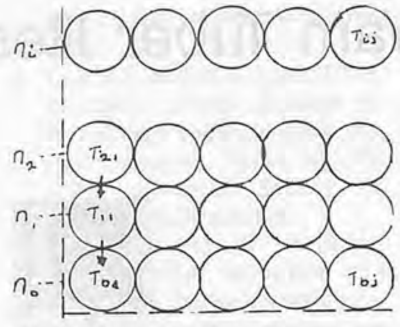

Fig. 2a Square arrangement

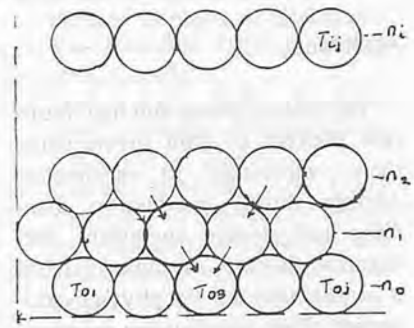

Fig. 2b Triangular arrangement

$$= \text{mgr} \cdot \frac{n}{2} [2a + (n - 1)d] =$$

$$= \frac{1}{2} \text{mg Dn}^2$$

Energy per unit volume

$$= \frac{\frac{1}{2}\,\text{mgDn}^2}{V} = \tfrac{1}{2}\rho\text{gDn}^2 \quad \ldots \; (2)$$

Equating (1) and (2),

$$U = \tfrac{1}{2}\rho\text{gDn}^2 = \frac{6^2}{2E}$$

$$n^* = \left(\frac{6^2}{\rho gE}\right)^{1/2} \cdot \frac{1}{\sqrt{D}} \quad \ldots \; (3)$$

Similarly, for the triangular arrangement

Total PE on TO_4 = $\text{mgDn}^2\text{Cos}\theta$

Energy per unit volume

$$= \frac{\text{mgDn}^2\text{Cos}\theta}{V} = \rho\text{gDn}^2\text{Cos}\theta \quad (4)$$

Equating (1) and (4)

$$\rho\text{gDn}^2\text{Cos}\theta = \frac{6^2}{2E}$$

$$n = \left(\frac{6^2}{2\rho gE\text{Cos}\theta}\right)^{1/2} \cdot \frac{1}{\sqrt{D}}$$

$$\theta = 30^\circ = \frac{\sqrt{3}}{2} \quad \text{for uniform sized tubers}$$

$$n^* = \left(\frac{6^2}{1.73\rho g E}\right)^{1/2} \cdot \frac{1}{\sqrt{D}} \qquad (5)$$

n^*, is the maximum number of layers of tuber for maximum allowable stress value on the tubers at the lowest layer.

Impact Load on Tubers

If a tuber of mass, m, dropped from a height, h, to a rigid body sustaining a deformation of δ. Applying strain energy theory,

$$mg(h - \delta) = \frac{\sigma^2}{2E} \quad V$$

$$\rho g(h - \delta) = \frac{\sigma^2}{2E}$$

$$h = \frac{\sigma^2}{2\rho g E} + \delta$$

If $\delta = 0$, i.e., at no deformation.

$$h^* = \frac{\sigma^2}{2\rho g E} \qquad (6)$$

h^*, is the maximum height for maximum allowable stress on the tuber.

List of Symbols

a	first term of the arithmetic series
d	difference of the arithmetic series
D	diameter of tuber
E	modulus of elasticity
Ed	modulus of deformability
g	acceleration due to gravity
h	height of fall
h*	critical height
m	mass of tuber
n_o	layers of tubers
n*	critical number of layers
r	radius of tuber
To1 Tij	individual tubers
u	strain energy per unit volume
v	volume of tuber
σ	limiting stress
σ_{yP}	bio-yield strength
σr	rupture strength
ρ	density of tuber
δ	deformation

Quasi-static Compression of Tuber Ground Tissue

Cylindrical specimens (diameter 21.5 mm, length 20 mm) of the ground tissue of *D. rotundata Poir* were used in studying the mechanical damage on yam tubers. Each specimen of known moisture content was compressed with an automatic recording universal testing machine (Monsanto tensormeter) at deformation rate of 0.0267 mm/s. (Nwandikom, 1984; Nwandikom and Mittal 1988a). At the onset of deformation, the specimen bulged and oozed sap. This was followed immediately after by a cracking sound before actual rupture. Figure 3 is a schematic representation of the force – deformation

Fig. 3 Force-deformation curve of yam tuber

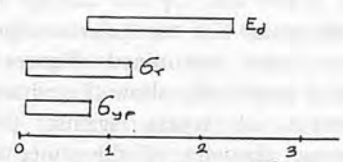

Fig. 4 Diagrammatic representation of the values of modulus of deformability (E_d), bioyield strength ($_{yp}$) and rupture strength ($_r$)

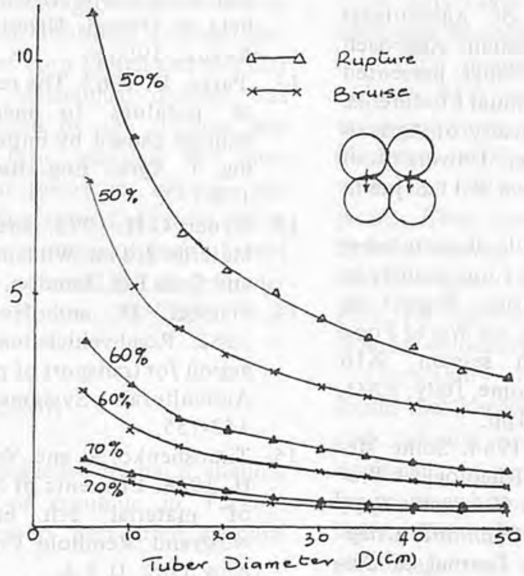

Fig. 5 Critical layer against tuber diameter for square arrangement

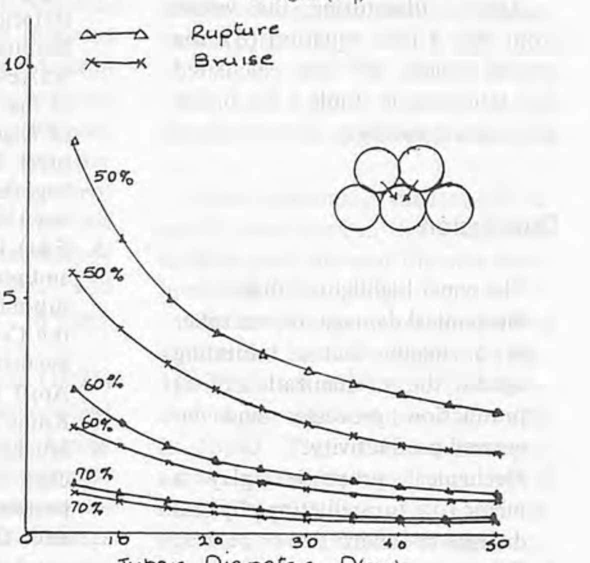

Fig. 6 Critical laer against tuber diameter for triangular arrangement

Table 1 Critical Height at Impact

Moisture content %	Bruise damage h* (cm)	Rupture damage
50	139.25	305
60	20.91	40.15
70	3.33	5.21
80	0.55	0.82

curve. The concavity of the curve is influenced by the amount of water the specimen contained.

The higher the moisture content, the shallower the curve. The values of bio-yield strength, rupture strength and modulus of deformability were calculated as in Nwandikom and Mittal (1988a 1988b) Anazodo (1982) and diagramatically represented in **Fig. 4**.

Prediction of Failure Condition

Substituting the values in **Fig. 4** into equations (3) and (5), the maximum number of layers to provide the maximum allowable stress for bruise and rupture damage in both square and triangular arrangement were determined. **Figures 5** and **6** graphically show the critical number of layers against the average diameter of the tuber at various moisture levels for bruise and rupture damage in square and triangular arrangement.

Again, substituting the values from **Fig. 4** into equation (6), the critical height h* was calculated and tabulated in **Table 1** for bruise and rupture damage.

Conclusion

The paper highlighted that:

1. Mechanical damage to yam tuber is a major factor militating against the mechanization of its production processes and increased productivity.
2. Mechanical properties play a major role in predicting physical damage to tubers.
3. Tubers at 70% moisture content and above of any size must be placed singly to avoid damage. They also should not be allowed to drop from a height above 3 cm.

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Mechanical Damage on Corn Kernel in Shelling Corn Ear

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Abstract

This study investigated the percentage of corn kernel damage as caused by the cylinder and the concave before and after the kernels were shelled from the cob and the effects of kernel moisture content and cylinder velocity on kernel damage. Three stationary sheller and TTM-813 and Karadeniz Yildizi corn varieties were used in this trial. Cylinder velocities of 7, 9 and 11 m/s were used in the shellers. Corn varieties were shelled in the kernel moisture content of 15, 20 and 25%. Damaged kernel percentage increased with an increase in moisture content percentage of corn kernel and cylinder velocity. Mechanical damage was also affected by the cylinder and concave type, physical and morphological properties of corn ear and feeding rate. Cold test germination percentages of sound kernel were not affected by the cylinder type and velocities ($P>0.05$).

Introduction

Corn is shelled by hand, shelling machine or combine in Turkey. Many farmers have used ear-corn sheller.

In corn shelling, the corn kernels are subjected to mechanical damage while passing through the shelling crescent.

Mahmoud and Buchele (1975) found that ear axis parallel to cylinder axis orientation suffered the least damage at all moisture content levels tested, followed by ears fed randomly to the cylinder. The highest damage was suffered by ears fed with their axis perpendicular to the cylinder. The minimum damage for all orientations was between 20 and 22% moisture content. They found that the corn kernel damage increased with an increase in moisture content and cylinder velocity.

In a laboratory study, Chowdhury and Buchele (1978) reported that total damage increased from 26% to 41% as cylinder velocity increased from 450 to 650 rpm. Minimum total damage was sustained at 23% moisture content (w.b.). They found that the mechanical damage by the laboratory sheller ranges between 26.3 and 42% for 12.8 m/s and 18.7 m/s cylinder velocities.

Chowdhury and Buchele (1976) found that kernel moisture content and cylinder speed were highly significant in analysis of variance for damaged corn kernel percentages. They found that average percentage of germination was 88.6% in standard germination for sound kernel.

Paulsen and Nave (1980) realized that cold germination percentages did not vary significantly with cylinder speed of threshing mechanism.

Objectives

The objectives of this study were to examine the quantity of damaged kernel in the three shellers; to investigate the effect of cylinder velocity and kernel moisture content on corn kernel damage; and to research the effect of cylinder velocities and type of sheller on germination of sound kernel corn.

Equipment and Procedure

Three stationary shellers (A, B and C) were used in this study. All shellers were run and the ears were hand-fed.

Sheller A was manufactured by Kuhne and has a feeding port (Fig. 1). The velocity ratio between crown gear (A) and bevel gear (B) is 13/40. The distance between crown gear and bevel gear is 10 mm. The part C in Fig. 1 can be operated to and fro about 40 mm.

Sheller B was manufactured by TZDK (Fig. 2). The shelling mechanism consists of peg drum and concave. The concave clearance is 30 mm. The distance between pegs is 60 mm.

Sheller C was manufactured by A.T. Ferrel (Fig. 3). The shelling mechanism consists of a peg drum and peg concave. The concave clearance is 25 mm. The distances between pegs of drum are 75 mm.

Two commercial varieties of corn (TTM-813 and Karadeniz Yildizi) were used in the experiment. The corn was hand-picked and husked from the fields of the Agricultural Research Institute in Samsun, Turkey. The levels of kernel moisture content used were approximately 15, 20 and 25% (w.b.).

Some properties of corn varieties are shwon in Table 1.

After each run, the shelled kernels were collected. The samples were then weighed and sieved with a 44 number sieve.

The sample of 100 kernels was soaked in 0.2% ink solution to aid in visual inspection. The samples were then sorted out by visual inspection with the naked eye for the damaged and sound kernel categories. A kernel was considered damaged if it was broken, cracked, chipped or had bruised pericarp or any hairline crack in the pericarp.

Sound kernels consisted of whole kernels without any of the injuries described. Those kernels did not absorb dye on any part of the kernel except the root tip.

Cold test: The soil was sieved to remove particles larger than 6 mm in diameter. A soil layer of 3-4 cm was then placed in a plastic container. Three replications of 50 seeds were planted from each sample. Then 0.5-1 cm of soil was added on the seeds. The containers were placed at 10°C for 7 days, followed by a 6-day period at 25°C and 85% relative humidity (Kietrieber, 1975; Potts and Baskin, 1971).

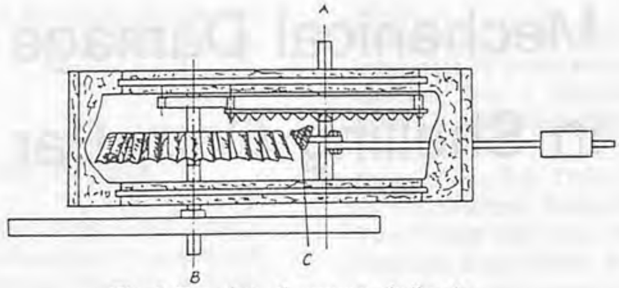

Fig. 1 Top view of corn-ear sheller A.

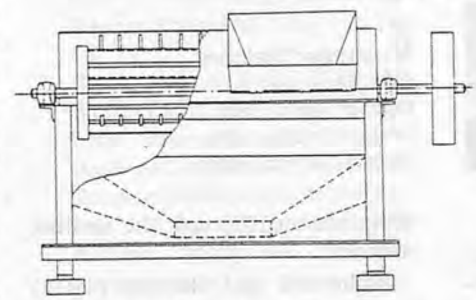

Fig. 2 Front view of corn-ear sheller B.

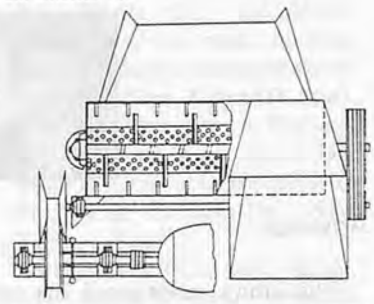

Fig. 3 Front view of corn-ear sheller C.

Table 1 Some Properties of Corn Varieties Used in the Experiment

Corn variety	Ear length (mm)	Ear large diameter (mm)	Cob large diameter (mm)	Weight of 1 000 kernels (g)
TIM-813	176	28	25	310
Karadeniz Yildizi	213	53	33	370

Results and Discussion

Damaged kernel percentages of Karadeniz Yildizi corn variety are shown in Fig. 4. Corn ears of this variety were shelled at 9 m/s cylinder velocity at various moisture content in the three shellers. As the kernel moisutre content decreased, kernel damage decreased.

Damaged kernel percentages of Karadeniz Yildizi shelled at different cylinder velocities in three shellers are shown in Fig. 5. The least damaged kernel percentage was 8, found at 7 m/s of cylinder velocity in sheller A. The highest damaged kernel percentage was 20, found at 11 m/s of cylinder velocity in sheller B.

Generally, the percentage of damaged kernel increased with the increase in velocity in A and B shellers. But in sheller C, with the

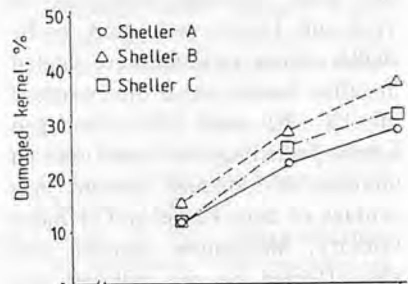

Fig. 4 Moisture content and kernel damage for Karadeniz Yildizi corn

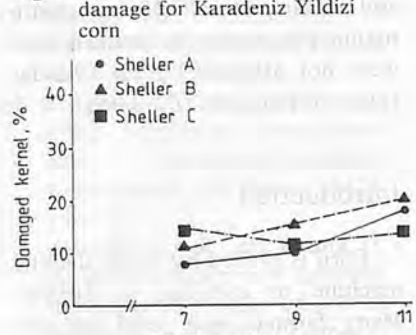

Fig. 5 Damaged kernel (%) and cylinder velocity for Karadeniz corn at 15% moisture content.

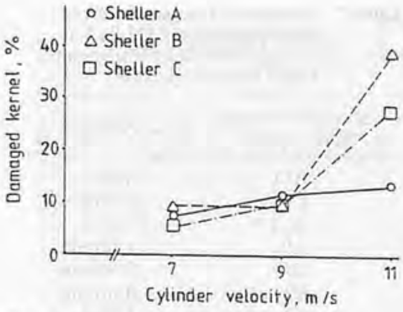

Fig. 6 Damaged kernel (%) and cylinder velocity for TTM-813 corn at 15% moisture content

increase of velocity, damaged kernel percentage first decreased and then increased. The reason for this may be the ears which were fed randomly and the long resting period of kernel in concave clearance.

The damaged kernel percentages of TTM-813 corn ear shelled at three cylinder velocities are shown in Fig. 6.

The damaged kernel percentage ranged between 6 and 39 in shelling TTM-813 corn variety.

As cylinder velocity decreased damaged kernel percentage decreased for all shellers used in this experiment for two corn varieties.

During shelling the cobs did not crack in shellers B and C due perhaps to cylinder design. Fine materials increased because of craked cobs.

Analysis of variance and Duncan test (Duzgunes, 1963) were applied to the damaged kernel percentages.

The sheller type and moisture content had high statistical significance on damaged kernel percentage for shelling of Karadeniz Yildizi corn ears (Table 2). Moisture content sheller type interaction had no significance (Table 3). The least damaged kernel percentages were found in 15% moisture content (av. 13.1%) for shelling corn ear in different shellers and moisture contents. It was followed by 20% m.c. (av. 25.6%) and 25% m.c. (av. 32.6%), respectively.

The sheller type had no statistical significance on damaged kernel percentages for shelling of Karadeniz Yildizi corn ears. But cylinder velocity had statistical significance on damaged kernel percentage. There was no difference between 7 and 9 m/s cylinder velocities (Table 5). But there was a difference between 11 m/s and them.

Sheller type, cylinder velocity and velocity sheller type interaction had statistical significance on damaged kernel percentages for shelling of TTM-813 corn ears (Table 6). The highest damages were shown at 11 m/s and 7 m/s cylinder velocities in sheller B type (Table 7). The least damage was caused at 7 m/s cylinder velocity in sheller C type. Compared to the other types, the reason for a lower percentage of damaged kernels may be caused by the steady feeding rate and ears axis coming in the same direction.

The least damaged kernel percentage in tested cylinder velocities was found at 7 m/s (av. 7.3%). As the cylinder velocities increased, kernel damage increased. This statement agrees with Sprague (1977) and Mahmoud and Buchele (1975).

The effect of sheller type on damaged kernel percentage has no significance for Kraadeniz Yildizi corn variety (Table 4) and highly significant for TTM-813 corn varie-

Table 2 Analysis of Variance for Damaged Kernel Percentages of Karadeniz Yildizi at 9 m/s Cylinder Velocity in Three Shellers and Three Moisture Content Levels

Source of variation	Sum of squares	Degree of freedom	Mean of squares	F
Sheller type, Factor A	152.10	2	76.05	39.60*
Replication	14.32	2	7.16	3.72
Error (a)	7.68	4	1.92	
Moisture, Factor B	1 762.20	2	883.60	47.76*
Interaction AB	30.80	4	7.70	0.42
Error (b)	222.00	12	18.5	
Total	2 194.10	26		

*Significant at 1% level

Table 3 Average of Damaged Kernel Percentages for Karadeniz Yildizi at 9 m/s Cylinder Velocity in Three Shellers and Three Moisture Content Levels

Sheller type	Average	Moisture content, %	Average
B	26.88a	25	32.66a
C	23.44b	20	25.66b
A	21.10c	15	13.10c

LSD (0.05)

Table 4 Analysis of Variance for Damaged Kernel Percentages of Karadeniz Yildizi at 15% m.c. in Three Shellers and Three Velocities Levels

Source of variation	Sum of squares	Degree of freedom	Mean of squares	F
Cylinder type, Factor A	29.41	2	14.70	2.04
Replication	75.63	2	37.81	5.25
Error (a)	28.82	4	7.20	
Velocity, Factor B	195.86	2	97.93	7.82*
Interaction AB	117.92	4	58.96	4.71**
Error (b)	150.22	12	12.51	
Total	596.86	26		

* Significant at the 1% level ** Significant at the 5% level

Table 5 Average of Damaged Kernel Percentages for Karadeniz Yildizi 15% m/c in Three Shellers and Three Velocity Levels

Velocity, m/s	Average
11	17.53a
9	13.10b
7	11.10b

LSD (0.05)

Table 6 Aanlysis of Variance for Damaged Kernel Percentages of TTM-813 at 15% m.c. in Three Shellers and Three Velocity Levels

Source of variation	Sum of squares	Degree of freedom	Mean of squares	F
Sheller type, Factor A	274.08	2	137.04	49.83*
Replication	21.63	2	10.81	3.93
Error (a)	11.03	4	2.75	
Velocity, Factor B	2 039.19	2	1 019.59	5.29*
Interaction AB	934.81	4	317.40	17.21*
Error (b)	221.34	12	18.44	
Total	3 202.08	26		

*Significant at 1% level.

Table 7 Average of Damaged Kernel Percentages for TTM-813 at 15% m.c. in Three Shllers and Three Velocity Levels

Sheller* velocity interaction	Average
B11	38.66a
C11	28.00b
A11	14.33c
A9	11.00cd
C9	9.66cde
B9	9.66cde
B7	8.33de
A7	8.00de
C7	5.66e

LSD (0.05)

ty (Table 6). It may be said that physical and morphological properties of corn varieties were affected in those conditions.

Germination percentages of all kernels having breaks, cracks or other injuries in their seed coat decreased highly. Cold tests of whole and sound kernels were done to understand the effect of sheller type and cylinder velocity during shelling on germination percentage (Table 8). Analysis of variance for cold test shows no difference among the cold test germination percentages (P>0.05).

The following conclusions are drawn:

1. The amount of damaged kernel decreased with a decrease of kernel moisture content.
2. As the cylinder velocity increased, the kernel damaged increased as well.
3. Sheller type, feeding type and rate of ears to the sheller, physical and morphological properties of corn ear may have effects on damaged kernel percentages.
4. Effects of sheller type and cylinder velocity on whole and sound kernels were not significant in the cold test.

Table 8 Average of Cold Test Germination Percentages of Whole and Sound Kernels of Karadeniz Yıldızı and TTM-813 Corn Varieties which were Shelled in Three Shellers and Three Cylinder Velocities

Corn variety	Sheller type	Cylinder velocity, m/s 7	9	11
Karadeniz Yıldızı	A	95	94	95
	B	95	92	93
	C	95	94	92
TTM-813	A	92	94	94
	B	96	93	94
	C	94	93	93

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Design, Development and Evaluation of Castor Bean Sheller

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Abstract

A hand/power operated castor bean sheller was developed and evaluated. It consists of a feed hopper with regulator, a screw auger, shelling discs, flywheel and blower. The unit can be either operated manually without connecting the blower or operated by 0.5 hp electric motor with blower. The unit was evaluated and compared with the performance of existing hand-operated and power-operated groundnut decorticators for shelling castor bean. The size and orientation of slots in the perforated sieve of groundnut decorticators were studied. When the slots were perpendicular to the direction of oscillation, the castor bean shelling efficiency is greater with minimum breakage to castor kernels. The output and shelling efficiency of power/hand operated castor bean shellers are 163.00 and 52.65 kg, 97.29% and 98.72% with a kernel breakage of 0.82% and 0.88%, respectively.

Introduction

In Tamil Nadu, castor bean is one of the important oilseed crops. It is grown mainly as intercrop with groundnut, turmeric, sugarcane, etc and is grown in an area of about 6 500 ha. Nowadays castor bean has become one of the precious agricultural products due to its use in industries and space research. Traditionally, castor bean is shelled after drying on floor under sunlight and manually beating or rubbing with wooden planks which consumes much human energy and time during the labour scarce period. With the advance in science and technology agricultural operations have to be mechanized not only to increase production but also to cope with the non-availability of agricultural labour.

