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