The peak castor bean harvest season is from January to April. Acute labour scarcity arises during this period due to harvesting and shelling of castor bean. Hence if mechanical castor bean sheller is introduced, much of human drudgery can be removed.

Materials and Methods

Castor Sheller

A hand/power operated castor sheller was designed and developed.

Construction features – The TNAU castor sheller consists of a trapezoidal shaped feeding hopper tapering towards the bottom with a shutter to regulate the feed rate. Below the shutter a screw auger is provided which passes the castor pods to the shelling portion. The shelling portion consists of two wooden discs fastened with 6 mm thick rubber sheet over the rubbing faces. One disc is mounted on the shaft and the other is rigidly fixed to the frame. The disc mounted on the shaft is held against the stationary disc by means of a compression spring, the tension of which can be adjusted by rotating a screw provided for it. The clearance between the discs can be adjusted to accommodate different sizes of castor by sliding the rotating disc on the shaft. To clean the shelled kernels a blower is fitted. The unit may either be operated manually or by a 0.5 hp electric motor. During operation with electric power the drive for the auger shaft is given by a V-belt through the grooves over the flywheel itself and for manual operation, the flywheel will be mounted on the other end of the shaft and the gears and handle will be fitted in that place. The electric power is disconnected during manual operation. The details of the unit is shown in **Fig. 1**.

Operation – The castor pods are fed into the hopper. From the hopper they are taken in between the shelling discs by means of the auger. The quantity of castor pods fed into the shelling portion is controlled by means of a shutter provided at the bottom of the hopper.

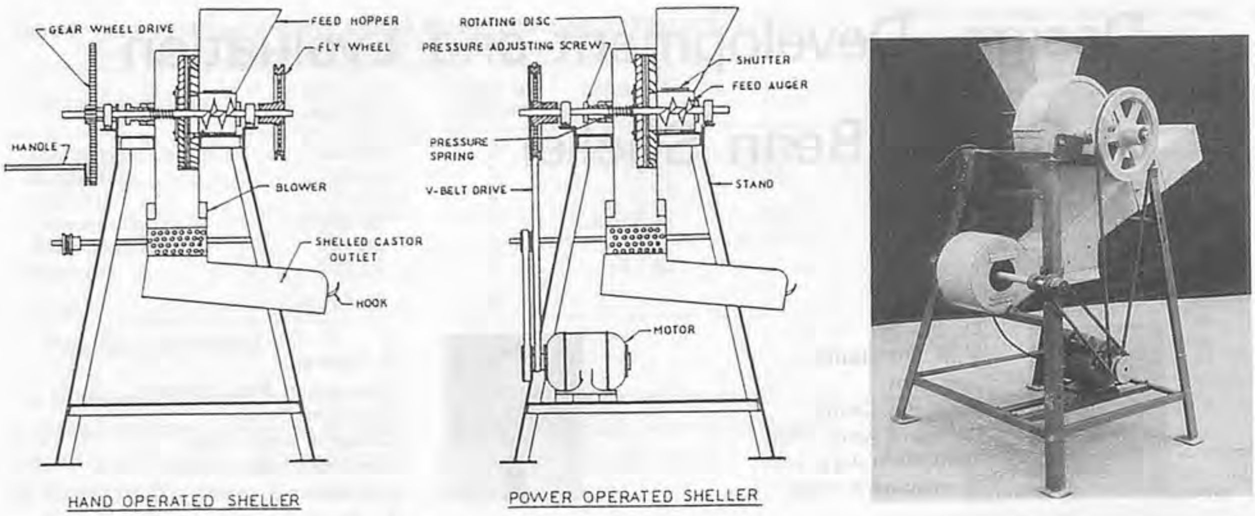

Fig. 1 TNAU castor sheller.

Due to the pressure exerted and rubbing action provided on the castor pods by the rotating disc, the castor seeds are separated from the pods and collected at the bottom along with husks. When the unit is manually operated the husks have to be separated from seeds by means of wind. On the other hand, if the unit is operated by electrical power, the husks are separated from the seeds by the blower. The clean seeds are collected at the outlet.

Modification of TNAU Hand-operated and Power-operated Groundnut Decorticators for Shelling Castor

Hand-operated groundnut decorticator – The hand-operated unit consists of curved 'L' angle frame and four legs as shown Fig. 2b. A perforated sieve in a semi-circular shape is provided. Seven cast iron peg assemblies are fitted in an oscillating sector. The groundnut pods are shelled between the oscillating sector and the perforated concave sieve. The kernels and husk are collected at the bottom of the unit. The clearance between the concave and the oscillating sector is adjustable to decorticate pods of different varieties of groundnut. The sieve is also replaceable according to the variety of groundnut.

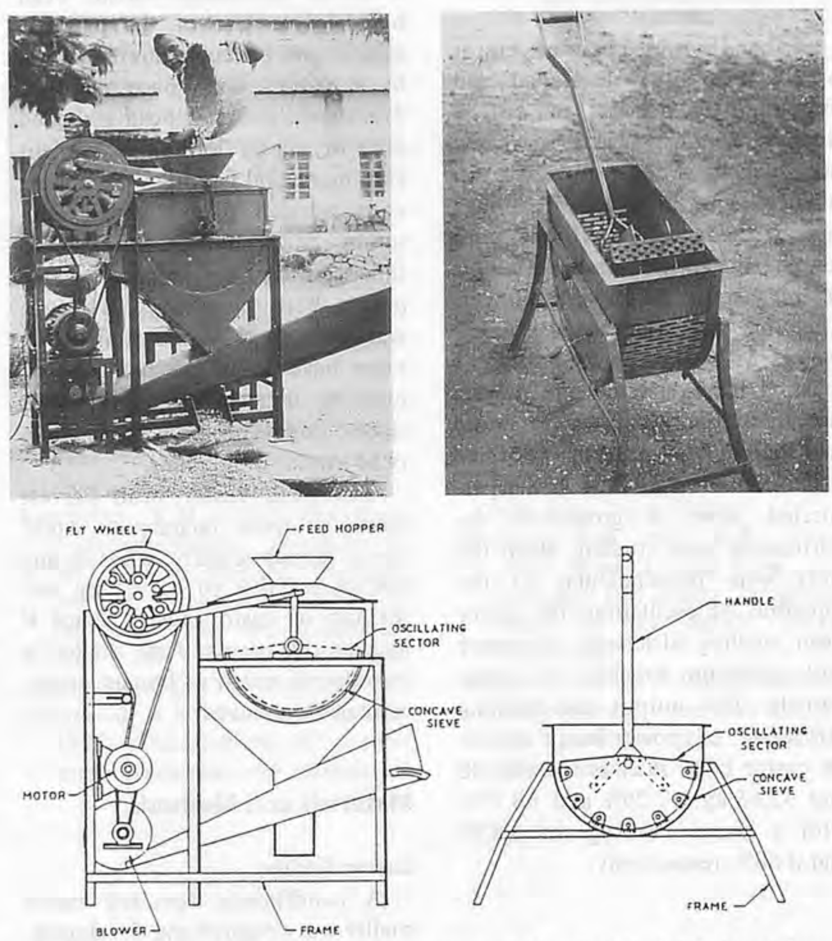

Fig. 2 Groundnut decorticators (left: power-operated type, right: hand-operated type).

Power-operated groundnut decorticator – The power operated pod opener or decorticator consists of a hopper, double crank lever mechanism, oscillating sector and a blower assembly, all fixed on a frame as shown in Fig. 2a. A number of cast iron peg assembles are fitted in the oscillating sector unit. The groundnut pods are shelled between the oscillating sector and the perforated concave sieves fixed to the frame. The blower separates the kernels and husk and the kernels are collected through the spout at the bottom. The clearance between the concave and the oscillating sector is adjustable to decorticate pods of different varieties of groundnut. Similarly, the sieves are also replaceable to avoid damage to kernels.

The Modifications carried out are as follows – The sieves were replaced by three different sieves with 20 x 6 mm perforations with orientations parallel, perpendicular and inclined to the direction of oscillation.

Treatments

Following are the treatments taken up for evaluating the castor sheller and groundnut decorticators for shelling castor. The specifications of the units are given in **Table 1**.

TNAU Castor sheller – Power-operated
TNAU Castor sheller – Hand-operated
Groundnut decorticator – Power-operated
Groundnut decorticator – Hand-operated

Conventional method of rubbing with wooden planks.

Evaluation – The length, width and thickness of the castor pods, capsules and kernels were measured by using a vernier caliper. The moisture content of the pods, husks and kernels were measured by oven drying method. Shelling capacity means amount of castor pods shelled per unit time. Cost of operation means fixed cost + variable cost.

For calculating the cost of operation the following assumptions were made:

Table 1 Specification of Castor Shellers and Groundnut Decorticators

Particulars	TNAU castor sheller		Groundnut decorticator	
	Power	Manual	Power	Hand
Make	––––– A ICRP ON FIM, TNAU –––––			
Type	Power	Manual	Power	Manual
Overall dimensions, cm				
i) length	105.0	105.0	127.5	115.0
ii) width	80.0	80.0	58.5	50.0
iii) height	132.0	132.0	133.0	132.5
Weight of the unit, kg	72.5	72.5	181.0	34.8
Power transmission system	V-belt	Gears	V-belt	Direct drive
Shelling unit				
i) Type	Circular disc. (One stationery)		Oscillating sector and perforated concave	
ii) Material	Wood with rubber facing		Cast iron pegs and m.s. perforated sieve	
iii) Dimensions of main parts, cm	Disc dia. 30.0 thickness: 3.5		Sieve size: 133 x 25	
Clearance adjustment	Automatic spring tension and manual adjustment		Manual adjustment	
Provision of blower	Provided	–	Provided	–
Method of feeding	––– Force feed –––		Manual	Manual
Feeding rate control	Manually adjusting the shutter opening		Manual	Manual
Labour requirement	1 man	1 man + 1 woman	1 man	3 women
Cost, Rs.	2 000	1 400	5 600	800

Life of the machine : 10 years
Scrap value : 10% of purchase price
Interest : 15% per annum
Repair and maintenance : 5% of purchase price per annum
Annual usage : 100 qtl of castor (for groundnut decorticator only 25% usage is taken for castor shelling)
Cost of power : Rs. 0.60 per kW

After shelling by the machine, the unshelled and uncleaned portion of the castor will be shelled and cleaned by woman labour, manually. In the case of hand-operated units the cleaning was carried out by woman labour.

Shelling efficiency :
[Total pods input–(unshelled pods + unshelled capsules)] / Total pods input

Cleaning efficiency :
Husk in the blower outlet/ Husk in the blower outlet and kernel outlet

Breakage of kernel :
Broken kernels/(Broken kernels + whole kernels)

Results and Discussion

Groundnut Decorticator

Trials were conducted to ascertain the best orientation of perforation in the concave sieve of the groundnut decorticators so as to attain greater shelling efficiency with minimum breakage to kernels. Three 20 x 6 mm slot size perforated sieves with different slot orientation as shown in **Fig. 3** were used in the trials. **Table 2** shows the results obtained with these sieves.

From **Table 2**, it is seen that shelling efficiency is more or less similar for sieves with slots perpendicular and parallel to the direction of oscillation, respectively. But when the slots are perpendicular to the direction of oscillation, the breakage of kernels is minimum. When the slots are inclined, the shelling efficiency is low. Hence, the sieve with slots perpendicular to the direction of oscillation was taken up for comparative study for

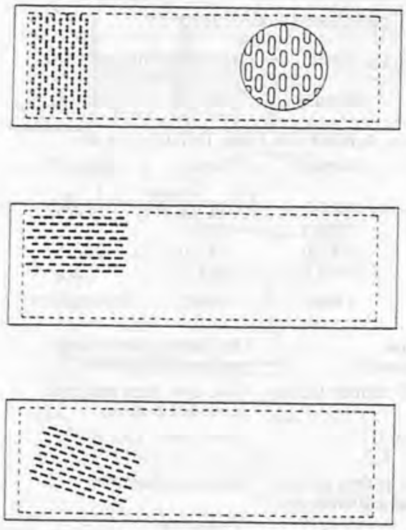

Fig. 3 Sieves with slots at three different orientation.

both in the hand-operated and power-operated groundnut decorticators.

Performance Evaluation

Performance evaluation of the TNAU castor shellers in comparison with power-operated and hand-operated groundnut decorticators and conventional method of rubbing were conducted in the farmers' field with rainfed castor crop. The results obtained are presented in Table 3 and Fig. 4.

i) From Table 3 and Fig. 4, it can be seen that when the TNAU castor sheller is operated by power, it can shell 163 kg of castor pods/h with shelling efficiency of 97.29% and breakage to kernels at 0.72%. The cost of shelling is Rs. 9.02/qtl of pods at an annual usage of 100 qtls. The cleaning efficiency of the machine at a blower speed of 2 050 rpm is 90.9%.

ii) When the same machine is operated manually, it can shell 52.63 kg of castor pods/h with shelling efficiency of 98.72% and breakage to kernels at 0.88%. The cost of operation is Rs. 22.53/qtl of pods at an annual usage of 100 qtl.

Table 2 Shelling Results with Different Orientation of Slots

Position of slots to the direction of oscillation	Size of kernels mm l b h	Shelling efficiency %	Breakage of kernels %	Unshelled %
Perpendicular	13.5, 8.5, 5.6	95.50	0.80	4.50
Parallel	–do–	95.20	2.20	4.80
Inclined	–do–	91.40	1.00	9.60

Table 3 Performance Test – Data Sheet

Particulars	TNAU castor sheller		Groundnut decorticator		Conventional method of rubbing
	Power	Hand	Power	Hand	
Make	TNAU		TNAU		–
Type	Rotary		Oscillating		–
Power required	0.5 hp	–	1.0 hp	–	–
Labour required	1 man	1 man + 1 woman	1 man	3 women	1 woman
Crop variety	Local, rainfed				
Moisture content, %					
i) pods	4.12				
ii) husk	7.53				
iii) kernels	2.64				
Kernel/husk ratio	75:25				
Size of the pods, capsule and kernel, mm					
i) length	17.57, 17.40, 13.50				
ii) width	15.50, 9.25, 8.25				
iii) thickness	15.50, 7.62, 5.60				
iv) shape	– oblong –				
Cylindrical drum, disc. rotation speed/cranking speed rpm, strokes/min	210	200	160	40	–
Blower speed, rpm	2 050	–	3 500	–	–
Time taken, %					
i) for shelling	24.73	18.42	12.53	12.61	49.71
ii) for cleaning	65.86	79.13	76.85	83.23	48;54
iii) for shelling and cleaning the unshelled portion manually	9.41	2.45	10.82	4.16	1.75
Output through kernel outlet, %					
i) Pure kernels	64.64	66.56	60.24	62.48	64.52
ii) Unshelled pods	0.40	0.00	0.00	0.00	0.16
iii) Unshelled capsules	2.00	1.24	1.36	4.52	2.84
iv) Broken kernels	0.48	0.56	1.40	0.80	2.28
v) Husk	2.52	29.80	0.24	30.32	30.72
vi) Immature kernels	0.28	1.56	1.24	1.72	1.40
Output through blower outlet, %					
i) Pure kernels	2.64	–	2.24	–	–
ii) Unshelled pods	0.00	–	0.00	–	–
iii) Unshelled capsules	0.28	–	1.00	–	–
iv) Unshelled kernels	0.00	–	1.04	–	–
v) Husk	25.24	–	30.16	–	–
vi) Immature kernels	1.40	–	1.00	–	–
Unaccounted	0.12	0.28	0.08	0.16	0.08
Shelling capacity, kg of pods/h	163.00	52.63	230.08	76.00	11.72
Cost of operation					
i) Cost of the unit, Rs.	2 000	1 400	5 600	800	–
ii) Wages for man labour, Rs/h			1.69		
iii) Wages for woman labour, Rs/h			1.57		
iv) Total cost of operation/qtl of pods (including cleaning), Rs.	9.02	22.53	9.30	18.87	26.95
Shelling efficiency, %	97.29	98.72	97.65	95.50	97.00
Cleaning efficiency, %	90.99	–	99.17	–	–
Breakage of kernels, %	0.72	0.88	2.27	1.26	0.48

Note: US$ 1 = Rs. 13.02

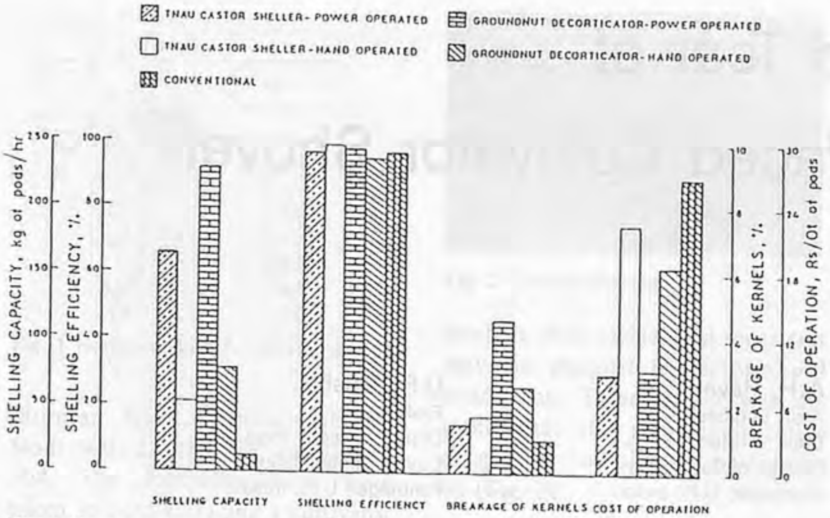

Fig. 4 Comparative performance of different methods of castor shelling.

iii) When the castor is shelled with power-operated groundnut decorticator with sieve containing 20 x 6 mm thick slots perpendicular to the direction of oscillation, the shelling capacity is 230.08 kg of castor pods/h with a shelling efficiency of 97.65%. The breakage of kernels in this decorticator is 2.27% and the cost of operation is Rs. 9.30/qtl of pods when the annual usage is 100 qtl of castor and 300 qtl or groundnut. The cleaning efficiency is 99.17%.

iv) The hand-operated groundnut decorticator when fitted with sieves of 20 x 6 mm perpendicular slots, the shelling capacity is 76 kg of castor pods/h with a shelling efficiency of 95.50%. The breakage of kernels noted in this decorticator is 1.26% and the cost of operation is Rs. 18.87/qtl of castor pods when the annual usage is 100 qtl of castor and 300 qtl of groundnut.

v) The shelling rate by conventional method of rubbing is 11.72 kg of castor pods/h/woman worker. The efficiency of shelling is 97% and the breakage to kernels noted is 0.48%. The cost of shelling and cleaning by conventional method is Rs. 26.95/qtl of castor pods.

Conclusion

i) When the groundnut decorticators are used for shelling castor, the perforation of sieves with perpendicular slots to the direction of oscillation gives the best result.

ii) The shelling efficiencies of TNAU power castor sheller, TNAU manual castor sheller, power and hand-operated groundnut decorticators are 97.29%, 98.72%, 97.65% and 95.50% respectively. The breakage to kernels noted are 0.72%, 0.88%, 2.27%, and 1.26%, respectively.

iii) The cleaning efficiency of TNAU power castor sheller and power-operated groundnut decorticator are 90.99% and 99.17%, respectively.

iv) The shelling capacity of the TNAU power castor sheller, TNAU manual castor sheller, power-operated groundnut decorticator and hand-operated groundnut decorticator are, respectively, 163.00, 52.63, 230.08 and 76.00 kg of castor pods/h. The total cost of operation is Rs. 9.01, 22.53, 9.30 and 18.87 per qtl of castor pods, respectively, as compared to Rs. 26.95 by conventional method of rubbing.

Wear and Tear of Hard-surfaced Cultivator Shovel

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Abstract

It is possible to combat the wear and tear of agricultural tools by hard-surfacing them with suitable electrodes. As a case study, hard-surfacing of cultivator shovel was done using electrodes: Ultimium N112, Cromcarb N6006, Modi 600, Lomet 303 and Lomet 304. Specific geometrical pattern based on critical wear locations was selected. For single-layer hard-surfacing, this was based on economical and technical consideration. A special soil-bin wear test was conducted on these shovels under controlled test conditions. From economic point of view, Lomet 303 has been found to be the best hard-surfacing electrode.

Introduction

India is a vast country. Its population of over 800 million is increasing at a tremendous rate. It is necessary to provide food to such a large number of people. The Green Revolution has ushered in new era of partial self sufficiency in food. Now agriculture is considered as an industry and the old methods of agriculture have been abandoned. Technology has contributed in a big way to farm mechanization. Lots of equipment and implements are in extensive use in the agricultural industry. Large scale industries are manufacturing mostly capital-intensive equipment, like tractors, combines, harvesters, threshers, diesel engines, pumps, power tillers, etc. However, the small-scale industries are making tools like ploughs, disks, shovels, shears, blades etc, which are used on a large range of implements. Due to limited resources and less technical know-how, the small-scale industries, have not been able to do justice with respect to design, performance and manufacturing technology of the agricultural tools. It is felt that advancement in the field of technology be fruitfully utilized for modernization of the agricultural tools, particularly in India.

In view of the foregoing, hard-surfacing can play a vital role. Hard-surfacing with specialized welding filler metal using the normal welding processes is used to replace worn out metal with metal that can provide more satisfactory wear than the original. Moreover, a good quality of coating can be applied to the tools.

Some work has been reported on hard-surfacing of agricultural implements (1, 2, 3, 4). Kaushal and Raval (5) reported that the abrasive wear under grinding wheel, of hard-surfaced mild steel is of reducing magnitude according to the electrodes used, Ultimium N112, Lomet 303, Cromcarb N6006, Lomet 304 and Modi 600. Therefore, the same electrode could be used for hard-surfacing of cultivator shovels.

It is possible to hard-surface the entire surface of a tool to minimize wear and tear by single-layer deposit, two-layer deposit and three-layer deposit. But it can be easily visualized that the maximum amount of material will be required if three layers are deposited. Not only is the cost of the material high but also the time and cost of welding are high. Even after the wear out of the first layer, the second time hard-surfacing may be done with ease and it will reduce the force on the tool in comparison to multi-layer deposit. Moreover, in single-layer deposit, grinding may be easily eliminated.

Furthermore, it is not necessary to hard-surface the whole surface of the tool since wear and tear commence from the critical contact locations between the tool and the abrasive environment. After identifying the critical locations, the final choice is made (**Fig. 1**).

Material and Procedure

Five mild steel shovels were hard-surfaced using the electrode

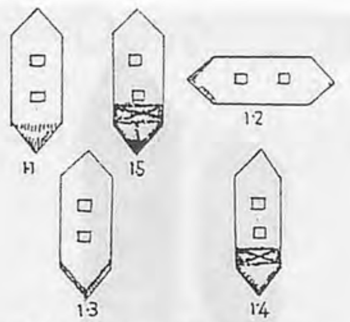

Fig. 1 Hardsurfacing of cultivator shovel.

Ultimium N112, Cromcarb N6006, Modi 600, Lomet 303, and Lomet 304. The following steps were taken in hard-surfacing a cultivator shovel.

1. Paint and rust was removed by grinding.
2. Fig. 1.2 shows the position of shovel while hard-surfacing the corner edge in fixture.
3. Using DC current with reversed polarity welding machine was set up at appropriate current and voltage value as recommended by electrode manufacturers. Of course, these values of current and voltage are higher than those used for normal welding.
4. Clamping the shovel in flat position, two parallel, two across, and two diagonal layers were deposited as shown in Figs. 1.3 and 1.4.

Finally, by weaving the electrode, the last layer was deposited running from the nose tip of the shovel to the centre line as shown in Fig. 1.5.

Experimental Set-up

In actual practice the shovels are fitted on cultivator-frame. The cultivator is run in the field. The condition of the soil varies from location to location. At certain locations the soil may be very hard and at certain locations it may be very soft. There may be little or more moisture, with or without pebbles and roots, etc.

Actual field test requires time and money. With a view to testing hard-surfaced shovels it was thought that accelerated wear test may be planned in uniform soil conditions. Therefore, it was decided that the standard practice of circular soil-bin test be followed (Fig. 2).

Fig. 2 Circular soil bin.

Circular Soil-bin

The circular soil bin is used for continuous testing of agricultural tools. The bin is circular in shape and is made of concrete. The circular bin has an outer diameter of 291 cm and inner diameter of 187 cm, thus with a width of 104 cm in which a tool can run continuously on top of the periphery wall of the bin where a rubber wheel rotates that is connected to the carriage. There is a provision to fix the shovel-mounting device on the carriage. The bin is filled up to desired level. The moisture condition of the soil can be maintained.

Shovel Wear Test

Initially the shovels were weighed on pantokilo top pan balance with 100 mg sensitivity. The shovels were fitted on the shovel mounting device. The depth of shovel under the sand was maintained constant at 13 cm. The sand conditions were also maintained constant. The test ran for a period of 10 h. The shovels were run at a peripheral speed of 5 rpm. After 10 h, shovels were removed from the device and weighed again. The process was repeated five times. Thus total test duration was 50 h.

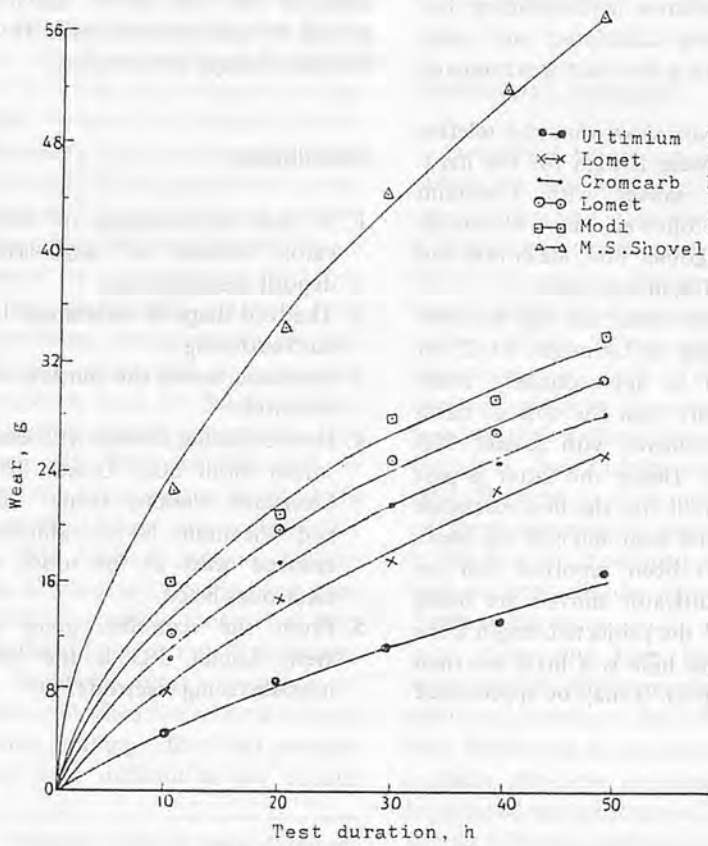

Fig. 3 Amount of wear vs time.

The difference in weight before and after the test is the amount of wear on the corresponding shovel. The result obtained are plotted in Fig. 3.

Discussion of Results

Fig. 3 will show the following:

1. The amount of wear increases with increase in time.
2. Maximum wear occurs in the case of mild steel shovel which is not hard-surfaced.
3. Hard-surfacing shovels with electrodes Modi 600, Lomet 304, Crom-carb N6006, Lomet 303 and Ultimium N112, exhibited reduced wear in the order of electrode listed.
4. The wear in the case of Ultimium N112 was lowest.

Relative Cost Analysis

The relative cost of wear and tear of different hard-surfacing electrodes was calculated and using these data, a bar chart was prepared (Fig. 4).

The bars show that the relative cost of wear is high for the hard-surfaced shovel with Ultimium N112, followed by Cromcarb N6006, Lomet 304, Modi 600 and Lomet 303, in that order.

However, wear and tear was least in the case of Ultimium N112 but the cost is approximately seven times more than the cost of hard-surfaced shovel with Lomet 303 electrode. Hence the latter is preferable as it has the best electrode for abrasive wear and cost the least.

It has been reported that on farms cultivator shovels are being run until the projected length from the centre hole is a little less than half (Fig. 5). It may be appreciated

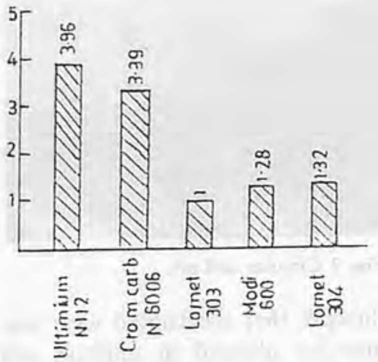

Fig. 4 Relative cost analysis.

than when the shovel has lost its edges and becomes almost of smooth-circular-profile, then its digging action is highly uneconomical, not only from amount of penetration but from load traction-wise also.

If the shovel is hard-surfaced then the question of loosing the intended profile is postponed for a long period of time. When the hard-surfaced material is found depleted on the shovel surface, it may be hard-surfaced again. Thus the shovel shape is maintained.

Conclusion

1. In the hard-surfacing of cultivator shovel a single-layer deposit is satisfactory.
2. The tool shape is maintained by hard-surfacing.
3. Substrate serves the purpose indefinitely.
4. Hard-surfacing shovels with electrodes Modi 600, Lomet 304, Cromcarb N6006, Lomet 303 and Ultimium N112 exhibited reduced wear in the order of electrodes listed.
5. From the economic point of view, Lomet 303 is the best hard-surfacing electrode.

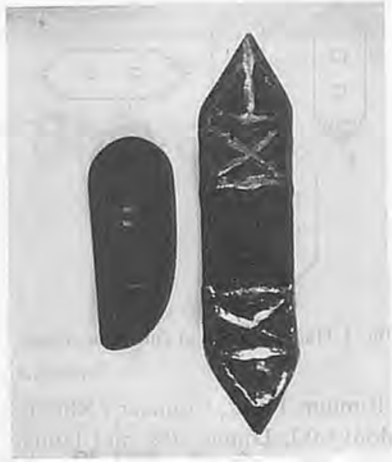

Fig. 5 Left-hand shovel shows wear due to use.

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Development of a Power-driven Sugarcane Detrasher

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Abstract

This paper discusses the efforts made to establish the type of mechanism suitable for detrashing the whole cane. Once established, a tractor mounted PTO-driven detrasher was developed. Under normal crop conditions the unit removes the dry and the green leaves off the cane. The capacity of the machine is limited by the rate of feeding the canes manually. However, the detrashing capacity is more than 1 t/h. The weight of the machine is about 350 kg.

Introduction

Although the pace of mechanization is rapid enough to help boost the production of wheat and paddy crops, it is still relatively slow for sugarcane crop production. The use of sett cutting machine, moist hot air seed treatment unit, and sugarcane planters have been widely accepted by the cane growers. The sugarcane harvester is making headway to the farmers' field. Mechanization of detrashing operation is still awaited. The demand is justified, too. If the cutting of cane consumes 23 man-days per hectare of a crop with 70 t/ha, the detopping, detrashing and stacking require approximately 120 man-days (Sharma and Singh, 1985). Field surveys show that on average, dry leaves also known as trash, vary from 6.5 to 7.4% by weight while green leaves, including tops, weigh about 13.6 to 13.9%

There is a considerable amount of increase in the manpower during the last three decades (120 million in '81*) but the manpower availability in farm has decreased due to migration from rural areas to urban areas (82.7% of population in rural areas in '51, to 79.3% in 1981*). Thus the peak requirement of manpower for a limited period of time is negotiated with untimely farm operations. In mill areas harvesting, cleaning and supply at purchasing centres is done by the farmers on receipt of a supply permit from the sugar mill which specifies date and quantity of cane to be supplied. To meet the limited labour availability in time, farmers continue harvesting, cleaning and stocking sugarcane slowly and supply them when they get the supply permit. Consequently, decline in sugar recovery is experienced when the canes are stored before milling. The fact remains that it is difficult to get enough labour to do the job of cutting and cleaning of canes on time. This being a perpetual problem which demands for a power-operated machine to handle the canes in bulk and which could handle job with less manpower. A project was thus initiated to develop a tractor-operated detrasher to meet the above requirement.

Review of Literature

Detrashing before or after harvesting has been of great concern to cane farmers and researchers. There is general practice of trash burning before harvesting. Srivastava and Singh (1987) reported various parameters which affect the trash management in India. There is a general practice in the interior villages to collect these trash in good condition for making roof and mats. However, it is an uneconomical farm operation if done manually. Most of the developed countries have adopted the use of sugarcane combine harvestor which normally cuts, chops and then blows the loose trashes. The remaining trash with the canes are cleaned in the mill. While this is not the practice in India, the canes are supposed to be cleaned and unchopped for mill supply. Efforts to define and investgate the parameters associated with

Acknowledgement: Help from Shri Someshwar Mishra and Shri R.N. Kureel is acknowledged.

*Source: Times of India, Directory, 1982.

detrashing have lagged behind.

Mason et al (1980) defined the extraneous matter (unwanted matter) removal efficiency (EMRE) and the removal efficiency for leaves and for cane tops alone along with the actual percentage of each in the cane supply in the following equation.

$$EMRE = \frac{\text{(EM levels in the field} - \text{EM levels in the harvested cane)}}{\text{EM levels in the field}}$$

Where EM is the extraneous matter.

Abreu and Abreu (1980) investigated the behaviour of a suction pneumatic chamber for sugarcane extraneous removal under varying feeding rates and concluded that cane losses which occurred during the removal process were not influenced by feed variables and the power consumption by the chamber was directly proportional to the initial extraneous matter composition. Fernandes et al (1963) reported that the percentage of trash in field cane is dependent on several factors, the main ones being the system of cutting and loading, the height of topping, weather conditions at the time of harvest, sugarcane variety, age of the crop, and the efficiency of burning, etc. They concluded that the cane cut by chopper harvester showed a total trash 2.07 times higher than the hand cut-mechanically loaded cane.

Other authors like Clayton et al (1974) Funjul (1971), Chang (1977), Pao (1973), Yang (1981) and Yamaguchi and Yabu (1982) reported on the management of trash and cutting resistance of sugarcane stalks. They, however, maintain that the varietal and qualitative characteristics of the sugarcane might be a significant parameter affecting the investigation. The quantitative and qualitative concept of detrashing the sugarcane stalk were investigated by Srivastava (1988). With the use of dimensional analysis he came out with the following final expression:

$$D_f = K \frac{A_c^2}{H_l D_n N_d}$$

where

D_f = force required to detrash the sugarcane, N

K = a constant, = 268.644 kg/cm.

A_c = cane area caught by leaf, cm^2

N_d = nodal diameter, cm

H_l = height of leaf from top of the cane, cm

The correlation coefficient between the observed and the estimated values of D_f was 0.818. It was reported that the maximum force required to detrash the moist, sticky dry green leaves from the nondefoliating varieties did not exceed to 25.2 N. The minimum value was 0.098 N.

Phase of Development

Detrashing is done twice during sugarcane cultivation; once during the months of August and September for disease and pest control and for tying the canes together in bunches to avoid lodging, the other one after harvest for milling purposes. Srivastava and Singh (1982) developed a simple manual detrasher-cum-collector which increases the efficiency of labour by 5-7 times.

In order to develop a power-operated detrashing unit for harvested canes, basic configuration of a machine was developed consisting of a cane conveying unit, a set of positive feeding spungy rollers, various detrashing mechanisms, a blower and the required power supply. The system was initially developed for a low velocity, for less than 1.5 m/s. Various mechanisms for detrashing the canes fed in a bunch of 5 to 10 pieces were tried with varying degree of success **(Fig. 1)**. The type of drive system to these mechanisms were

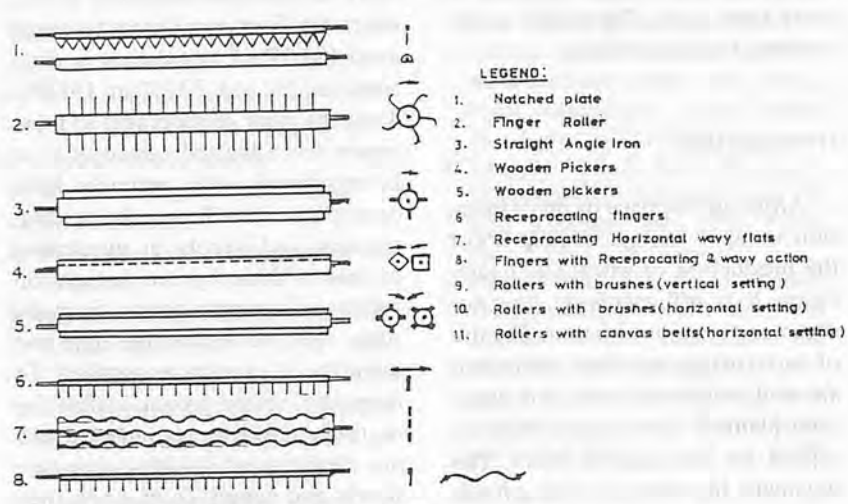

Fig. 1 Mechanisms used for sugarcane detrashing: phase of development

one of the following, stationary, rotary, reciprocating and wavy combined with the reciprocating.

In the beginning, the canes were fed to the machine from top through a stationary plate having a set of v-notches. The cane leaves were scratched through this device with nodes being damaged and with too much of intermingling of the loose trash with the result that the efficiency of the blower was considerably low. The green tops were not cleaned. The device was not satisfactory for even the detopped canes. The rotating mechanisms were then tried. With the use of 10 cm long curved fingers 5 cm spaced apart, the whole canes were being detrashed but due to improper alignment of canes with respect to the finger configuration, choking was frequentlly experienced. To avoid this, straight angle iron pieces were welded on the periphery of the rollers. There was apparently no choking but detrashing was considerably less. Efforts were then concentrated on the principles of pickers. The devices as shown in Fig. 1. serial number 4 and 5 were developed to pick up the loose cane leaves while the whole canes were being pushed forward through positive feeding set of spungy rollers. Results were less encouraging.

The efforts were then concentrated on the reciprocating devices. The device consisting of 10 cm straight fingers spaced 5 cm apart was provided with reciprocating motion through simple crank drive. This system proved better than the horizontal wavy flats as shown in Fig. 1. However, the results were not up to the mark. Thus the set of fingers were driven in a wavy combined with reciprocating motion. This device could produce desired results with a limitation of feeding input which could not be increased to more than 5 to 10 cane pieces at a time and at a low speed less than 1.5 m/s. This did not meet the objective of the project. Therefore, efforts were once again made on the rotary motion. A pair of rollers with steel wire brushes on its periphery was developed and tested. The results were encouraging. The system had a problem of disposing the loose trashes so the rollers were set horizontally. The trash started flowing downward partially due to the rotary action of the rollers (moving opposite to each other) and partially due to the blow of air provided through the blower. However, clean canes were observed having bruises on the surface. The nodes were also found damaged to a large extent. Since the surface to grip the leaves had to be rough and since the action had to be faster than 2.0 m/s, another set of rollers of larger diameter (20 cm) and with higher peripheral speed (4 m/s) was developed to do the detrashing operation without producing bruise on the cane surface and without damaging the nodes. The rollers were provided with spring-cushion and canvas belts at their periphery. Field trials confirm that this mechanism with proper combination between the diameter of the rollers and its peripheral speed would, however, be able to produce the desired results.

The Power-operated Cane-detrasher

Based on the previous trials, a tractor-mounted type, and PTO-operated sugarcane detrasher was finally developed (Fig. 2) The cross sectional view of the machine is shown in Fig. 3. The apperance of the machine is more like a well-adopted wheat thresher machine. It contains: 1) two rollers moving in opposite direction to each other, 2) one cane feeding beater, 3) one cane take off beater and 4) one blower. The unit receives power from the PTO of a tractor which would also be able to lift the unit (about 350 kg) for transportation. The drive is then transmitted to various parts of the system through sprocket chain drive, gear drive and through v-belt pully. Except for the blower which runs three

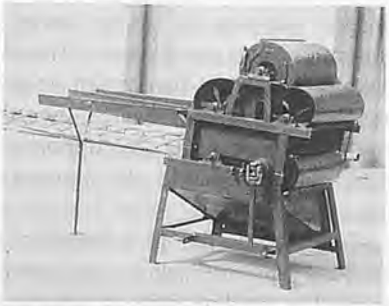

Fig. 2 Tractor-mounted, PTO-driven sugarcane detrasher (IISR)

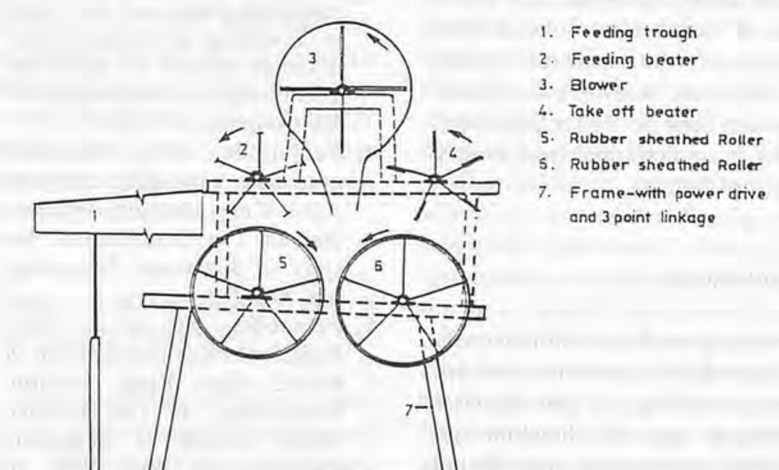

Fig. 3 Cross-section of sugarcane detrasher (IISR)

times faster than the PTO speed, other rotating parts are driven at the PTO speed. The variation in peripheral speeds was obtained by changing its effective diameter.

The cane feeding beater was provided with angle iron pieces faced with 1 cm thick layer of canvas belt. The cane take-off beater is provided with flats and angle iron fastened with 10 cm wide canvas belts. The belt is cut making 5 cm square flaps on its periphery in order to protect the canes being damaged. The detrashing rollers were provided with 1 cm thick and 10 cm wide rubber canvas belt on its periphery. The diameter of these rollers is 45 cm. This results in a peripheral speed of 10 to 12.7 m/s depending upon the PTO speed. The outer surface being rough and the air passing through the holes provided on the surface of the rollers ensure proper gripping of loose leaves, including the green ones. These trash along with the tender tops are then thrown downwards due to the rollers rotating in opposite direction and due to the blow of air.

The cane is fed in a bunch of 10 to 15 pieces each by two persons. The feeding rate is dependent upon the frequency of the person who is to lift the whole cane in bunches into the feeding trough of the machine. Canes fed are seen thrown away simultaneously due to faster peripheral speed in a detrashed and mostly detopped fashion.

Conclusions

Various mechanism for detrashing the whole cane were tried and a unit consisting of a pair of rollers moving in opposite direction and installed horizontally was found satisfactory in removing dry and green leaves off the canes. The efficiency of detrashing was much dependent upon the peripheral speed of these rollers.

Thus a machine with a cane feeding beater, a cane take off beater, a pair of rollers, a lower and a feeding trough was developed to be operated through the PTO drive of any tractor. The unit being mounted type makes it easy for transportation.

The machine is capable of detrashing and detopping (under normal crop condition) the canes simultaneously. Its capacity is more than 1 t/h depending upon the rate of feeding.

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Determination of Food Grain Moisture Content by Microwave Heating

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Abstract

Research work on the use of microwave heating of food grains for quick moisture determination is reviewed in this paper. The theory and principles of microwave heating are discussed in brief. Different methods employed for moisture determination by microwave heating are described. The findings of various research workers about the effectiveness of this method are critically reviewed. Results comparing the moisture determination by microwave heating with moisture meters and oven method are also presented. Other applications of microwave heating in agriculture and food industry, its advantages, limitations and prospects are discussed.

Introduction

In food processing and testing, one of the most important and most widely used measurements is moisture determination. Knowledge of moisture content of grain is important to both processer and consumer as it determines the final grain quality. Knowledge of moisture content is needed for grain drying and storage.

Moisture content can be determined by the direct method of oven drying or by microwave heating. In the direct oven drying methods different standards have been used by the ASAE (1983), AOAC (1975) and USDA (1959) for different food grains. However, all these methods are very time-consuming. Microwave heating is the type of radient process which causes heating of water molecules (dipolar) by oscillation at high frequencies (Click and Baker, 1980). The moisture is removed by microwave heating through the sample.

Microwave heating for moisture determination has become popular in recent years due to the lower time requirement of microwave heating compared with the standard convection ovens (5 to 15 min compared to 6 to 72 h). Therefore, the microwave oven can be used to determine the moisture content in a very short time. This helps in making decisions on operations that depend upon moisture content such as harvesting or drying.

Theory and Principle of Microwave Heating

Microwave frequencies are a part of the radio frequency portion of the electromagnetic spectrum. Microwaves are considered to consist of that portion of radio frequency region with frequencies above about 1 GHz (IEEE, 1977). Some consider microwaves as electromagnetic radiation that have frequencies between 1 to 10 MHz. The wave lengths are approximately 1 mm to 1 m and can penetrate most nonmetallic materials (Copson, 1975).

Heating by microwave results from the transformation of electrical energy into heat energy upon absorption of microwave by the material being heated. Foods are heterogeneous mixtures containing molecules which are not electrically neutral. In an electric field, these behave like magnets trying to line up with the field which is being charged about millions of times per second but are restricted with their movements due to other forces. The energy of microwave drying to overcome these forces is converted to heat. This heat is used to heat the food products (Decareau, 1967).

The different components involved in microwave heating are microwave generators, wave guide transmission, resonant cavities and the power supply. Special oscillator tubes known as magnetrons, klystrons and others of this sort can be employed to generate higher frequencies. Both the klystron and the magnetron are electron tubes which generate microwaves. The magnetron is a cylindrical diode with a ring of resonant cavities which act as the anode structure (Copson, 1975).

In microwave heating the dielectric properties of the materials are important as they have a strong influence on energy absorption in dielectric heating. Microwaves are primarily a radiation phenomenon. They are able to radiate into a space which could be inside of an oven or cavity. When dielectric materials are placed in their path, such a material will absorb energy from the waves.

In microwave heating, the power dissipated per unit volume in the dielectric material can be represented as follows (Nelson, 1987):

$$P = 55.63\ fE\ \epsilon''r \times 10^{-12} W/m^3 \quad \ldots\ldots (1)$$

where f is the frequency in Hz and E is the root mean square electric field intensity in V/m. $\epsilon''r$ is indicator of the materials' capacity for dissipating energy from the alternating electric field. The time rate of temperature rise as a consequence of the power absorption is given by,

$$dT/dt = 0.239\ P/c\ \delta o\ c/s \quad \ldots (2)$$

where c is the specific heat of the material and δo is its specific gravity.

Heating Methods and Sample Preparation

Okabe et al (1973) described moisture meters which utilize microwaves compared to conventional meters utilizing the change in capacitance or resistance at low frequencies. After various experiments they selected 9.4 GHz frequency. At this frequency the characteristic of the microwave attenuation was found to depend mainly upon the moisture content of the grains but was independent of its salt content as well as the moisture distribution gradient in each grain.

Gorakhpurwalla et al (1975a) used an experimental microwave applicator to expose samples of high-moisture corn and grain sorghum to microwave energy at 2.45 GHz. The applicator was designed and built from a section of WR-340 rectangular wave guide. They held the grain sample in a cylindrical cup fabricated from a block of stycast. The cup had a capacity to hold 30 to 40 g of grain and was rotated on its axis. A water load was used to absorb the unused portion of microwave energy. Grain samples, 32.5 g, at 20 to 40% moisture range were placed in the sample-holder cup and exposed to microwave power and preheated air for various times up to 8 minutes. Weights of moisture removed from samples were determined by weight difference.

Farmer and Brusewitz (1980) used a conventional household type, 120 V carousel model R7600 manufactured by the Sharp Electronics Corporation with an output of 700 W and 2 450 MHz. A water reservoir was used initially to protect the oven's magnetron by absorbing the excess microwave energy generated. Subsequently, however, an asbestos pad of 1.25 cm thickness was fitted to the oven's corousel. They recommended that either the water reservoir or asbestos pad must be used in tests. The modified microwave oven was used to determine the moisture content of alfalfa. The freshly cut alfalfa was air dried to the desired moisture content and then kept in cold storage at 8°C in plastic bags. Samples were placed on a preweighed common picnic paper plate.

Noomhorm and Verma (1982) used a commercial Toshiba make, model "Brain Wave" (ER-899 BT-1) microwave oven with variable power control and a maximum output at 100 per cent power level of 720 W at 2 450 MHz and 120 V. The same oven was later used by Verma and Noomhorm (1983) to determine the moisture content of sorghum leaves, wheat, soybeans and rough rice. To protect the magnetron in the oven, a 33 x 30.5 x 1 cm asbestos board was placed inside the oven to absorb the excess microwave energy. Glass petri dishes were used to place the grain samples as recommended by Farmer and Bruiswitz (1980). About 50 g of sample was used for each test.

Verma and Noomhorm (1983) used the same method of sample preparation for sorghum leaves as used by Farmer and Brusewitz (1980) for alfalfa leaves. A pyrex beaker was used to keep 10 g of sample in the oven.

Brusewitz (1984) used two types of microwave ovens in his study, a common home microwave oven and a laboratory microwave drying oven. The home microwave was a Sharp model with rated output of 700 W at 2 450 MHz at 120 V. The laboratory microwave oven was a CEM model MDS- 81 with 600 W power output programmable in 1% increments.

Backer and Walz (1985) used the Sears Kenmore Model 565.8758410 with a capacity of $0.0227\ m^3$ and a variable output cooking power of 90 to 600 W for moisture determination of sunflower seeds. They used 50 g samples for microwave testing. Samples were spread on a paper towel and kept in a microwave oven. Colenbrander et al (1983), used a beaker of water in a back corner of the microwave oven to protect the magnetron from radiation damage. Click and Baker (1980) used asbestos board inside the oven to protect the magnetron from over heating.

Moisture Content Determination

The samples for moisture determination are subjected to rapid drying to low moisture levels in the microwave ovens. The moisture content is determined by sample weight loss and calibration to a standard air or vacuum oven method. Various research workers estimated the moisture content of grain by this procedure after drying the grain.

Okabe et al (1973) used microwaves of 9.4 GHz for the moisture determination of unhulled and unground grains. They found that moisture content of grains can be measured more accurately by microwaves than the conventional meters using the change in capacitance or resistance at low frequencies. The accuracy was high and the error was less than +0.5% in the measurements for both rice and wheat. They remarked that microwave moisture meters can be applied to the measurements of the moisture contents of tea, sugar, pulp and many other organic and inorganic materials by changing the structure of the vessel.

Gorakhpurwalla et al (1975a) concluded that it might be possible to use microwave energy at 2.45 GHz to dry small samples of high moisture corn or grain sorghum faster and perhaps more economically than with the standard air-oven methods used to measure moisture content. Later, the same authors (Gorakhpurwalla, 1975b) used an applicator with a rotating sample holder for determining moisture content of grains. They plotted drying curves for corn and grain sorghum using an incidence power of 850 W at 2.45 GHz. These curves showed a decaying exponential characteristic. The time required to dry 32.5 g of grain from an initial moisture content of about 35% to about 1% of its initial moisture content was about 12 min for corn and 16 min for grain sorghum.

Backer and Walz (1985) used a conventional microwave oven at 50% and 100% power levels to determine the moisture content of sunflower seed. They found that a conventional microwave oven can be successfully used for very rapid determination of high moisture sunflower seed. The microwave oven took only 4 to 6% as much time as the air oven.

Parrin et al (1980) used microwave energy for rapidly determining moisture in snap beans. They noted that microwave energy has a high potential for moisture determination because of its ability to reduce drying time. Burning of the sample, however, was experienced as a problem at high power levels.

Beewar et al (1977) dried blended samples of sweet corn with the microwave oven. A drying time of 3 min gave consistent moisture values. Longer time periods did not appreciably change moisture values and charred the samples.

Verma and Noomhorm (1983) conducted a study to evaluate the use and accuracy of a household microwave oven for quick moisture determination of sorghum leaves, wheat, soybeans and rough rice. They found that considerable time can be saved in moisture determination of agricultural products using a microwave oven than by using a conventional hot air oven. The moisture content of sorghum leaves and ground samples of wheat and rough rice were accurately determined by them.

Click and Baker (1980) compared the drying time between the microwave method and the standard oven for determining the moisture content of various products such as alfalfa, earcorn, shelled corn, soybeans and potato chips. Lee and Lathum (1976) found that pet food moisture content can be accurately determined by microwave drying. Farmer and Brusewitz (1980) studied the moisture content in alfalfa and found that 25 g of alfalfa dried in a microwave oven in 10 min. Darrah et al (1977) also did some experiments on alfalfa. The microwave oven has been used for rapid moisture determination of high moisture silage (Aerts, 1974) and refuse (Cardenas, 1977). Carlier and Van Hee (1971) used microwave drying for about 10 min to dry fresh lucerne and pasture grass samples. Jones and Griffith (1968) dried 400 g of herbage in a commercial microwave oven in less than 20 min. Hoffman (1975) dried 200 g of ryegrass in 6 min and found the dried samples were comparable in moisture to those that were freeze-dried.

Sharma (1986) suggested that the microwave oven can be used for rapid moisture determination using a two-stage procedure, i.e., to first expose the sample initially for specified time to microwaves and, subsequently, re-expose the grain to microwave heating when a body of water is kept in the oven.

Casada and Walton (1985) determined the moisture content of tobacco by microwave heating. They found that accuracy was improved for shredded samples than when whole leaf samples were used. Christic et al (1985) dried fish flesh for moisture determination by a microwave oven. Charlie et al (1982) compared the moisture determination of soils using a temperature controlled microwave oven and a conventional air oven. Drying times were proven to be 13 times faster when full power microwave oven techniques were used as compared to the conventional one.

Comparison of Microwave Heating with Other Methods

Noomhorm and Verma (1982) conducted a comparative study of moisture of rough rice using a microwave oven, air oven and four electrical meters with reference to the standard AOAC (1975) method. They used two electrical moisture meters of resistance type and the other two were of capacitance type. In the microwave and air oven methods, whole grain as well as ground samples were tested. The range of moisture for the long grain Labelle variety of rice used in this study was 10 to 18% (w.b.). The results show that the microwave method of moisture measurement (for ground samples) agreed closely with the standard AOAC technique. The air oven method (for whole grain sample) showed the highest deviation.

Backer and Walz (1985) compared the results obtained by the microwave method with the mechanical convection air oven. They found no statistical difference between these two methods when the microwave oven was run at 100% power level. Parrin et al (1980) compared the performance of microwave oven with the conventional oven and found that microwave energy has a better potential for moisture determination.

Sharma (1986) revealed that by using a two stage procedure for microwave drying, results close to AOAC method can be obtained. Some authors have recorded that microwave drying results in a slight under-estimation of moisture content in alfalfa than the conventional air oven method (Bilanski and Ghate, 1978; Farmer and Bruisewitz, 1980 and Click and Baker, 1980).

Click and Mobley (1984) recommended procedures which if followed strictly gives microwave heating results equivalent to those obtained by the conventional oven method.

Advantages and Limitations

Deep penetration of power and rapid heating are the most noticeable advantages offered by microwave heating. Although microwave instrumentation is generally more costly than that for the lower frequencies, the microwave frequencies offer a few more advantages for moisture measurement. In the microwave, the effects of electrical conduction losses are much smaller than at lower radio frequencies and physical contact between the measuring equipment and the product is not necessary (Nelson, 1987).

The major limitation of using microwave energy is the higher direct cost compared to the conventional method. Also, in applications where temperature is required to be constant, the temperature control is complex to be practical for common use. The use of various methods to avoid over-heating of the magnetron have been reported by some authors. Burning of samples, spot burning, popping and breaking of glass sample containers have also been reported.

Other Applications and Scope

Many microwave heating applications, mainly in food industry, have been described by Copson (1975). In agriculture it has many applications like product drying, seed treatment, insect control, product processing, etc. Recently a good review on various applications of microwave heating in agriculture has been published by Nelson (1987).

Butcher (1970) developed an automatic tempering system for wheat which employed microwave attenuation. Absorption of microwaves and energy at lower frequencies has also been of interest in determining moisture content of paper and textile material (Busker, 1968; Slocombe et al, 1969).

Robert (1977) used microwave heat to gelatinize the surface layer of grains and to reduce the pastiness. Nofsinger et al (1980) demonstrated that microwave can be used to reduce internal mold development in shelled corn. Dardo (1985) observed that microwave heating of head rice increased safe storage period of high moisture paddy because fungal invasion was delayed. However, germination was found to be affected by heat treatment.

Kraszewski (1973) and Stuchy and Hamid (1972) illustrated the principles and techniques of measuring the moisture content of materials at microwave frequencies.

Efforts have been directed at utilizing the electrical properties of grain and similar commodities for on-line monitoring of moisture content and for control of grain dryers (Ban and Suzuki, 1977; Mathews, 1963). The development of on-line sensing for grain dryer control appears to be an application that deserves further attention. In the operation of grain dryers, there is an opportunity to save energy costs and improve the quality of products if the moisture content is automatically and correctly sensed (Nelson, 1987).

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(Continued on page 60)

Existing On-farm Grain Storage Facilities in Nigeria and Suggested Improvements

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Introduction

About 80% of the national agricultural production efforts is undertaken by small-and medium-sized farmers whose skills in food storage and prevention of post harvest losses are still at the rudimentary stage.

Efficient storage method plays a prominent part in minimizing the waste and loss of foodgrains. The storage system has a direct relation to the economy of the nation. Hence, the need for an appropriate and efficient storage system in the country is imperative. Improved storage structures prevent stored grains from spoiling, allow the storage of seed grains for longer period without loss of quality and help to maintain better economic/ commercial value. They also permit effective pest control practices and render convenient and efficient grain loading and unloading operations.

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Existing On-farm Grain Storage Facilities

The on-farm storage has been considered important for two basic reasons, i.e., i) 60-70% of grain produced in the country is retained by the farmers; and ii) storage losses are considerably high. With a view to modernizing the on-farm grain storage system in the country a nation-wide programme has been launched by the Processing and Storage Unit of the Federal Department of Agriculture and Rural Development under the technical assistance of Commonwealth Fund for Technical Co-operation (CFTC). According to the field study conducted, it the existing on-farm grain storage facilities available in the country are not found satisfactory, they lead to maximum storage losses to the extent of 40-50%.

Farming families store the grains like sorghum, maize, millet, cowpea, rice, groundnut, etc in traditional storage structures like Mud "Rumbu", Thatched "Rumbu", underground pit structure, local crib, indoor and structure, etc and other storage facilities like bag storage, storehouses and earthen pots. These storage structures are constructed from locally available materials like straw, split bamboo, mud, mud bricks, wood, etc. The salient features of some of the existing storage structures are explained below:

"Mud Rumbu"

These are the mud structures of 3.0-4.0 t capacities constructed in Kano, Kaduna and Sokoto states for storage of foodgrains like millets, sorghum, maize, etc both in threshed and unthreshed condition (Fig. 2) The floor/ bottom is usually constructed of wood and plastered with mud inside while the wall and the conical roof are constructed from specially prepared mud. The structure is supported on stone pieces 15"-20" above the ground level. The roof is conical in shape and has an inlet opening of 800 mm diameter at the centre for carrying the loading and unloading operations.

Thatched "Rumbu"

These structures of different capacities ranging from 0.5 to 2.0 t are made of wood and straw for storage of foodgrains in unthreshed condition and groundnut in pods. These are placed on low raised platform and, therefore, are easy access for rats to enter the structures. A conical thatch roof is provided at the top (Fig. 3).

Underground Pit Structures

The underground pit structures

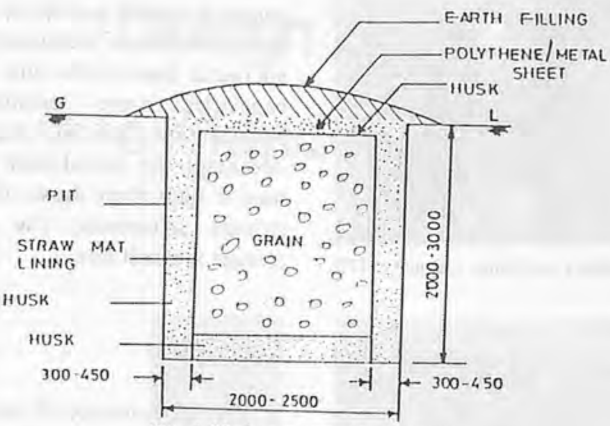

Fig. 1 Underground pit structure.

of 2.0 to 3.0 t capacities as shown in Fig. 1 are found quite common in Borno state and used for storage of foodgrains in threshed condition. There is no protection against the entry of surface and sub-surface moisture. There is easy access for rats to enter the structure. The straw mat lining is replaced after every use.

Local Maize Crib

These structures of 1.5 to 4.0 t capacities are found common in Imo and Bendel states and used for storage of maize in dehusked form. These are rectangular in shape with elevated base/platform and made of wood, bamboo and thatch (Fig. 4). The platform is made of wood and bamboo while the wall is made of either bamboo or straw. The structure is supported on wooden posts and the thatch roof is provided at the top. The life of the structure is 5-10 years and the storage loss is rated at 40-50%.

The general defects observed in these structures are: 1) easy access for rats to enter the structures; 2) the wooden base/floor is subject to termite and rat damage, 3) they are not moisture proof, 4) not air-tight and, therefore, the control of insect pest is difficult; 5) no efficient method for loading and unloading; 6) no protection against fire and theft; 7) storage losses are considerably high; 8) quality of grain cannot be maintained for long periods and 9) the life is short and annual maintenance cost is high.

Other Storage Facilities

In addition, substantial quantities of grains are stored in jute bags, store houses and earthen pots and get damaged due to insects, rats and moisture. There is a considerable loss of food grains in this method of storage and there is an acute need to provide improved storage facilities.

In the southern states, where there is high rainfall and high humidity, the storage problems are very acute. The existing storage facilities are very poor and as a result the storage loss is as high as 40-50%. The farmers usually dispose of 70-80% of their products within 2-3 months after harvest almost at a half price with fear that if they continue to store the grains for longer periods, they may loose a large part of it to insects, rats and moisture. Only small quantities of grains are stored for their own consumption and seed purposes. At the time of storage the moisture content of grains is usually high and, therefore, besides the improved grain storage facilities, there is also a acute need to provide suitable improved crop drying facilities.

Suggested Improvements

Based on the analysis of the field study, the following designs of grain storage structures and dryers were developed to suggest the necessary improvements. Some of them have been fabricated/constructed and some are in the process of fabrication.

1. Metal bins of 200, 400 and 1 000 kg capacities (Figs. 5, 6), modified oil drum of 175 kg capacity (Fig. 7) and indoor brick masonry structure with compartments of 2.0 t capacity (Fig. 8).
2. Improved mud "Rumbu" structures (cap.: 3.0 t)


Fig. 2 Mud rumbu structure in Kaduna state. Capacity: 3 t.


Fig. 3 Thatched rumbu structure in Kano and Borno state. Capacity: 3 t.


Fig. 4 Local maize crib in Imo state. Capacity: 1.5 t.

Fig. 5 Metal bins. Capacity: 200 and 400 kg.

Fig. 6 Metal bin. Capacity: 1000 kg.

3. Underground R.C.C. and brick masonry structures (cap.: 3.5 & 5.0 t).
4. Reinforced brick masonry structure (cap.: 5.0 t) and outdoor metal bin (cap.: 5.0 to), and
5. Fuel-operated crop-dryer using agricultural waste.

The main advantages of these improved structures are: 1) they are rat- and moisture-proof, 2) no damage due to termites; 3) adequately air-tight and, therefore, no damage

Fig. 7 Modified oil drum. Capacity: 175 kg.

Fig. 8 Indoor brick masonry structure (under construction). Capacity: 2 t.

due to insects, 4) efficient method of loading and unloading; 5) adequate protection against fire and theft; 6) storage losses may be very low or negligible; 7) quality of grain can be preserved for longer periods and can expect better market values; and 8) shelf life is long and annual maintenance cost is low.

Besides, the cost of storage of grain per ton per annum was estimated for four different existing storage structures and ranges between ₦166.50 and ₦614.00. Similarly, the cost of storage of improved metal bins of 400 and 1 000 kg capacities were estimated at ₦80.00 and ₦66.50, respectively. Although the initial cost of metal bins is high than those of existing storage structures, the cost of storage is much less.

Conclusion

The performance of the existing on-farm grain storage structures was not satisfactory. As a result there was a substantial loss of foodgrains both in quantity and quality while in storage. There is an urgent need to improve the storage facilities in the country and, therefore, necessary efforts are being made to improve the existing on-farm grain storage system.

The producers have to be educated regarding the importance of drying of foodgrains before storage and marketing. Efforts are also being made to develop simple designs of dryers using cheap fuel, solar energy and agricultural waste. ■■

(Continued from page 57)

Determination of Food Grain Moisture Content by Microwave Heating

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Design and Development of a Hand-operated Feed Mixer

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Abstract

Majority of the Kenyan farmers are small holders. Domestic animals play a definite role in their farming system. Dryland farming is practised in most of the semi-arid and arid regions of the country. In such situation, farmers face on acute shortage of animal feed, specially the small holders, as they cannot afford costly feed but still want to keep their domestic milk cattle and draft animals.

In order to help solve the feed problem at the village level, where agricultural by-products such as wheat and rice straw are available in large quantities, it was decided to develop a hand-operated feed mixer as a graduate student project. Engineering analyses were done and the strength of the feed mixer was tested while mixing a full load of maize stover with molasses. The main emphasis was on developing the mixer of 0.2 m^3 capacity in the Agricultural Engineering Department and detailed testing on homogeneity of the mix and evaluation of related nutritional quality was left to the Animal Production Department of the University. However, the mixer's performance was satisfactory considering visual inspection of the mix.

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Introduction

Almost 75% of Kenya's 582 600 km^2 area is arid and semi-arid, where economic activities are limited to small scale farming. A smallholder farmer keeps some animals for milk production in order to meet family consumption besides some personal income. In addition, draught animals are useful in tillage and transport. Production of fodder crop is out of the question as the priority is to produce food for the ever-increasing population. Keeping small scale livestock is, therefore, increasingly getting difficult due to insecurity of fodder supply and the high cost of concentrates. Occasional droughts create an even worse situation for small farmers.

On the other hand, there is a considerable amount of farm waste mainly from straw of different crops which can be used as feed after improving their qualities. Table 1 shows the estimated available straw in Kenya compared to Africa and the world.

Several researchers have tried to mix additives with farm crop-straw in order to improve the quality of low quality roughage. Said and Tubei (1981) used ammonia to mix with maize stover and observed limited success in Kenyan situation. Similarly, in Tanzania, Kiangi (1981) experimented mixing maize, wheat and rice straw with anhydrous ammonia at a rate of 50 g/kg of dry matter. Some water was

Table 1 Estimated Straw Availability (000 t)

Name of crop	World	Kenya	Africa
Wheat	728 530.50	337.08	13 648.56
Paddy	595 850.40	57.60	12 329.28
Barley	274 184.24	138.40	5 530.81
Maize	107 957.25	5 377.50	78 535.40
Rye	38 912.07	–	15.90
Oats	69 998.16	11.13	333.90
Millets	47 148.27	206.70	16 348.38
Sorghum	114 454.56	349.80	17 766.66
Total straw	1 977 035.00	6 478.21	144 508.89

(After Nath and Muchiri, 1984)

also added to raise the moisture to 40% (wb).

Studies conducted at the Indian Institute of Technology, Kharagpur, (1981) regarding proliferation of paddy-rice straw for animal feed showed that mixing the straw with 10% molasses and feeding to the animal increased the straw intake by 22 to 28%. In most of these studies mixing was done manually resulting in not very homogeneous mixture. Straw treatment machines are available in countries such as Denmark, German Democratic Republic and some other developed countries often meant for mixing a large quantity of low quality roughage by spraying alkali-solutions. But these machines are very expensive and require skilled manpower. Mechanical hand operated mixers based on the engineering design-principle are not readily available. A mechanical mixer involves a process in which two or more components are interpersed with one another. Mechanically, a flow is generated which results in a uniform distribution of components being mixed. Stationary pan-mixers, tumbler mixers, horizontal trough-mixers and ribbon type mixers have their own merits and limitations of use.

In this paper a hand-operated mixer is discussed for its design and operational capability. The volumetric capacity of the mixer was $0.2\ m^3$ and the additive used was molasses. The emphasis had been mainly on the application of engineering design to fabricate a handy mixer. The mixer, after fabrication proved successful, its price was estimated to be Ksh 1 000.00 (US$60).

Design of the Mixer

Theoretical considerations to develop the mixer included cylindrical drum, flanges, flange support, shaft, bearing support, handle arm and handle for their strength and safety under failure. Fig. 1 provides a general configuration related to mechanics of the mixer's components.

Notations

em = Unit weight of mix
e = Unit weight of steel
x = Lever arm length
F = Force required to rotate the mixer components
W = Total weight of the mixer plus feed
I_D = Mass moment of inertia of the drum
I_F = Mass moment of inertia of the flange
Is = Mass moment of inertia of the hollow shaft
Im = Mass moment of inertia of feed
I_T = Total mass moment of inertia of mixer and feed
L = Length of drum
t = Thickness of drum metal
do = Outer diameter of the drum
di = Inner diameter of the drum
Y = Distance between centre of the flange support and centre of the shaft
l = Flange support length
$\bar{d}$ = Diameter of the flange support
Ls = Length of the shaft
Do = Outer diameter of the shaft
Di = Inner diameter of the shaft
Ea = Actual energy required to rotate the shaft while mixing
E = Theoretical energy required to rotate the shaft while mixing
n = Number of rev/sec made by the shaft
f = Bending stress of the shaft
= Torsional shear stress
T = Torque required to rotate the shaft
d = Width of the lever between handle and the shaft
b = Thickness of the lever between handle and the shaft
J = Polar moment of inertia
g = Acceleration due to gravity

(A) Assumptions: These are given as follows:

i) Mass moment of inertia of the flanges is negligible.
ii) A 20% of input energy is lost in the bearing due to friction.
iii) Mixer is supposed to operate full, though in real practice it is not so.
iv) Unit weight of maize stover plus molasses mix is about $4\ KN/m^3$. The moisture con-

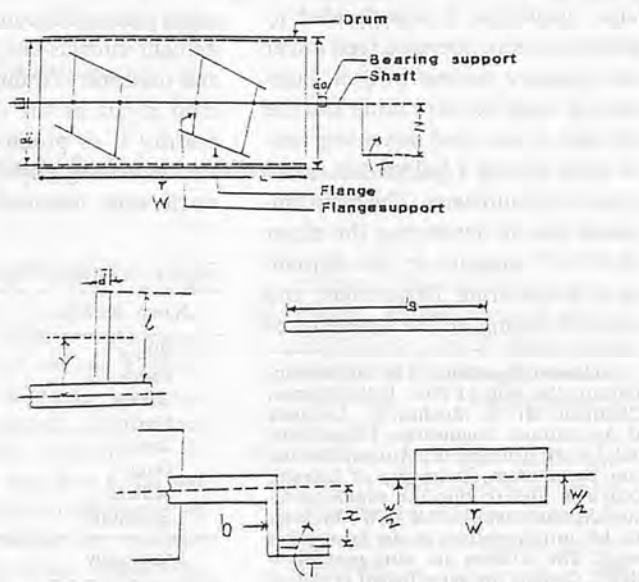


Fig. 1 General configuration used for establishing design equations.

tent of maize stover being 33% (wb.) and the maize-cut-pieces to molasses ratio is kept constant.

v) Unit weight of mild steel used for fabrication, is 76.5 KN/m^3.

vi) An average man can apply a force of 200 Newtons.

(B) Design Equations: The following equations have been used to decide the dimensions and check the failure of different parts.

$$I_T = I_D + I_F + I_S + Im \qquad (1)$$

$$I_D = 2\left[\frac{\Pi}{2}\left(\frac{do}{2}\right)^2 + \frac{e}{g}\left(\frac{do}{2}\right)^2\right] + \frac{2\Pi\, do\, L\, t\, e}{16\, g}\left[do^2 + (do-2t)^2\right] \qquad (2)$$

$$I_F = \frac{\Pi\, \bar{\bar{d}}\, l\, e}{4\, g}\left[\frac{l^2}{12} + Y^2\right] \qquad (3)$$

$$Is = \frac{\Pi\, Ls\, e}{32\, g}(Do^2 - Di^2)(Do^2 + Di^2) \qquad (4)$$

$$Im = \frac{1}{32}.L.\frac{em}{9}\, do^4 \qquad (5)$$

$$Ea = \frac{I_T}{1.6}(2\Pi\, n)^2 \qquad (6)$$

$$x = \frac{2\, I_T\, \Pi\, n}{1.6\, F} \qquad (7)$$

$$\tau = \frac{2\, F.\, x\; ro}{\Pi\,(ro^4 - ri^4)} \qquad (8)$$

ro and ri are, respectively,

$\frac{do}{2}$ and $\frac{di}{2}$

$$f = \frac{6T}{bd^2} \qquad (9)$$

The dimensions of the mixer were as follows:

L = 845 mm
do = 567 mm
di = 563 mm
t = 2 mm
d = 12 mm
l = 170 mm for short flange support
= 235 mm for long flange support
Ls = 1 245 mm, and

the distance between drum and the bearing was 100 mm.

Substituting different values in equations 2, 3, 4 and 5 and adding together yielded total moment of inertia as 8.67 kgm^2. Volume of mixer, shaft, flange-support and flanges were 0.2127 m^3, 4.66 x $10^{-4}m^3$, 1.83 x $10^{-4}m^3$ and 74.4 x $10^{-6}m^3$, respectively. Considering bulk density of chopped straw as 400 kg/m^3 at 33% moisture and weight of the mixer as 28 kg, the torsional shear stress was 17.1 MN/m^2 using equation (8). The bending stress was 113 MN/m^2. The shear and bending stress for failure are 150 and 250 MN/m^2, hence the design proved to be safe.

From the data assumed/calculated load bearing area is 4.662 x $10^{-3}m^2$ and in rotating situation if the reaction is equivalent to 1 130 N; stress developed is only 242 KN/m^2. The bearing used is of brass whose compressive strength is 310 MN/m^2. Similarly, diameter and length of drilled hole through wooden housing for bearing is 61.5 and 50.0 mm and if force applied is also equal to 1 30 N, stress developed will be only 117 KN/m^2 which is far less than 5 MN/m^2. Hence, the design is safe. (See **Figs. 2a** and **2b** for details).

Performance Test of the Mixer

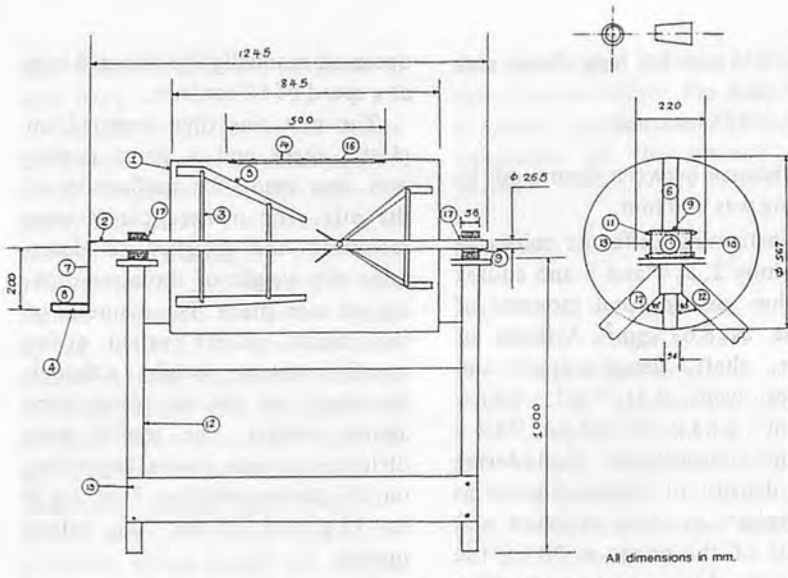
The equipment was run empty first to see that all the parts work well without any peculiar noise. Maize stovers were chopped to about 5 cm long and 50 such pieces were chosen at random, weighed and numbered. These pieces were loaded with other chopped pieces of maize stover. Molasses at the rate of 25% of chopped straw was added through the opening gate. The mixer was operated manually for about 4 min at a speed of 60 rev/min.

The mix was then emptied on plastic sheet and a visual inspection was made for uniformity of the mix. The marked pieces were recovered and weighed to determine the weight of molasses sticking on each piece. The diameter of the maize stovers varied giving equally varying weight although the length of the cut pieces were almost similar. The results were divided into four groups, depending on the pieces weighing 7 to 9 g, 8 to 15 g and 15 to 20 g before mixing.

It may be pointed that the positioning of flanges which provide agitation was done by trial. During the operation that mixer was easy to operate. The height of the stand proved to be comfortable for normal operation. The recommended speed of 60 rev/min would take about 4 min to achieve one load of mixed feed. The detail test on homogeneity of the mix and other nutritional qualities was not done. However, the mean value of the weight of molasses retained in groups 1 to 4 were 0.22, 0.22, 0.24 and 0.35, respectively. The deviations among the groups were due to variation in surface area of the cut pieces.

Conclusions and Recommendations

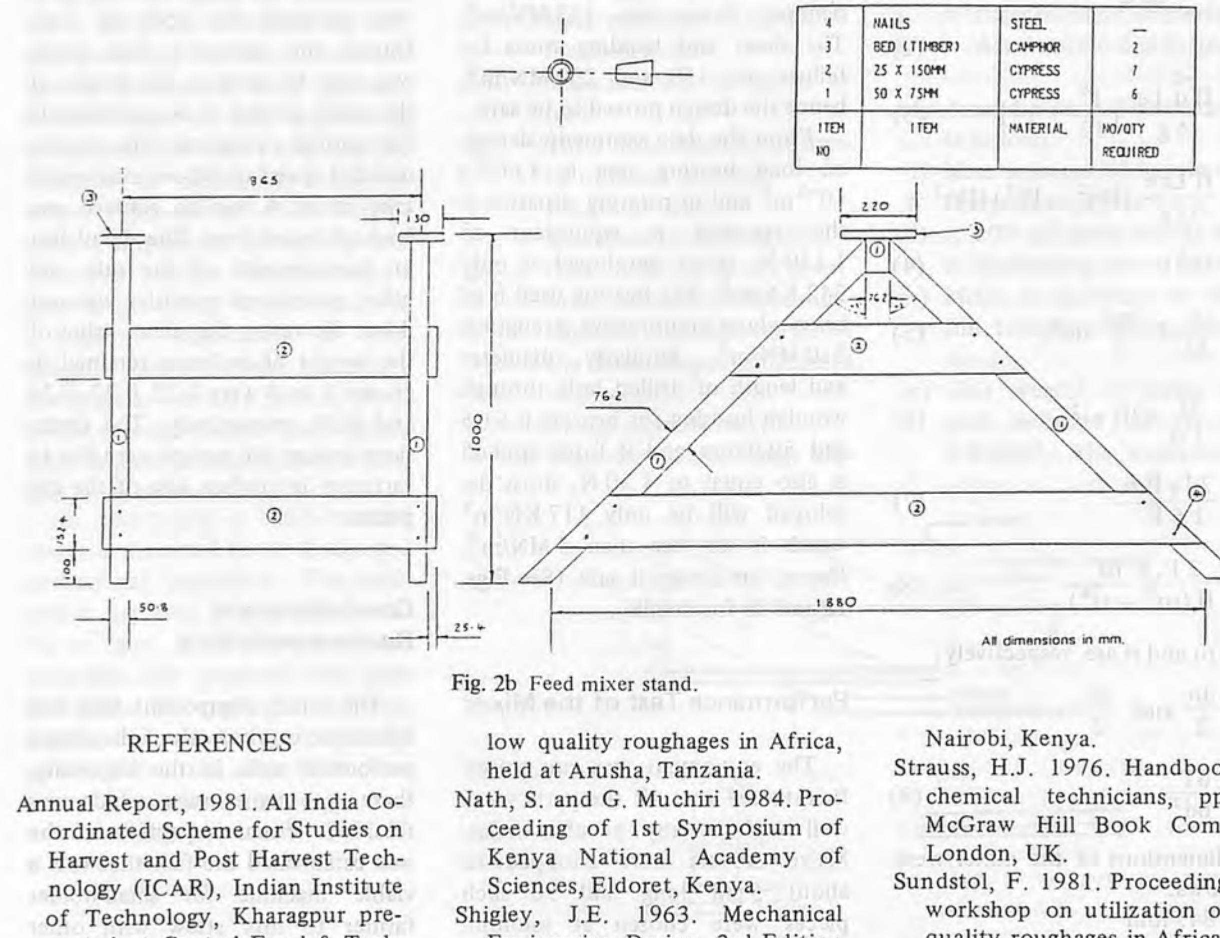
The mixer component that was fabricated on the basis of the design performed well. In the beginning, there was some noise which was rectified. Visual inspection of the mix established the fact that it is a viable machine for small-holder farmer to mix straw with other additives. However, detail testing is needed to fix the precise time of operation for paddy rice-straw, sorghum straw and millets, etc, which are normally grown in the arid and semi-arid areas of Kenya.



ITEM NO.	ITEM	MATERIAL	NO/QTY REQUIRED
17	WASHER	MILD STEEL (2.5MM THICKNESS)	2
16	DOOR (500MM X 300MM)	STEEL	1
15	NAILS	STEEL	—
14	SELF TAPING SCREWS	MILD STEEL	30
13	ANGLE BAR (SUPPORT)	MILD STEEL (2.5MM THICKNESS)	4
12	STAND	TIMBER	1
11	BOLT AND NUT	¼" DIA., 6" LENGTH, SINGLE THREAD MILD STEEL	4
10	BUSH HOUSE	CAMPHOR TIMBER	2
9	BUSH BEARING	PHOSPHOR BRONZE	2
8	HANDLE COVER	AS ITEM 2	1
7	LEVER ARM	MILD STEEL PLATE (3MM THICKNESS)	1
6	DRUM REINFORCEMENT	MILD STEEL FLAT BAR (2.5MM THICKNESS)	2
5	FLANGE	MILD STEEL PLATE (1.5MM THICKNESS)	4
4	HANDLE	AS ITEM 3	1
3	FLANGE	MILD STEEL ROD	8
2	HOLLOW SHAFT	GALVANISED MILD STEEL	1
1	DRUM	STEEL	1

All dimensions in mm.

Fig. 2a Feed mixer assembly.



ITEM NO	ITEM	MATERIAL	NO/QTY REQUIRED
4	NAILS	STEEL	—
3	BED (TIMBER)	CAMPHOR	2
2	25 X 150MM	CYPRESS	7
1	50 X 75MM	CYPRESS	6

All dimensions in mm.

Fig. 2b Feed mixer stand.

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Development of Process and Equipment for Soyflakes in India's Rural Areas

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Abstract

A simple, low-cost technology was developed to process soybean in the form of flakes to be used as protein supplement in cereals and pulses. The process consists of cleaning whole soybean, splitting them by burr mill, blanching to remove antinutritional factors, semi-drying and flaking by a flaking machine. The flakes are dried to 8% moisture content for safe storage and further processing. Three equipment, viz soybean flaking machine, soybean blanching unit and a natural connection tray type dryer using agricultural waste were developed. The flakes produced by this process have 44% protein and 19% oil with no urease activity. An economic analysis of the pilot plant based on the process using the above three equipment was conducted. The plant provides employment to two rural labourers and at the sale price of Rs.8/kg of soyflakes and Rs.5/kg for soygents, the pay back period is 1.066 year at benefit cost ratio of 4.28:1. The internal rate of return was 93% at 15% rate of interest on investment.

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Introduction

India produces about 0.96 million t of soybean annually (ASI, 1986). At present 97% of the soybean grown is used for oil extraction. Though soya is a protein and fat rich crop it is not gaining popularity as a food crop. Undoubtedly soybean can be an inexpensive source for combating malnutrition in an ever growing population of a country like India.

About 70% of India's total population lives in villages, and badly needs nutritious food at affordable price. The main constraint in accepting soybean as a food crop is the non-availability of processing technology in rural areas. Therefore, it is necessary to develop techno-economically feasible technology for people living in villages.

Among the several snacks being taken daily in India, flakes are popular. They are prepared from rice, maize, cassava, gram, etc. Therefore, research on making flakes from soybean was undertaken at the Central Institute of Agricultural Engineering, Bhopal and a feasible process and equipment suitable at cottage industry level were successfully developed. An economic analysis of the pilot plant producing 100 kg flakes per day is presented.

Review of Literature

The hull content of soybean is about 10% of the total composition of the bean. The hull needs to be removed from the bean before processing it for food purposes. On the upper surface of the bean, the hull is loosely attached and is easily removed by any simple rubbing method for which an attrition mill and a cylinder concave mechanism were found suitable for dehulling operation. A burr mill with 200 mm diameter stone at 450 rpm was found to have 70 kg/h capacity. The dehulling was 88% at moisture content of 7%. The optimum moisture content for dehulling was reported at 11%. The cylinder concave mechanism was tested for dehulling of soybean (Shyeh et al, 1980). It was reported that a dehuller with spacing between roller and concave at 4 mm and at 330 rpm gave a dehulling efficiency of 88%. However, rubber roller treatment was required to loosen the adhering hull. The concentric cylinder mechanism, where dehulling takes place while the grain passes spirally has also been found suitable for dehulling of soybean. A manual dehuller based on this principle was developed at CIAE-Bhopal (Singh and Sinha, 1988). The cylinders of 286 mm and 300 mm diameter and 860 mm length at 19° slope gave a capacity of 35 kg/h at 125 rpm. The dehulling efficiency was reported at 96% and brokens were 3-4% only.

The raw soybean or soysplit contains antinutritional factors viz, trypsin inhibitor activity, lypoxygenase activity and hemaglutinin toxin (Rackis JJ, 1972). They have to be eliminated to make soybean fit for human consumption. It has been reported that lypoxigenase enzyme intact in whole soybean is released if soy cotyledons are mechanically injured (Nelson et al 1979). The beany flavour was found to set in when injured soybean came in contact with cold water or moist atmosphere. Therefore, blanching of soybean by pouring them directly into the boiling water was recommended. It has been reported that antinutritional factors and toxins were eliminated effectively from hydrated tissues of soybean. The effective time of cooking to eliminate these antinutritional factors was 20-30 min.

Process Development

Based on information available and on experiments conducted towards obtaining good quality soybean flakes, a process was developed (Patil et al 1986) Figs. 1a and 1b. The process consists of cleaning of raw soybean by pedal-operated cleaner to remove the impurities, brokens and shrivelled grains. The capacity of the cleaner was 300 kg/h with cleaning efficiency of 98%. The cleaned raw soybean is then dehulled by a mini-burr mill at 450 rpm with clearance of 3.5 mm between the stones. The capacity of the mill was 70 kg/g. The dehulled soybean is again passed through the cleaner to aspirate the hulls. The hull free splits are then blanched by pouring them into boiling water in a blancher. The blanched soy splits, after their urease activity is reduced to nil, are removed from the blancher. The moisture content of the blanched splits is about 62%. They are dried to 30% moisture content level in a dryer. The semidried soysplits are then pressed in a flaking machine and the flaked soybean is again dried to 8% moisture content level for safe storage and further processing.

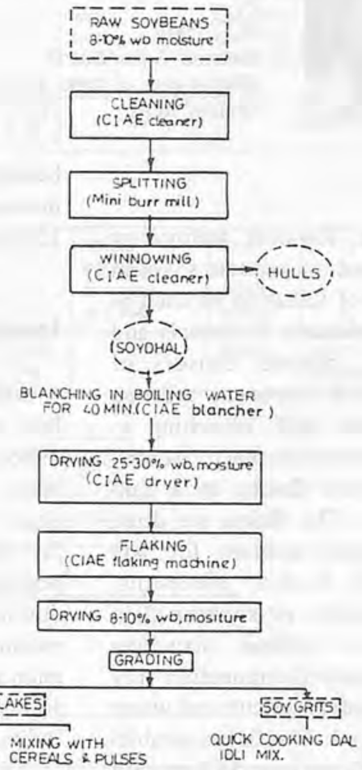

Fig. 1a Process flow chart for making soyflakes at rural level

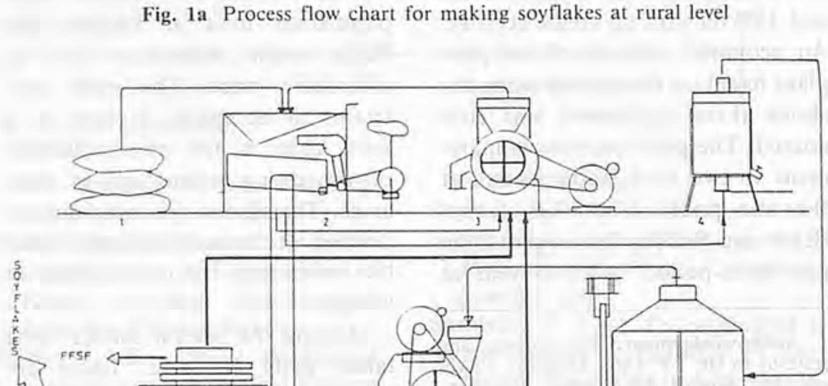

Fig. 1b Flow chart for 100kg/day soyflaking plant

Equipment Development

The process explained earlier requires a minimum of three specific-purpose equipment, i.e., blanching unit, flaking machine and a tray dryer. These units have been developed by keeping in view the techno-economic status of the rural enterprenuers. The dryer and blancher uses agricultural waste as fuel whereas the flaking machine can be run by single phase 1 hp electric motor using domestic power supply.

Blanching Unit

Blanching of soybean can be done in ordinary containers as it is a simple cooking of soysplit in excess water. But the operation at 100 kg per day capacity with this level of technology will not only be cumbersome but highly inefficient. Therefore, a simple energy efficient unit using locally available fuel to suit the cottage industry's need is essential, hence, a blancher was developed (Patil et al, 1987) Fig. 2. It is a simple unit with two concentric cylinders made of GI sheet. The water for cooking is filled in annular space and fuel is burnt in a central cylinder. The soybean to be blanched is kept in 4 GI perforated cages which are lowered in the boiling water and kept until the antinutritional factors are eliminated to a desired level. It was found that 60 min cooking of 20 kg batch of soy-splits is sufficient to reduce the urease activity (an indicator of antinutritional factors) to nil level. This unit can process about 100 kg soysplits a day.

Tray Type Natural Convection

The blanched soybean contains about 62% moisture and requires drying to 30% before flaking. The open sun drying though possible cannot always be used due to contamination of dirt and dust and also its unsure operation. Drying is a most energy-consuming operation in such kind (wet processing) of processing technologies. The commercial tray dryers cost about Rs.20 000 (US$2 000) and hence cannot be recommended for cottage level industries. Therefore, a tray dryer using agricultural waste as fuel and working on the principle of natural convection of hot air currents was developed (Patil & Shukla, 1988). The dryer is made of two parts (Fig. 3). The bottom portion, i.e., plenum chamber, is made of mild steel angle frame and covered with asbestos sheet from sides and wire mesh from top. A drum type burning-heat exchanging unit with fins for effective heat transfer are located at the centre of this chamber. A chimney with a regulator valve was provided at the other end for escape of smoke. The opening is kept at the bottom for entry of fresh air. A drying chamber made of soft wood and plywood with provision to keep 20

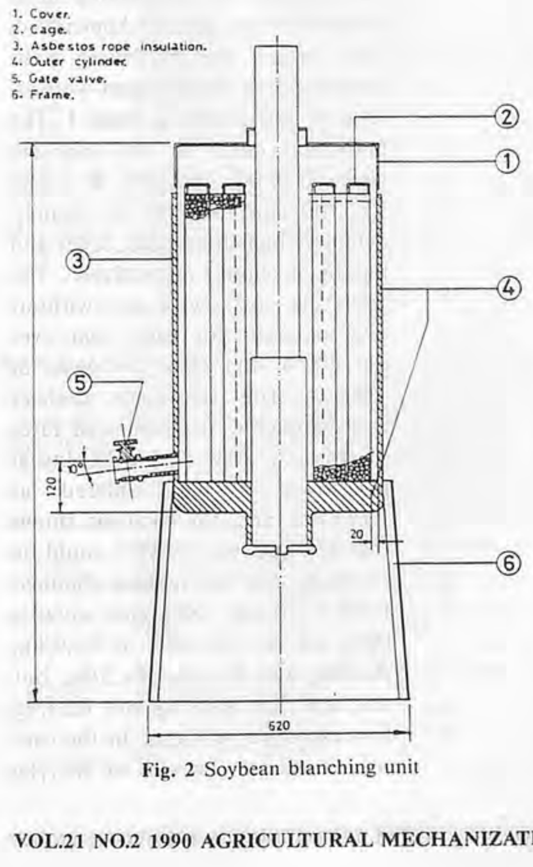

Fig. 2 Soybean blanching unit

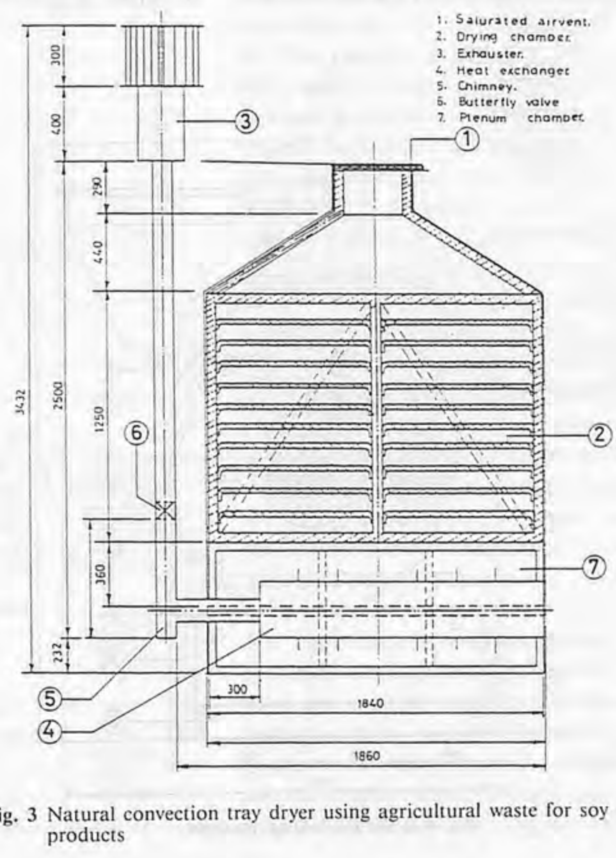

Fig. 3 Natural convection tray dryer using agricultural waste for soy products

trays is kept on the plenum chamber. The bottom of the drying chamber which rests on the plenum is open and the top portion is provided with air vent with adjustable opening. Fuel is burnt in the burning chamber at the rate of 3 kg/h. The dryer can take 100 kg load of wet material. The average temperature in the dryer at this rate of combustion is 49°C at no load and 46°C while drying. The trays are interchanged and the material is mixed/stirred at one-hour interval. The drying time for soysplit to reduce moisture from 60-10% was 15 hours and to dry flakes from 30-10%, MC required 6 hours. The cost of the dryer is about Rs.5 700 (US$570) and the cost of drying is about Rs.0.25/kg. (US$25/t).

Soybean Flaking Machine

A three-roller flaking machine as shown in **Fig. 4** was developed. (Patil and Shukla, 1988). The machine consists of 3 knurled rollers to make a 2-stage operation. The clearance between rollers is adjustable. Due to differential speed, the position of relatively stationary roller was kept alternately in order to get stretching effect from both sides. The fabrication of the machine is very simple. The motor is mounted on the top and a foundation is provided. The machine costs around Rs.4 500 (US$450) and cost of flaking is to about Rs.0.20/kg (US$20/t) at a flaking capacity of 20 kg/h.

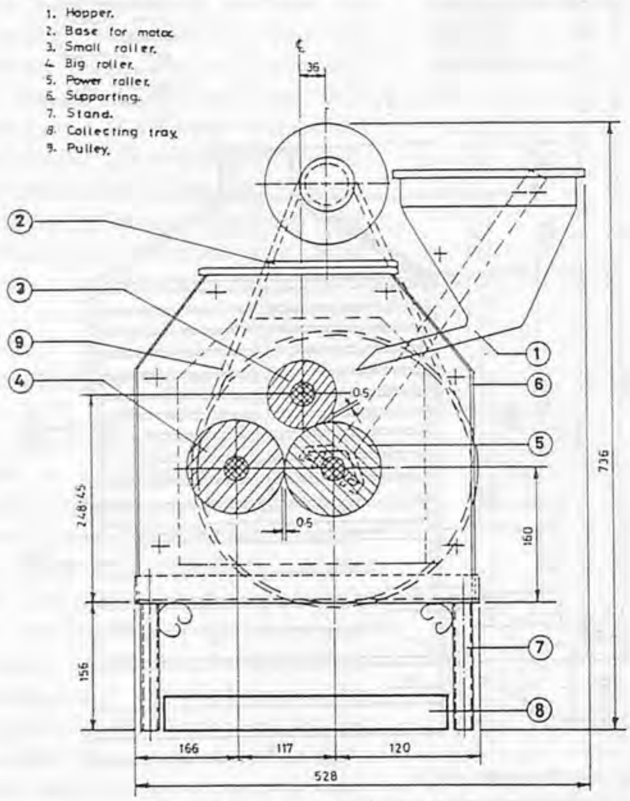

Fig. 4 Soybean flaking machine

Soyflakes Quality

The flake produced by the process explained above and using the equipment developed has a composition of 44% protein, and 19.1% oil at 8% m.c. The urease activity was nil. The bulk density and water absorption capacity of 0.54 mm thick flakes was 500 kg/m³ and 227%, respectively.

Storage studies were conducted in order to determine the shelf life of flakes in polyethylene bags, tin containers, cloth and paper bags. There was no appreciable rise in FFA for 5 months. Insect infestation, however, was observed after 5 months of storage.

An organoleptic evaluation on a 9-point hedonic scale shows that general acceptability and colour of the flakes were rated very good whereas taste and appearance were good. Feeling and flavour which are factors inherant in soybean were rated between good and fair. (Patil et al, 1986).

Economic Analysis

With the required equipment for soyflaking process, the space requirement is about 42 m². An economic analysis was conducted in order to determine the economic feasibility of the process (Patil et al, 1986). The evaluation was done with net present value (NPV), discounted benefit cost ratio (DB-CR), annuity (A), pay back period (PBP) and internal rate of return (IRR). The formula for calculating these parameters are given in Appendix-I. The cost of the soyflaking plant annually over the life span were estimated and shown in **Table 1**. The individual costs of the machine were Rs.2500, Rs.1000, Rs.1300, Rs.5700 and Rs.4500 for cleaner, dehuller, blanching unit, dryer and flaking machine, respectively. The operating costs with and without raw materials for each year over the life of the plant are given in **Table 2**. The sensitivity analysis was conducted at discounted rates of 15 and 20% **(Table 3)**. Initial investment was considered as Rs.18592 and the analysis shows that the positive of NPV could be retained until the returns obtained from soyflakes (SF) and soygrits (SG) are at the rate of Rs.9/kg, Rs.5/kg and Rs.8/kg, Rs.5/kg, but not less than Rs.8/kg and Rs.4/kg for respective products. In the case of revenue at the rate of Rs.7/kg

Table 1 Estimated Cost of Soyflaking Plant

Year	Initial investment, Rs.	Electricity connection, Rs.	Labour cost, Rs.	Raw material, Rs.	Maintenance & repair, Rs	Working capital requirement, Rs.	Room rent, Rs.	Installation charges Rs.	Insurance charges, Rs.	Fuel charges, Rs.	Electricity charges, Rs.	Material transportation, Rs.	Cost of small tool, Rs.	Total expenditure cost, Rs.	Total revenue, Rs.	Net benefit, Rs.
0 year	15 000	100	–	–	–	2 865	200	200	75	–	–	–	150	18 590	–	−18 590
1st year			9 600	129 000	600	–	2 200	–	75	10 200	900	185	–	152 760	187 200	+34 440
2nd year			9 600	129 000	750	–	2 400	–	75	10 200	900	185	–	153 110	187 200	+34 090
3rd year			9 600	129 000	900	–	2 400	–	75	10 200	900	185	–	153 260	187 200	+33 940
4th year			9 600	129 000	900	–	2 400	–	75	10 200	900	185	–	153 260	187 200	+33 940
5th year			9 600	129 000	900	–	2 400	–	75	10 200	900	185	–	153 260	187 200	+33 940
6th year	5 000		9 600	129 000	1 350	–	2 400	–	75	10 200	900	185	–	158 710	187 200	+28 490
7th year			9 600	129 000	1 350	–	2 400	–	75	10 200	900	185	–	153 710	187 200	+33 490
8th year			9 600	129 000	1 350	–	2 400	–	75	10 200	900	185	–	153 710	187 200	+33 490
9th year			9 600	129 000	1 350	–	2 400	–	75	10 200	900	185	–	153 710	187 200	+33 490
10th year			9 600	129 000	1 225	–	2 400	–	75	10 200	900	185	–	153 510	187 200	+33 690
Total	20 000	100	96 000	1 290 000	10 675	2 865	24 000	200	750	102 000	9 000	1 850	150	1 557 590	1 872 000	314 410

Year = 300 workingdays
Raw material = Rs. 430/q
Transportation = Rs. 185/year
Insurance charges = Rs. 5/1 000/year
Electricity charge = Re. 0.50/unit
Room rent = Rs. 200/month
Labour rate = Rs. 16/day/labour
Maintenance rapairs = 4 to 9% of investment
Fuel charges = Rs. 0.5/kg

Table 2 Operating Costs for Soyflaking Plant

Year	Total cost including raw material cost, Rs	Cost, h, Rs	Cost/kg, Rs	Total cost excluding raw material cost, Rs	Cost/h, Rs	Cost/kg, Rs
1	160 352	66.81	6.68	31 352	13.06	1.31
2	154 475	64.36	6.44	25 475	10.61	1.06
3	154 642	64 43	6.44	25 642	10.68	1.07
4	154 661	64.44	6.44	25 661	10.69	1.07
5	154 684	64 45	6.44	25 684	10.70	1.07
6	160 163	66.73	6.67	31 163	12.98	1.30
7	155 200	64.67	6.47	26 200	10.92	1.09
8	155 249	64.69	6.47	26 249	10.93	1.09
9	155 326	64.72	6.47	26 326	10.97	1.10
10	155 288	64.70	6.47	26 288	10.95	1.10
Total 10 years	1 560 040	650.00	65.00	270 040	112.5	11.25
Average	156 004	65.0	6.50	27 004	11.25	1.13

Table 3 Data Showing Economic Viability of the Project

Different levels of discounted rates, %	Criteria of evaluation	Initial investment, Rs 18 592 Revenue SF @ Rs 9/kg SG @ Rs 5/kg	Initial investment, Rs 18 592 Revenue SF @ Rs 8/kg SG @ Rs 5/kg	Initial investment, Rs 18 592 Revenue SF @ Rs 8/kg SG @ Rs 4/kg	Initial investment, Rs 18592 Revenue SF @ Rs 7/kg SG @ Rs 5/kg
@15%	PBP	0.54 years	1.066 years	1.93 years	–
	B/C ratio	9.39:1	4.28:1	1.94:1	0.039:1
	NPV	151 859	69 195	31 404	−640
	A	30 258.27	13 787	6 257	−127.52
	IRR	181%	93%	52%	–
@20%	PBP	0.54 years	1.066 years	1.97 years	–
	B/C ratio	8.07:1	3.63:1	1.58:1	0.015:1
	NPV	125 135	56 289	24 517	−230
	A	29 848	13 426	5 848	−54.86
	IRR	181%	93%	52%	–

and Rs5/kg the NPV was less than zero. The BCR is less than one, hence at these rates it is not ideally and safely bankable. The sensitivity analysis was further extended by assuming an increase over the initial investment by 5% and 10% (Table 4). The analysis reveals that NPV, BCR and A, were positive at 5% increase in cost even at the revenue levels of Rs.8/kg and Rs.5/kg in case of soyflakes and soygrits, respectively. However, when the cost is increased by 10% the economic analysis parameters were positive only when the price of soyflakes and soygrits was kept at Rs.9/kg and Rs.5/kg, respectively.

For all new products developed it is essential to provide guidelines on how to use them. Since soyflakes are high protein product they are not recommended for use as whole meal but rather added into daily dietary preparations like curries, etc, to the amount of 15%. The byproduct soygrits can be used as quick cooking *dal* (split pulse). It is also a good ingredient in preparing other Indian fermented products like *idli, dosa* etc, which are commonly eaten by rural people. In such case the soygrits are

Table 4 Sensitivity Analysis of the Project

Different levels of rate	Criteria for evaluation	Cost increases 5%, without corresponding increase in revenue, initial investment Rs 19 522 Revenue SF @ Rs 9/kg SG @ Rs 5/kg	Cost increases 5%, revenue decreases 8.97% SF @ Rs 9/kg SG @ Rs 5/kg	Cost increases 5%, initial investment Rs 19 522 SF @ Rs 8/kg SG @ Rs 4/kg	Cost increases 10%, initial investment Rs 20 451 Revenue SF @ Rs 9/kg SG @ Rs 5/kg	Cost increases 10%, initial investment Rs 20 451 Revenue SF @ Rs 7/kg SG @ Rs 5/kg	Cost increases 10%, revenue decreases 5%, initial investment Rs 20 451
	PBP	0.73 years	2.16 years	19.18 years	1.08 years	26.90 years	0.72 years
	BCR	6.62:1	1.66:1	0.52:1	4.11:1	0.37:1	6.75:1
15%	NPV	112 473	28 157	8 849	73 090	6 610	120 112
	A	22 410	5 610	1 763	14 563	1 317	23 932
	IRR	136%	45%	–	91%	–	138%
	PBP	0.73 years	2.23 years	20.85 years	1.08 years	29.34 years	0.72 years
	BCR	5.66:1	1.33:1	0.50:1	3.47:1	0.34:1	5.78:1
20%	NPV	92 149	21 718	7 801	59 166	5 809	98 438
	A	21 980	5 180	1 861	14 113	1 385.6	23 480
	IRR	136%	45%	–	91%	–	138%

added directly to wet paste of rice and pulse and then fermented overnight before preparing the dish. The soyflakes can be used as filler for pattis, rolls and cutlets, and by mixing in other fried snacks. It may be mixed with rice and corn flakes to a level of 10-15% to improve the nutritional status of the dish.

Conclusion

The process for making soybean flakes and the equipment developed for it are simple, low cost and use locally available raw materials for fuel. The flakes produced have 44% protein and 19% oil and can solve protein calorie malnutrition of the masses in the rural areas. The product is similar to existing food habits hence readily acceptable. A cottage industry based on this technology can provide employment to three persons while providing nutritious food at low costs.

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Power Tiller Potential in Forestry

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Abstract

Being a small and compact machine, the power tiller promises to be a good source of power for transportation of tree seedlings, digging pits, plant residue collection and tree-felling in forestry. The operation of pit digging using the power tiller in operating an auger digger has been found to be cheaper and faster compared to the use of tractors and manual pit digging. However, the transportation cost per unit time and per unit seedlings with the use of power tiller was greater than for the tractor.

Introduction

In view of the present emphasis on improvement of environment and large scale afforestation in India, it has become imperative to mechanize the afforestation system. There is a good scope for mechanizing the arduous jobs like pit digging, tree-felling and forest residue collection. Power tiller, as a source of power, has a very good potential for operating pit diggers, traillers, tree-felling machines and garbage collectors. The power tiller has small turning radius and can move on narrow paths in the waste lands due to its compactness and small size. The low centre of gravity of the power tiller facilitates its movement on slopes and undulating terrain. It is a versatile source of power and can be used for many field and stationery jobs in forestry management.

This paper discusses the prospects of utilizing the power tiller in digging pits and transportation of seedlings and compares other available technologies for these two operations in forestry management system.

Acknowledgement: The authors are thankful to Dr. T.P. Ojha, Director, Central Institute of Agricultural Engineering, Bhopal for his able guidance and for providing facilities for the research.

Experimental Procedure

Pit Digging

Pit digging with the use of power tiller in operating an auger digger of 22.5 cm size (developed at the Tamil Nadu Agricultural University, Coimbatore, India) and commercially available tractor-operated auger digger of 30 cm size were compared with manual digging. The pits were dug at 4 m centre to centre distance in a field with black clay soil and undulating topography. Pickaxe and spade were used to dig the pits manually to a bottom diameter of 22.5 cm. The depth of pits was maintained about 45 cm for all three methods of digging.

The observations recorded were moisture content of soil, capacity of machine, fuel consumption, man-power requirement and size of pits. The cost of operation for digging pits by tractor and power tiller was determined by adding the costs on depreciation, interest on investment, repair and maintenance, taxes, shelter, insurance, diesel and lubricants and wages of labourer and operator (**Table 1**). The cost of digging pits manually was based on labour cost only.

Transportation

Normally, seedlings of trees are transported from nursery site to the site of plantation by tractor trailer or bullock carts. A power tiller trailer was used to transport seedlings to a distance of 10 km and compared with tractor trailer transportation. The observations recorded were capacity of trailer, speed on farm road and fuel consumption. The cost of transportation of seedlings was based on a standard procedure (**Table 1**).

Results and Discussion

Pit Digging

The data on pit digging (**Table 2**) indicates that the time taken in digging 100 pits by tractor auger digger was 2.78 h compared with 2.38 h with power tiller auger

Table 1 Cost Calculations for Pit Digging and Seedling Transportation by Power Tiller and Tractor

Item	Tractor	Power tiller	Tractor		Power tiller	
			Auger digger	Trailler	Auger digger	Trailler
Initial cost, Rs	95 000	35 000	3 000	15 000	2 000	9 500
Service life, h	10 000	8 000	1 000	4 000	1 000	3 000
Depreciation, Rs/h	8.55	3.94	2.70	3.38	1.80	2.85
Interest on investment, Rs/h (@ 14%)	7.32	3.37	2.31	2.89	1.54	2.44
Taxes, shelter and insurance, Rs/h (@ 2%)	1.90	0.88	0.60	0.75	0.40	0.63
Repair and maintenance, Rs/h (@ 10%)	9.50	4.37	3.00	3.75	2.00	3.15
Cost of diesel, Rs/h (@ Rs.3.91/1)	–	–	9.78	5.87	4.89	1.76
Cost of lubrication, Rs/h (@ 30% of fuel cost)	–	–	2.93	1.76	1.47	0.53
Wages of labourer, Rs/h	–	–	2.17	–	2.17	–
Wages of operator, Rs/h	3.13	3.13	–	–	–	–

Table 2 Comparative Performance of Pit Digging by Tractor Auger Digger, Power Tiller Auger Digger and Manual Digging

Method	Moisture content of soil % (db)	Size of pit Depth (cm)	Size of pit Diameter (cm)	Time taken/ 100 pits (h)	Fuel consumption (1/h)	Cost of operation Rs/h)	Cost of digging 100 pits (Rs)	Remarks
Tractor-operated auger digger	20.0	45	30	2.78	2.50	53.89	149.81	–
Power tiller-operated auger digger	20.5	45	22.5	2.38	1.25	29.96	71.30	–
Manual digging by pickaxe and spade	19.8	43	44.50 (top) 22.25 (bottom)	32.94	–	–	71.48	Irregular shaped pits

Table 3 Comparative Cost of Transportation of Forest Tree Seedlings by Tractor and Power Tiller

Mode of transport	Average speed (km/h)	Capacity, no. of seedling bags	Fuel consumption (1/h)	Cost of operation (Rs/h)	Cost of operation (Rs/km/1 000 seedlings)
Tractor trailer (Sartaj)	5	911	1.500	48.80	10.71
Power tiller (Mitsubishi)	3	364	0.450	27.05	24.78

digger due to the fact that it took little more time to adjust the tractor to dig the pits at right location. The time taken in manual digging was much longer than that for power tiller digging. The data on cost of digging was highest at Rs 149.81 in digging 100 pits by tractor due to high initial cost of tractor and auger digger and greater fuel consumption compared to the power tiller. A minimum cost of Rs.71.30 was incurred in digging 100 pits using the power tiller auger digger. The digging of pits manually was arduous with not much difference in cost as compared to power tiller digging. An added advantage of tractor and power tiller digging was that completely cylindrical holes could be dug while the shape of pits was irregular in manual digging.

Transportation

The data on transportation of tree seedlings show that the capacity of tractor trailler was 2.5 times greater than that of the power tiller (**Table 3**). The cost of transportation per 1 000 seedlings per km was 57% less for the tractor as compared to the power tiller.

For a square planting of 4 m x 4 m, the number of pits to be dug will be 625 per ha. Considering the mortality of about 37.5%, it may be assumed that 1 000 tree seedlings would be necessary. When this is the case, the cost of digging and transportation will be equal for power tiller and tractor if the seedlings were transported to a distance of 17 km (34 km to and fro). Therefore, the power tiller will be an economical choice for square planting of 4 m x 4 m if it is used to dig the pits and transport the seedlings from a distance less than 17 km.

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A Single-board Computer-based Data Acquisition System for Agricultural Machinery Evaluation

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Abstract

A portable, single-board computer-based field data acquisition system to measure pull force, time and other parameters of animal-drawn machines and implements was developed in 1985-86. The system is compact, lightweight, and rugged. Software is in Basic and assembly language. Data can be collected automatically under program control using the on board real time clock, or manually by using the status of the push-button switches as a condition in the program. The real time clock can be used to log time and data for data. This system improves the quantity and quality of data collected in the evaluation of agricultural implements and machinery.

Introduction

Large quantities of accurately collected data are needed to assess performance of soil-engaging implements and machines. In conventional data collection, the pull force is usually measured with a spring dynamometer **(Fig. 1)**, time observations of various operations are made with stop watches, and the observations are noted manually. These techniques may not achieve good resolution of data, and often lead to erroneous results, because of the fluctuations of the pointer of the dynamometers and more than one stop watch is used for different time intervals, along with other human related factors. It is necessary to have better instrumentation and computerized data acquisition, to sense and record different parameters affected by the design of the implements and machines under field operating conditions. A portable-computer based data acqusition system can collect large amounts of data accurately in the field (Clark and Adsit 1985), and this data can be reduced, analyzed, and printed in the field directly or transferred to a mainframe computer for analysis and permanent storage.

A portable single-board computer based data acquisition system was developed at ICRISAT for use with animal-drawn machines and implements to record the pull force, and time references in the field in 1985-86. This system allows the use of up to eight different input channels.

For one year the output data was collected using a 24-character wide portable printer **(Fig. 2.)**. Printed data required careful handling until it was fed in to a mainframe computer, and manual feeding of large amounts of data requires killed operators and careful rechecking. The system was, therefore, modified using a hand-held data terminal in place of the printer.

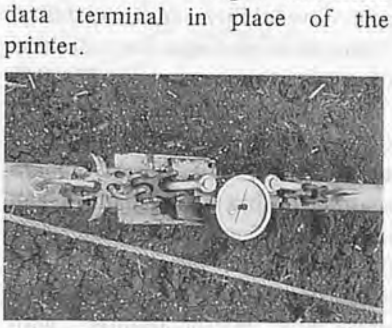

Fig. 1 Spring dynamometer fixed on a telescopic beam.

Fig. 2 Data acquisition system with printer. 1—System, 2—Pull force transducer.

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Hardware

The block diagram of the system in **Fig. 3** shows the pull transducer, signal conditioning circuit, analog to digital converter, single-board computer, and a hand-held portable data terminal.

The pull force was measured using a strain gauge-based tension load transducer with a load capacity of 0 to 500 kg.

Figure 4 shows the hardware of the data acquisition system. The signal conditioning circuit interfaces the transducer to the analog to digital converter. This is constructed using a strain gauge amplifier module consisting of three sections, a high quality instrumentation amplifier, adjustable transducer exitation, and gain control over a wide range. The selection of different gains for a linear calibration could be done by the selection of different hardware components.

The analog to digital converter (ADC) and the single-board computer (ARC 41) were chosen from Arcom Control Systems*. These parts were chosen because of the cost, availability and capability. Commercial packages for such kind of application were about $15 000 (Clark and Adsit 1985), the present system was developed at a cost of about $1 000 only. The ADC board is of eight bit, eight channel, and this was configured to accept +10 V full scale input signal. The single-board computer is based on Z 8671 single-chip microcomputer with built-in Basic interpreter (1983). A 4k EPROM, 4k RAM (expandable up to 16k), two IO (input/output) ports, and an RS 232 serial port for interfacing to a printer or another computer are provided. Port 2 is wired to 7 push-to-on switches and one toggle switch, which can be

*The company and the product name is mentioned for specific information only and should not be considered as an endorsement.

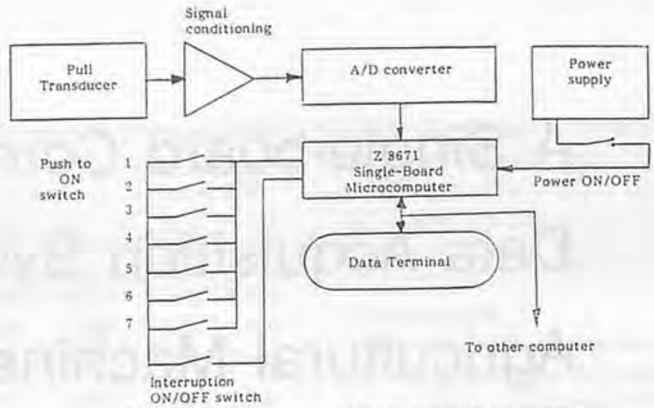

Fig. 3 Block diagram of data acquisition system.

called into the program when manual control is required.

The data terminal has two lines of 40-character wide liquid crystal display (LCD), a 50-key miniature ASCII keyboard in standard Qwerty style, and 10k of battery backed memory that can be organized into files. An RS 232 port is provided for communication with other computers. The data terminal comes with rechargeable batteries and consumes 65 mA.

The power supply board is supplied with DC voltage from a 6 V, 10 Ah rechargeable alkaline battery, from which ±5 and ±12 V were derived. The total current requirement of the system is about 600 to 800 mA. The battery requires recharging after 6 to 8 h of total operation.

All of these components of the data acquisition system are fixed inside a compact box weighing 3.1 kg, and 90 x 180 x 200 mm in size are shown in **Fig. 5**. The battery and the system were either carried in hand or placed on the machine according to convenience. The transducer **(Fig. 2)** was fixed to a telescopic beam with chain links such that the entire pulling force transmitted through this link. A person carrying the system is able to walk along with the machine in collecting the data, hence, portable.

Software

The program is written in BASIC and assembly language (1981) for

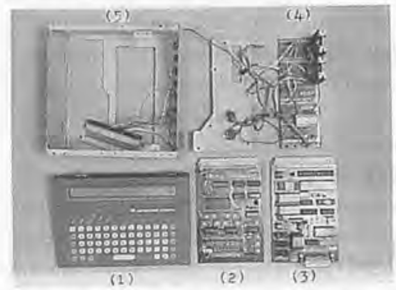

Fig. 4 Data acquisition system hardware. 1—Data terminal, 2—ADC board, 3—z 8671 single-board computer, 4—Power supply and signal conditioner, 5—Switch box.

Fig. 5 Data acquisition system components. 1—Data acquisition system, 2—Battery, 3—Pull force transducer.

measuring the pull force only. The flow chart **(Fig. 6)** of the program for pull force measurement was developed to achieve a procedure of data acquisition as shown in **Fig. 7** using the push-to-on switches to control data acquisition. These switches are repeatedly used in the program to control the start-stop operations, e.g., run, data collection and any interruptions. At the end of each run this program prints a summary of the number of data points and average pull force in kgf. The retrieved sample data shown in **Fig. 8** corresponds to the scheme of data acquisition **(Fig. 7)**. The data collection status is displayed on the terminal throughout the

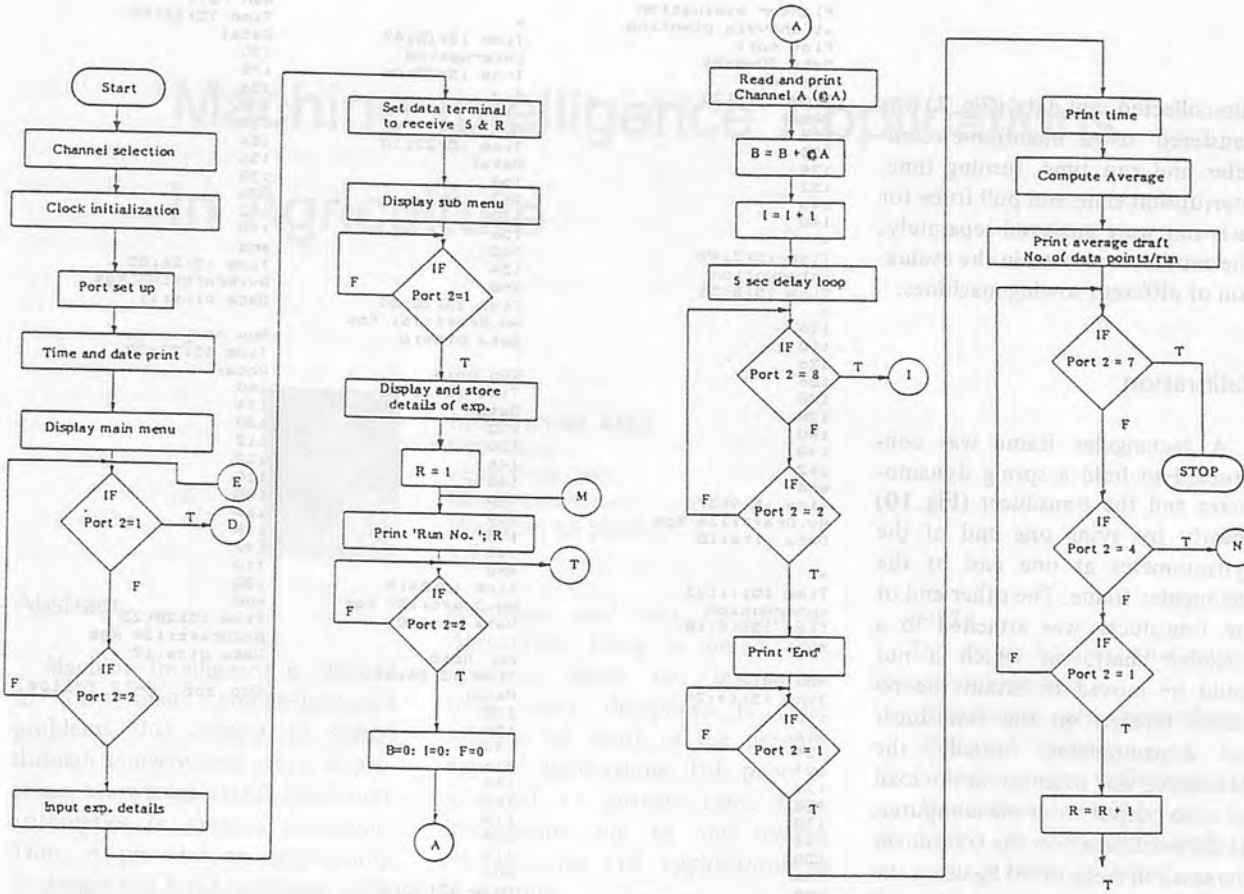
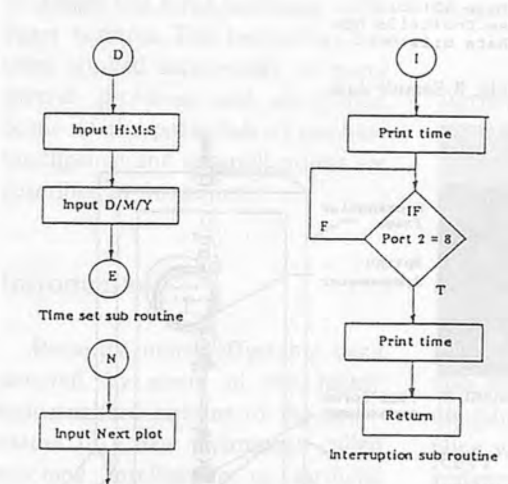

Fig. 6 Flow chart of the program.

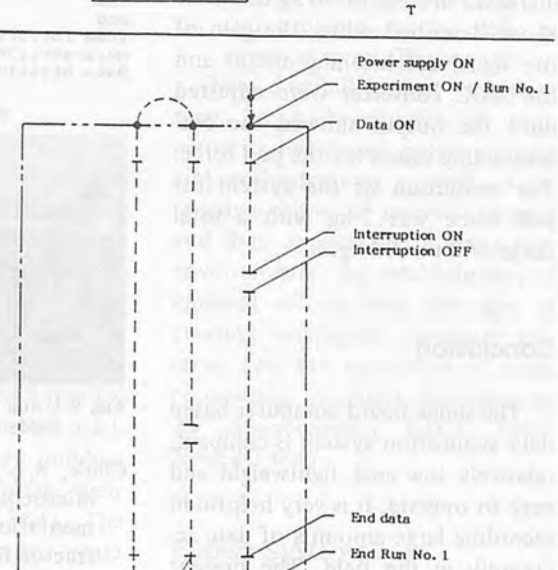

Fig. 7 Procedure of data acquisition in the field.

operation. The data terminal handles the storage of data in the form of files that can be transferred later to another computer. After transferring the data to a mainframe computer timing details such as running time, turning time, and interruption time can be separated, along with average draft and number of data points for each run.

Results

The complete setup of the data acquisition system was used in the farmer's fields (Fig. 9) in the evaluation of different sowing machines. The data was collected for pull force and time for each sowing machine using the data acquisition system for the 1986 rainy season.

```
Planter evaluation
at Chevela planting
Plot no:1
Date 30-6-86
Run no:1
Time 15:2:20
Data:
148
128
124
152
146
148
*
Time 15:2:49
interuption
Time 15:8:55
*
116
110
126
126
128
128
140
148
142
end
Time 15:9:37
Av.Draft:134 Kgs
Data bits:15

*
Time 15:11:23
interuption
Time 15:14:18
*

Run no:2
Time 15:14:20
110
116
124
124
126
138
138
122
150
146
end
Time 15:15:12
Av.Draft:129 Kgs
Data bits:10

*
Time 15:15:47
interuption
Time 15:22:06
*

Run no:3
Time 15:22:10
Data:
164
162
170
156
162
154
end
Time 15:22:30
Av.Draft:161 Kgs
Data bits:6

Run no:4
Time 15:23:25
Data:
132
120
146
148
140
134
158
118
end
Time 15:24:9
Av.Draft:137 Kgs
Data bits:8

Run no:5
Time 15:24:44
Data:
122
154
134
116
142
116
116
124
112
end
Time 15:25:27
Av.Draft:126 Kgs
Data bits:9

Run no:6
Time 15:25:59
Data:
130
148
156
128
158
156
156
138
136
132
140
end
Time 15:26:55
Av.Draft:143 Kgs
Data bits:11

Run no:7
Time 15:27:28
Data:
140
134
130
112
132
110
168
160
148
142
110
122
end
Time 15:28:23
Av.Draft:134 Kgs
Data bits:12
(Run nos. 8-12 follow)
```

Fig. 8 Sample data.

The collected raw data (**Fig. 7**) was transfered to a mainframe computer and run time, turning time, interruption time and pull force for each run were analyzed separately. The results were used in the evaluation of different sowing machines.

Calibration

A rectangular frame was constructed to hold a spring dynamometer and the transducer (**Fig. 10**) linearly by tying one end of the dynamometer at one end of the rectangular frame. The other end of the transducer was attached to a threaded shaft, on which a nut could be moved to attain the required tension on the transducer and dynamometer. Initially, the transducer was balanced at no-load for zero output from the computer. As the tensile load on the transducer increased in steps of 50 kg using the above described setup, the gain of the signal conditioning circuit and the ADC converter were adjusted until the output showed the corresponding values for the pull force. The resolution of the system for pull force was 2 kg with a total range of 0 to 500 kg.

Conclusion

The single-board computer based data acquisition system is compact, relatively low cost, lightweight and easy to operate. It is very helpful in recording large amounts of data accurately in the field. The present system is programmed to record only one parameter and other parameters such as depth of working of an implement, speed of the machine, temperature and other conditions could also be included for simultaneous recording.

Fig. 9 Using data acquisition system in fields.

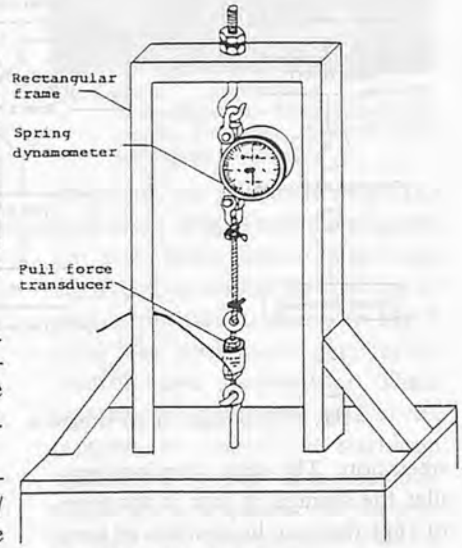

Fig. 10 Calibration setup.

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Machine Intelligence Applications in Agriculture

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Abstract

Machine Intelligence is claimed to solve many knowledge-based problems that cannot be solved through conventional ways. It processes knowledge rather than mere arithmetics or number crunching. Thus, it provides an opportunity to design and build intelligent computer systems. This technology has been applied successfully to many diverse problems and disciplines. Some of the potentials of machine intelligence and its applications are described in this paper.

Introduction

Recently much effort has been devoted by some of the highly industrialized nations to the application of a new technology called machine intelligence or artificial intelligence (AI). AI is the main potent force behind the development of the Fifth Generation Computers. It is described as a cutting edge technology, and the technological opportunity of the century. AI has become a symbol of advancement and breakthrough for many diverse disciplines ranging from engineering to medicine. Besides many of its distinct features, the main strength of AI lies in symbolic processing, human-like reasoning, and user friendliness. Agriculture being a broad area involving input and interaction from many disciplines is quite suitable for many of the present-day AI applications. This paper is intended to provide some basic information on AI and related concepts and its applications in agriculture.

Artificial Intelligence

Artificial intelligence is defined as the part of computer science concerned with designing intelligent computer systems that exhibit characteristics associated with intelligence in human behavior (Barr and Feigenbaum 1981). AI is also described as both an empirical discipline and an engineering discipline which progresses by building systems and demonstrating their performance (Newell 1984). The goal of AI research is to create systems that demonstrate some of the following characteristics:

a) the ability to assimilate unstructured information and to act independently in complex situations;
b) the capability of natural language interaction (e.g., in English) with humans;
c) common sense, and the ability to reason from experience (Waltz 1983).

The major AI areas that mirror human abilities are:

i) locomotion and manipulatory skills in robotics;
ii) communication skills in natural language and speech;
iii) ability to distinguish and recognize image in vision;
iv) and problem solving skills in expert systems (Harvey 1987).

The possibility that machines may be made capable of such activities has drawn public interest and enthusiasm as a result of increasing power of microcomputers and their application in many new environments, the establishment of national efforts with the aim of creating intelligent computer systems, and the emergence of some commercial products that embody AI characteristics (OTA 1985, Newell 1984).

Expert Systems

Expert Systems (ES) are one of the first and most commercially viable applications of AI at present. An ES is a computer program that embodies the expertise of one or more experts in some domain and applies the knowledge to make useful inferences for the user of the system (Hayes-Roth et al 1983). The development of ES is termed as knowledge engineering. It covers the following two aspects (Harvey 1987):

i) knowledge acquisition, and storage in the knowledge base in a usable form; and
ii) knowledge processing, which is the application of that knowledge to solve a problem.

An ES consists of three main components: user interface, inference engine, and knowledge base. Intelligence requires knowledge: it is one of the few hard and fast results to come out of past AI research (Rich 1983). Knowledge base, therefore, is considered the most important component of an expert system (Harvey 1987). It contains experts' knowledge and expertise. A major advantage of the ES is that the knowledge base is separate from the inference engine and the control structure. This enables knowledge to be added or changed without worrying about control or going through the lengthy process required for conventional programs. Another important characteristic of the ES relates to their dealing with the real-world domain problems, which require the capability of functioning with uncertain, unreliable, noisy, sparse, erroneous, and incomplete data (Gaultney 1985, Waterman 1986). Expert systems have the ability to effectively integrate numeric, judgmental or inferential, and uncertain information in rational ways. Expert Systems also help in more effective management by humans and machines (Huggins et al 1986); to rival human experts (OTA 1985); and can provide easier documentation, storage, retrieval, transmission, duplication, and modification of knowledge (Waterman 1986). Expert Systems represent one avenue by which developing countries can free themselves from dependence on outside expertise, when such expertise is in short supply within the country itself (Anon. 1986). The present day ES, however, have narrow and restricted domains, are highly customized; they are difficult and expensive to build and test (Waltz 1983), and lack capability in handling common sense knowledge.

The knowledge for an ES can be obtained from several sources, i.e., text books, data bases, technical specifications and papers, simulation programs, statistical programs, numerical analysis programs, data acquisition programs, domain experts, and case studies. The primary source of knowledge is generally the domain expert. The knowledge extraction process can be complicated and lengthy, because most human experts do not effectively communicate the facts and procedures they use for decision making. Not mentioned above, the ES are also faced with the following paradox of knowledge engineering; "The more competent domain experts become, the less able they are to describe the knowledge they use to solve problems."

At present, there are no methods available for the automatic transfer of knowledge from the domain expert to the ES, except for limited ability of some programs like ELIZA (Weizenbaum 1977), and the deduction of rules from examples in Expert-Ease (Annon. 1985). This topic, however, is one of the active AI research areas (Waltz 1983).

Knowledge Representation

A knowledge engineer must choose a suitable representation technique to describe the expertise or expert's knowledge. Expressive power of the representation or the ease with which the expert's knowledge can be described and read, and the commutational efficiency are the most important factors in knowledge representation (Harvey 1987). A highly expressive representation may require a natural language to describe the knowledge, while a representation based on a programming language may be desirable and often a necessity for rapid execution. In practice, the chosen technique is a compromise that is understandable to the experts, so that the knowledge base can be maintained and validated for performance, yet provides an acceptable speed of execution.

Barr and Feigenbaum (1981) describe the representation of knowledge as a combination of data structures and interpretative procedures which when used will lead to intelligent behavior. For intelligent behavior of a system, both declarative and procedural knowledge are needed. The declarative knowledge includes facts about objects, events, and situations; the procedural knowledge incorporates information about courses of action to obtain the necessary facts.

Knowledge can be represented through logic (propositional, predicate, nonmonotonic, probabilistic, fuzzy), production rules, and structured representations (semantic nets, conceptual dependency, frames, scripts, and procedures). The detailed discussion of these techniques are included in Barr and Feigenbaum (1981), Buchanan and Duda (1983), Hayes-Roth et al (1983), Rich (1983), and Winston (1984). The principal knowledge representation techniques used in ES applications are production rules, semantic nets, and frames (Harvey 1987).

The most popular format for representing knowledge in a way that maintains its procedural character is the production rule which is simply a single statement program of the form;

"IF Condition (antecedent) THEN Action (consequent)." When the current problem situation satisfies or matches the "IF" part of a rule, the action specified by the "THEN" part of the rule is performed. Production rules provide a natural way of describing processes driven by complex and rapidly changing environments. The production system's power and usefulness arises out of its close similarity to fundamental mechanisms of human cognitive processes (Buchanan and Shortliffe 1984). Rules provide a formal way of representing recommendations, directives, or strategies; they are often appropriate when domain knowledge results from empirical associations developed through years of experience solving problems in an area (Waterman and Hays-Roth 1978). The rules, when exceeding a few hundred in number, and if changed or modified, may affect the overall problem solving behavior (Harvey 1987). This effect can be minimized by organizing the knowledge in efficient chunks (Abelson and Black 1986), and/or grouping of knowledge to address different aspects of the problem (Harvey 1987).

A production system consists of classifications and relationships, rules, procedures, and a control structure. The classifications and relations are termed as parameters or attributes and values, which essentially hold the declarative knowledge. The procedures are a set of rules of IF-THEN type, and the control structure (inference engine) determines the order in which the rules are tried. There are two important ways in which rules can be used in a rule-based system. One is called the forward chaining, and the other backward chaining (Waterman 1986).

Semantic nets are the most general representational scheme, and also one of the oldest in AI. In a semantic net, information is represented as a set of nodes connected to each other by a set of labelled arcs, which represent relationships among the nodes. Flexibility in creation of new nodes and links, and inheritance (Ability of one node to inherit characteristics of other nodes) are the two major advantages of semantic nets (Harmon and King 1985). The main problems with the use of semantic nets are the difficulty in handling quantifications (Rich 1983), and the general-purpose exception handling (Harmon & King 1985).

The term frame refers to a special way of representing common concepts and situations. Frames like semantic nets are another general-purpose structure in which particular sets of domain-specific knowledge can be embedded. A frame is a description of an object or situation that contains slots for all of the information associated with the object or situation. Slots may contain values, default values, or pointers to other frames, sets of rules, or procedures by which values may be obtained. Frames, therefore, are more useful than semantic nets (Rich 1983), and allow far richer representations of knowledge (Harmon & King 1985). Frame systems are useful for problem domains where expectations about the form and content of the data play an important role in problem solving such as interpreting visual scenes or understanding speech (Waterman 1986).

Expert Systems in Agriculture

The wide availability of computers has affected the way humans think, make decisions, and solve problems. Agriculture is a broad area requiring input from many diverse disciplines. Today, the types of decisions that managers of agricultural systems make fall into the category of decisions which can be best made by experts. Decision making is information intensive, and the ever increasing volume and complexity of information in agriculture is demanding more and more experts in an expanding list of domains. Agricultural problems are complex both in the number of variables which must be considered and in the amount of uncertainty involved at each decision node (Gaultney 1985). Expert systems on the other hand are capable of handling complex problems having uncertainty in their elements (Huggins et al, 1986).

Norris (1987) anticipated the prevalence of ES in areas of agriculture where;

1) knowledge bottlenecks are present,
2) job performance is inconsistent,
3) a process must be performed more rapidly than is currently possible,
4) adverse working conditions and tedious or repetitive tasks make human involvement unpleasant,
5) rapid change is being experienced, and
6) knowledge intensive tasks are key.

Huggins et al (1986) emphasized that the role of ES in agriculture was feasible because of their ability to integrate the distinct classes of information essential to decision making and management.

The application of ES in agriculture is relatively new but has recently received a great deal of attention. As a result, several ES have been developed and more are in the process of development. It is estimated that in the near future about 200 expert systems will be required in agriculture to help farmers make decisions (Norris 1987). Some of the ES developed primarily for agriculture are briefly described below;

Afzal and Clark (1988) and Afzal et al (1988) developed Energy Crop Selection Expert Systems (ECE. 1 & ECE. 2). ECE were low-cost and PC-based with minimum hardware requirements. Schueller et al (1986) developed an ES with speech synthesis for trouble shooting grain combine performance. Another ES named COMBES was developed to reduce losses of a combine's cleaning shoe (Newton et al, 1986).

McKinion and Lemon (1985) developed COMAX, a cotton management expert system which used a knowledge base of extension expertise and information generated from a dynamic cotton crop simulation model. Whittaker et al (1986) developed an ES for real time monitoring and control of a greenhouse. Black (1986) developed a tillage speed selection expert system.

A farm level intelligent decision support system "FINDS" was developed for sizing and selecting machinery for whole-farm cropping systems (Kline et al, 1986). FINDS integrated a whole-farm management linear program with a knowledge-based expert system. Such integrations generally impose larger hardware requirements than a PC environment. Consequently, FINDS required a Texas Instruments Business Pro computer for its ES, and a VAX/11-750 computer for the linear programing analysis.

Conclusions

AI technology, especially the Expert Systems, can be applied to many complex agricultural problems involving diagnostics, synthesis, and design processes. These systems sometimes referred to as knowledge-based systems can be readily used for planning, design, extension, and educational and/or training purposes.

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(Continued on page 84)

ABSTRACTS

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

Appraisal of Agricultural Mechanization, Government Policies and Agricultural Productivity in Nigeria: A.Y. Sangodoyin; K. Ogedengbe, Dept. of Agric. Engg., Faculty of Technology, University of Ibadan, Ibadan, Nigeria

It is often said that the survival of Nigeria depends on the innovative approach to the development and exploitation of technology which will meet the food and fibre requirements of the ever growing population. In this paper, about 100 agricultural establishments served as the focus for a study of issues associated with agricultural machinery and equipment manufacturing, cost, level of usage and resulting productivity together with continuously changing government policies. The result reveals that tools have been developed and continue to be developed for use by small and large scale farmers thus relieving dependence upon heavy imported machinery. Suprisingly, the tradition of small farm holdings and cutlass-and-hoe technology is still very strong. The discussion focuses upon several problems affecting small agricultural equipment manufacturing industry, in particular, problems in disseminating information, lack of funds for development of prototype, insufficient technical skills and aggressive competition with imported brands. The paper is interspersed with illustrations of price trends and hiring rates for some selected equipments within the past decade. Increases range from 300% to 1 500%; the high figures being closely associated with recent government measures viz: structural adjustment programme and foreign exchance market which led to the devaluation of the currency. Efforts are made to suggest lines of approach along which strategies for small farm implement/equipment manufacture and utilization through appropriate pricing could operate.

Management of Ground Water — Its Development and Utilization Aspects in Orissa, India. J.C. Paul, Post Graduate Student, C.A.E.T.; B. Panigrahi, Lecturer, C.A.E.T.; P.C. Senepati, Agric. Engineer, Dry Land, Orissa Univ. of Agriculture and Technology, Bhubaneswar, India

The state of Orissa has extensive agricultural and water resources. It possesses vast amount of ground water potential as high as 1900886 hectare metres out of which only about 7% has been tapped so far and the rest (93%) is still to be exploited for obtaining maximum agricultural production. Land utilization pattern in the state, district-wise production and food grain variation, existing irrigation projects, utilization of lift irrigation potential and the future exploitable ground water of the state are discussed in the study. Suggestions are incorporated on how to improve water use efficiency in the lift irrigated projects and the manner in which the ground water potential of the state can be developed.

Performance Evaluation of three manually-operated Weeding Devices from Engineering and Ergonomic Considerations — A Case Study: V.K. Tewari, R.K. Datta, Jr. Res. Engineer and Prof., respectively, Agric. Engg. Dept; A.S.R. Murthy, Prof., Reliability Engg. Centre, I.I.T., Kharagpur, India

Three commonly used manually-operated weeders were tested from mechanical and ergonomic considerations. For the purpose of field testing, three operators were selected as subjects, based on their anthropometric data representing the 5th, 50th and 95th percentile values from amongst the 125 available farm workers.

Laboratory tests were conducted to establish relationships between E.E.R. and O.C.R. vs H.R. for each of the subjects.

Field testing was carried out in a farm with Arhar crop (*Cajannus cajan* L.) in the month of Aug-Sept. 1983 when the average ambient temperature and relative humidity were 30°C and 82%, respectively. The results of this investigation suggest that weeding by all the three selected handtools come under the category of 'moderately heavy work'. However, E.E.R. in the case of Khurpi was less than other two handtools. The working posture with a 3-tine hoe (80% erect position) appeared to be more comfortable than that of the local hoe (60% erect position), the most comfortable one being the Khurpi (squatting position). From the consideration of higher output the sequence observed to be local hoe, 3-tine hoe and the Khurpi. However, from the point of weeding efficiency, the trend was observed to be just the reverse.

Model III Batch Process Cassava Peeling Machine: E.W. Odigboh, Prof. (Agric. Engg.), Faculty of Engineering, University of Nigeria, Nsukka, Anambra State, Nigeria

All available evidences show that the mechanization of cassava peeling is still a chellenging engineering problem. This model III batch process cassava peeling machine, developed in 1986, evolved from a model I of 1978 and the model II of 1980. It consists of a drum of expanded metal attached to the inside surface of a framework of small pipes. The drum is mounted eccentrically on a shaft. Inside the drum, four abrasive cylinders of expanded metal are mounted and driven by a planetary gear arrangement to rotate at four times the rpm of the main drum. To operate, whole cassava tubers and some abrasives are loaded into the drum which is then rotated at 40 rpm; the resultant shaking motions of the drum and the faster rotation of the abrasive cylinders lead to the fast peeling of the tubers. Peeling, achieved at about 300 kg/h, is so thorough that hand trimming is eliminated.

Farm Mechanization in Northwest Cameroon — Farmers' Views: Edward A. Baryeh, Prof., ENSIAAC, BP 455, Ngaoundere, Cameroon

Some questionnaires on farm mechanization were given to randomly selected farmers in the five divisions of the Northwest Province of Cameroon to answer. From the answers given, it was found that the majority of the farmers will accept the use of small farm machines to increase their crop production. They also indicated that most of them will accept irrigation practice and the use of fertilizers in order to cultivate more than one crop a year.

Numerical Modeling for Field Evaluation of Hydraulic Roughness for Irrigation Basins and Borders: Md. Harun-ur-Rashid, Principal Scientific Officer (Ag. Eng.), Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh

This study was undertaken in an effort to develop a tool (model) for predicting hydraulic roughness values in the field with reasonable accuracy and hence to remove the present difficulty which lies in determining or selecting reasonable roughness values.

The present study uses three well-known equations—volume balance, continuity and manning—for constructing the model. The "forward differencing approximation" of "finite difference technique" was used as the solution tool.

Field data collected from Grand Valley, Colorado, western USA was used to test the model. Roughness values predicted by the model were compared with the reported values; a reasonably good agreement or conformity was found.

Effect of Irrigation Methods on Energy Inputs and Outputs of Maize and Wheat Crops: B.S. Panesar, Assoc. Prof.; C.P. Singh, Prof.; B.S. Gill, Asst. Prof., Dept. of Agronomy, Punjab Agric. Univ., Ludhiana, India

The effect of irrigation method on energy inflows and outflows was studied on maize and wheat crops. Two irrigation methods for maize and three for wheat were decided with a view to reducing the energy requirements of irrigation operation. In the case of maize, ridge and furrow irrigation saved about 24% energy for this operation in comparison with the long border method. Irrigating wheat with small border saved about 36% and 9% of energy for this operation over flood and long border, respectively. The total energy output-input ratio for maize-wheat rotation was 6.9 to 7.6 depending upon treatment. Small border method and ridge and furrow method of irrigation are recommended, respectively, for wheat and maize to conserve energy input.

Evaluation of Land Preparation Methods in Small Farm Holdings in Northern Sudan: Hamid Fakki, Agric. Economist, Agric. Res. Corp., P.O.B. 126, Wad Medani, Sudan; Mamoun Dawelbait, Agric. Engineer, Rahad Res. Station, P.O.B. 2325 Khartoum, Sudan

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

Design, Development and Evaluation of Weeder Simulation Test Rig for Estimating Operator's Fatigue: V.J.F. Kumar, Assoc. Prof., Regional Res. Station, Tamil Nadu Agric. Univ., Aruppukottai-626107, India; C. Divaker Durain, Asst. Prof., Dept. of Farm machinery, Tamil Nadu Agric. Univ., Coimbatore-641003, India

A weeder simulation test rig was designed and developed for push-pull and pull type weeders to simulate the weeding condition since control of certain parameters, viz soil moisture, weed population, depth of operation, force applied on weeder handle in the field is difficult when observations are

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done for ergonomic studies with different subjects and weeders. In the test rig the pole shaft actuation as affected by the weeder, the soil manipulating force encountered, push-pull and reversible loading conditions and quick return phenomena are simulated. Two subjects were tested using the test rig with different loading conditions for four different weeders in order to determine the fatigue induced.

Tractor Systems Failure Analysis: B.A. Adams, Agric. Engg. Dept., University of Ilorin, Ilorin Nigeria

The incidence of failures in some common tractors in Nigeria farms is studied. The study involved 120 tractors of four makes of various models: all in the medium power range spread across the country.

The recorded failures are categorized under tractor systems and occurrence at tractor-hour intervals. A time-between-failure (TRF) analysis was employed where appropriate and reliability levels are estimated based on the number of recorded failures in the tractor systems.

The power drive was found to be the most failed system for all makes. It was also observed that the most failed components in the tractor systems were direct-operator-control components, especially the clutch and brakes in the power drive, the power lift arms in the hydraulic and the throttles in the fuel system.

All the makes also exhibit a fair share of peculiar problems in other systems other than the power drive.

Comparative Performance of Spike and Angle Iron Bar Type Clod Crushers: T.C. Thakur, Prof.; B.P. Varshney, Prof.; P. Singh and S. Gupta, Ex-Graduate Students, Dept of Farm Machinery and Power Engg., G.B. Pant University of Agriculture and Technology, Pantnagar 263145, India

A spiked clod crusher was designed and developed using basic mechanics of soil cutting by rotary powered tillage tools. The performance of spiked crusher was evaluated alongside a corrugated angle iron bar crusher under field conditions on the basis of change in clod mean-weight-diameter, dry bulk density and draft requirement. The speed and load were varied from 1.5 to 7.5 km/h and 250 to 450 kg/h width of crusher, respectively. The clod MWD was minimum at about 3.5 km/h speed for both the crushers. For loads lower than commonly used values of 350 kg/m width on agricultural land rollers, spiked crusher resulted in greater reduction in clod size in comparison with the others. The bulk density increased with the increase in speed up to 3.5 km/h and thereafter, it decreased. The loads on crusher and speed of travel had significant effect on clod MWD but their effect was non-significant in respect of bulk density of soil. The type of crushers had no significant effect on clod MWD and bulk density of soil. There was significant increase in draft due to load, speed and type of crushers. In general, spiked crusher required 15% less draft than angle iron bar crusher and produced about 0.83 kN/m width draft for 350 kg/m load at 3.5 km/h speed.

Development of a Machine for Processing Agricultural Crop Residues into Fuel Briquettes: Stephen A. Dada, Dept. of Agric. Engg., Faculty of Technology, University of Ibadan, Ibadan, Nigeria

The dwindling natural fossil fuel deposits and the rising costs of fossil fuel energy have resulted in the need to search for a unique method of improving the impending energy shortage. This paper describes the design, construction and testing of a manually-operated machine that can be used for processing agricultural crop residues into fuel briquettes. The machine consists of simple mechanisms fabricated from locally available materials. The briquettes produced by the machine had heating values ranging from 14.48 to 14.79 MJ/kg at moisture content range of 8.0 to 10.0%. The specific gravity values of the briquettes range from 0.5 to 0.7. The machine can be a potential source of cheap fuel for the rural population, especially in the fuel wood-deficient zones of the third world countries.

Fuel Characteristics of Some Nigerian Biomass Solid Materials: A.A. Olufayo, Lecturer, Dept. of Agric. Engg. and Mechanization, Federal Univ. of Technology, Akure, Nigeria

The heating values, proximate and ultimate analyses of six Nigerian biomass solid materials: maize cob, maize husk, saw dust, groundnut shell and palm kernel shell are reported in this paper. In addition, the quality of air required for perfect combustion, volume of products of combustion and the temperature of combustion products have been calculated.

The moisture free gross calorific values of the materials range from 13.68 MJ/kg to 25.46 MJ/kg.

Potentials and Constraints to the Adoption of Agricultural Mechanization Technology in the Middle East Region: Imad Haffar, Technical Director, Agric. Res. and Education Center, United Arab Emirates Univ., Al Ain, U.A.E.; Mahmoud H. Ahmed, Lecturer (Agric. Engg.), Faculty of Agric. Sc., U.A. E. Univ., Al Ain, U.A.E.

Several conditions converge in the Middle East region in a manner that retards the effective application of agricultural mechanization technology and the consequent development in agricultural practices. This paper presents some of those conditions, and reviews the recent issues pertaining to both the obstacles and potentials of the adoption of this technology in the region.

Constraints have been divided into primary: land, capital and technology adoption, and secondary: lack of a supporting production system, product price structure, servicing and spare-parts, research and testing, training and extension, import system and assembly, and adequate infrastructure. A back-view on the region's current food status and that of its potentials are presented.

An Analysis of Soil Movement on Ideal Mathematically Expressed Mould Board Surfaces: C. Divaker Durairaj, Asst. Prof., Farm Machinery Dept; K.R. Swaminathan, Dean, College of Agric. Engg., Tamil Nadu Agric. Univ., Coimbatore 641003, India

Two mould board surfaces to fit mathematical expressions were developed and tested for their soil flow pattern. The velocities and accelerations of the soil slices in different planes were theoretically computed and the mould boards' performance predicted.

Ergonomics of Hand-cranking and Pedaling of Agricultural Machines: T.V. Job, Assoc. Prof.; C. Divaker Durairaj, Asst. Prof.; K.R. Swaminathan, Dean; College of Agric. Engg., Tamil Nadu Agric. Univ., Coimbatore 641003, India

An attempt is made to study the ergonomic aspects of pedaling and hand-cranking of manually-operated agricultural machines. The results corroborate the normal range of human capacity to use such machines.

Ergonomic Assessment of a Pedal-operated Winnower: C. Divaker Durairaj, Asst. Prof.; T.V. Job, Assoc. Prof.; K.R. Swaminathan, Dean; College of Agric. Engg., Tamil Nadu Agric. Univ., Coimbatore 641003, India

Two subjects with varying anthropometric characteristics were evaluated for their man-machine interaction on a pedal operated winnower. A novel torque transducer was developed and used to record the power input of the operators. The results obtained were analysed in order to determine the optimum ergonomic requirements.

Agricultural Engineering – A Solution to Dry Farming in India: Ajay Kumar Sharma, Asst. Prof., Farm Machinery and Power Engg., College of Technology and Agric. Engg., Rajasthan Agric. Univ., Udaipur, India

In this paper attempts are made to emphasize the role of agricultural engineering in dryland farming in India. Agricultural engineering applications can solve the problems, to a large extent, of dryland farmers and increase their production and productivity under limited soil moisture conditions.

An Electronic Eye to Determine Seed Distribution of Planters: Muhammad Afzal Shahin, Agric. Engineer, Farm Machinery Institute, Pakistan Agric. Research Council, Islamabad, Pakistan

An "eye" to determine the longitudinal seed distribution of planting machinery was designed and developed using electronic components. The device was tested to assess its performance and was found suitable for laboratory testing of seed metering mechanisms. A response time of 20 ms was recorded. Thus, it can sense seeds being planted as close as 3 cm at a planter speed of 5 km/h. ■■

(Continued from page 80)

Machine Intelligence Applications in Agriculture

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No.1 GOLD MEDAL at 61st SIMA
Rotary Plough
by KUHN S.A.

This new plough was designed to offer a response to the problems involved in ploughing compacted soils, or under extreme conditions—with very dry or very wet earth—in which the traditional types of equipment are of limited use.

A rigid frame or chassis supports a horizontal rotor, tilted at a 64 degree angle. The unit is made to rotate by the tractor power take-off, and is equipped either with discs with spades and associated with "scrapers-moldboards", or with large curved spading units. The lateral stress is absorbed by a stabilization ploughshare.

The equipment's large working width (2.5 meters) limits soil compacting. The plough pan disappears. The soil structure is aerated, and ploughing resumption is facilitated. The gearbox and the two rotor versions make it possible to adapt to different soil structures, making this equipment markedly multipurpose.

★ ★ ★

No.2 GOLD MEDAL
Multi-track Hydraulic Connector MACH System
by MAILLEUX S.A.

When hitching tools to hydraulic assistance, it is necessary to connect up a certain number of pipes or electrical circuits with the supply source or with the tractor.

Generally speaking, the connection is made individually for each hydraulic circuit, a fact that represents a source of mistakes, improper functioning, and accidents. Moreover, such connections turn out to be particularly difficult when there is some residual pressure in one of the circuits to be connected up.

An automatic cover, after disconnection, avoids any pollution of the hydraulic circuits. The connector acts as a shut-off valve, a safety element when traveling or parked.

This connector allows simultaneous connection of five hydraulic tracks or channels and of six electrical tracks by means of a simple manual tilting or tipping (effortlessly) of all of the connections.

The system resolves the various problems that are encountered, especially in connection with hitching hydraulic tools to the tractor, and particularly with respect to front loads.

No.3 GOLD MEDAL
Electronic Injection Control System
by SAME FRANCE

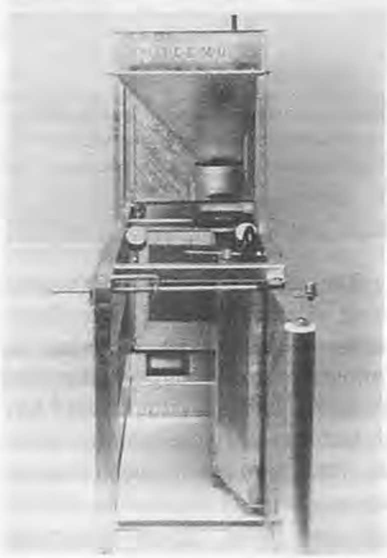
The electronic control (regulation) unit consists of a central electronic control device receiving information concerning engine performance and operating level from an initial sensor placed on the steering wheel, and from a second one in a potentiometer located on the accelerator pedal. There is a third source of information: the control keyboard (in manual mode). After analysis by the central unit, the injection control system acts directly on the pump rack.

With a vertical regulation curve, one enjoys a gain in power thanks to the absence of the action zone occasioned by the traditional type of control system. The engine operating level reacts instantaneously to variations in loads or to the driver's orders. The manual control unit, which is very easy to use, has 3 sensitive control keys offering great accuracy and memorization of a constant engine operation level. This is a particularly important in connection with the quality of performance of agricultural tasks, such as sowing or spreading, which require great similarity of performance after each turn. We should also point out the possibilities offered for electronic connection with on-board computers one other data acquisition units.

No. 1 GOLD MEDAL at 7th SIMAVIP

Feed Stall with Consumption Measurement

by ACEMO



This stall carries out distribution of feeds for pigs on a group breeding basis, while an electronic weighing arrangement based on stress gauges also sees to measurement of the amounts consumed, each animal being identified individually (there is one decorder for each 8 stalls).

The weighing system is isolated from rest of the stall during the weighings (this makes for greater accuracy and fewer risks of deterioration).

The information is stored on hard discs by the central unit at the frequency selected by the user and there is software making it possible to consult or print out the information without interruption of the dialogue between the central unit and the stalls.

This system meets the needs of official inspection-control stations and of experimental stations, and should make it possible to reduce their operating costs while upgrading the measurement quality.

No.1 GOLD MEDAL at 12th SIMAVER

Forestry Chain Saw

by MATEM

The new JONSERED "2051" chain saw is the first one to be equipped with an air intake arrangement for putting the unit under pressure in the sealed intake chamber. This extra pressure improves the cylinder filling, and makes it possible to enjoy better recoveries in connection with accelerations.

Furthermore, the air intake system is equipped with a centrifugal purification arrangement that eliminates solid particles suspended in the air, the purposes being to reduce the number of air filter cleaning operations (twice a month, instead of twice a day, in professional use).

Finally, on the "2051 C" version, a microprocessor monitors the engine operating level at start-up, when idling, and at peak operating level, a feature that makes it possible, in particular, to avoid engine racing at start-up time and chain rotation. It upgrades user safety and the performance levers of the chain saw.

No.2 GOLD MEDAL

Lawnmower for Seated Driver

by OUTILS WOLF

This lawnmower is of completely new design, and meets the most exacting requirements in connection with grass pickup.

It can be called a veritable "all-weather mower", and the main originality relates to the cutting platform with two symmetrical volutes marked by strong grown and rear ejection. The cutting system, consisting of two indexed despun blades that overlap, provides an intake and blast effect thanks to the blades in the interest of grass removal by way of the wide central ejection channel.

To make it possible to arrange a grass catcher at the end of the channel, the axlebox is not located in the axis of the wheels. Various equipment items of the automobile type contribute to comfortable driving (single-disc, clutching, drum brake on the rear wheels, pedal-controlled clutching and braking, etc).

With a 14-HP or 12-HP engine, a cutting width of 1 meter, and a grass catching with emptying controlled from the driver's seat, a triple safety system for start-up of the unit has been developed (cutting system, seat presence and forward movement). ■■

The Development and Impact of Mechanical Reapers in the Philippines

(Philippines)

by F. Juarez et al.

The report is divided into five major parts. The first is the introduction which outlines the role of machines in agricultural development and describes the environment in which mechanical reapers were introduced in the Philippines and selected Asian countries. The second portion written by Stickney and coworkers (1986) describes IRRI's collaboration with the Chinese Academy of Agricultural Mechanization Sciences (CAAMS) to modify the original Chinese reaper design to meet the economic and technical conditions of countries in South and Southeast Asia. This collaboration represents a unique opportunity to assess the potential benefits of agreements for technology transfer between countries and international organizations. It also briefly summarizes the program to promote the CAAMS-IRRI reaper in the Philippines by the Department of Agriculture and Food (DAF) and IRRI. This collaboration includes direct involvement by local manufacturers. A third section details the results of the technical survey (Stickney et al 1986) and the socio-economic survey (Te et al 1985) to evaluate the extension, performance, and impact of the reaper. Given special emphasis in the fourth section is the impact of the reaper on landless labor (Crissman 1986). The final portion of the report integrates the lessons learned from this experience, including suggestions for future collaborative engineering work in the Philippines and other developing countries.

Size: 27.5 x 21 cm, pp 106, paper cover. Price US$15.00.

Published by International Rice Research Institute, P.O. Box 933 Manila, Philippines

Agricultural Mechanization Policy and Strategy

(Japan)

By A.G. Rijk

Of all modern agricultural technologies, mechanization has probably stimulated the most critical debate, since it is often associated with rural unemployment and other adverse developments. The overall purpose of this book is to contribute to the understanding of the role of agricultural mechanization in a developing economy. The book emphasizes the need to formulate sound mechanization strategies and policies for developing countries to ensure that the objectives of mechanization are achieved at minimal social and economic costs.

The specific objective of the study, which resulted in this book, has been to develop a rational approach to mechanization policy and strategy formulation, including the development of a model for analyzing the effect of policy and development scenarios on the progress of mechanization.

The book reviews the agricultural mechanization process in a historical context, and discusses the main developmental issues associated with mechanization. Extensive reference is made to the findings and conclusions of a large number of studies. The formulation of a model for mechanization policy and strategy formulation and its application to the central region of Thailand is described in detail.

Size: 23 x 15 cm, pp 283, soft cover.

Published by Asian Productivity Organization, 4-14, Akasaka 8-chome, Minato-ku, Tokyo 107, Japan

Biotechnology and Other Alternative Technologies for Utilization of Biomass/Agricultural Wastes

(India)

by Amalendu Chakraverty

The biomass generated by plants is significant; there is ample scope for development of improved technologies, namely, thermal, thermo-chemical, chemical and biochemical processes for the conversion of these vast renewable sources (in India and other developing countries) into food, feed, fuel, energy, chemicals and other value added products. Hence a comprehensive book covering all aspects of biomass conversion technologies would be of real use to all students, teachers, researchers and professionals engaged in the fields of agricultural science, technology an engineering and rural energy engineering.

In the present context, the book has been organized in four sections – Section I covers the important aspects of different sources, classification and characteristics of biomass; Section II deals with the combustion, pyrolysis and gasification of biomass/agricultural wastes; Section III covers anaerobic biogasification and alcoholic fermentation of biomass; and Section IV is devoted to the production of pure silica, silicon, furfural, ceramics and paper from agricultural wastes/biomass. Emphasis has been placed on principles, actual practices, designs (including some worked out examples) and some useful data relevant to Indian conditions.

Size: 22.5 x 14 cm, pp249, hard cover. Price: Rs. 75.00.

Published by Oxford & IBH Publishing Co. Pvt. Ltd., 66 Janpath, New Delhi 110001, India ■■

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BACK ISSUES

(Vol. 20 No. 1, Winter 1989 ~)

COMPUTERIZED AMA INDEX AVAILABLE

A computerized index of technical articles in *Agricultural Mechanization in Asia, Africa and Latin America* has been compiled for the years 1971 through 1989. Each citation includes truncated versions of the title, first and second authors' names and four keywords. Year, issue and page number of each article are given. The citations along with software for searching the database are all included on a single computer diskette for use with IBM-PC, -XT, -AT or compatible type computers.

Anyone wishing to receive this material may send one formatted. 5 1/4-inch, 360 Kbyte, double-sided, double-density diskette to William Chancellor, Agr. Eng. Dept., Univ. of Calif., Davis, CA 95616, USA. The database and searching software will be copied to that diskette, and it will be returned by airmail along with software documentation. There is no charge. Any special customs or postal designation or specifications required should be stated in the letter of request. Annual updates will be available in the future.

OCHIAI is the top-ranking tea-leaf picker manufacturer in Japan. OCHIAI's products are used in tea-producing areas worldwide.

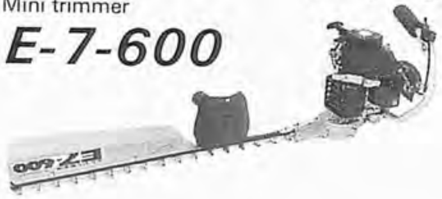
Engine tea-tree trimmer
E-7AT-750

Clipper type tea-leaf picker V8-NEWZ₂

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

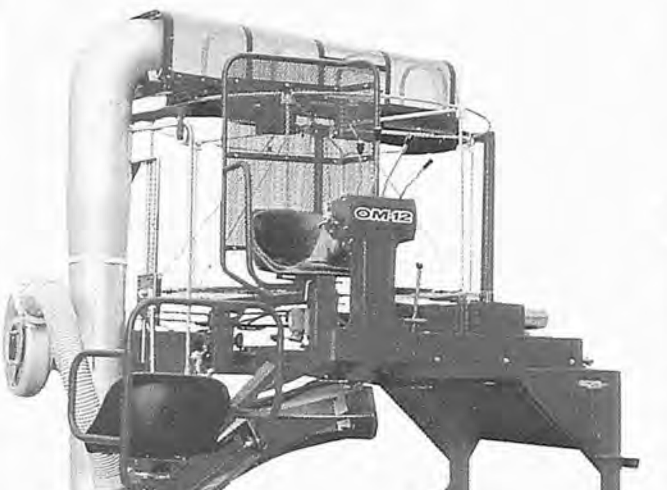
Engine tea-tree trimmer
E-7-750

Mini trimmer
E-7-600

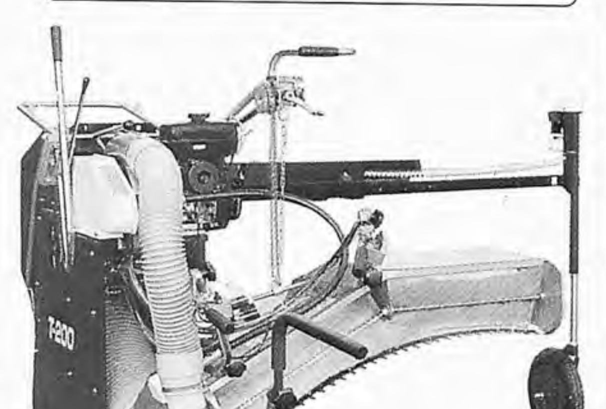


GUIDE TO OCHIAI

- Succeeded in devising Japan's first automatic tea-leaf picker in 1959.
- Received the Director of the Board of Scientific Technology Award in 1967.
- During the intervening period (1959-1967) obtained a number of patents, as well as receiving a variety of awards and prizes in the domain of science and technology.
- The top-ranking tea-leaf picker and tea-tree trimmer producer, holding 60% of the shares in the same line of business in Japan, surpassing the other manufacturers in sales and product, and leading the related business worlds in its expansion and development.



Riding tea-leaf picker
OM-12 ■ two operators ■ weight/750kg



Self-propelled
tea-leaf picker
(one man, Clipper type)
T-200
■ weight/150kg

OCHIAI HAMONO KOGYO CO LTD

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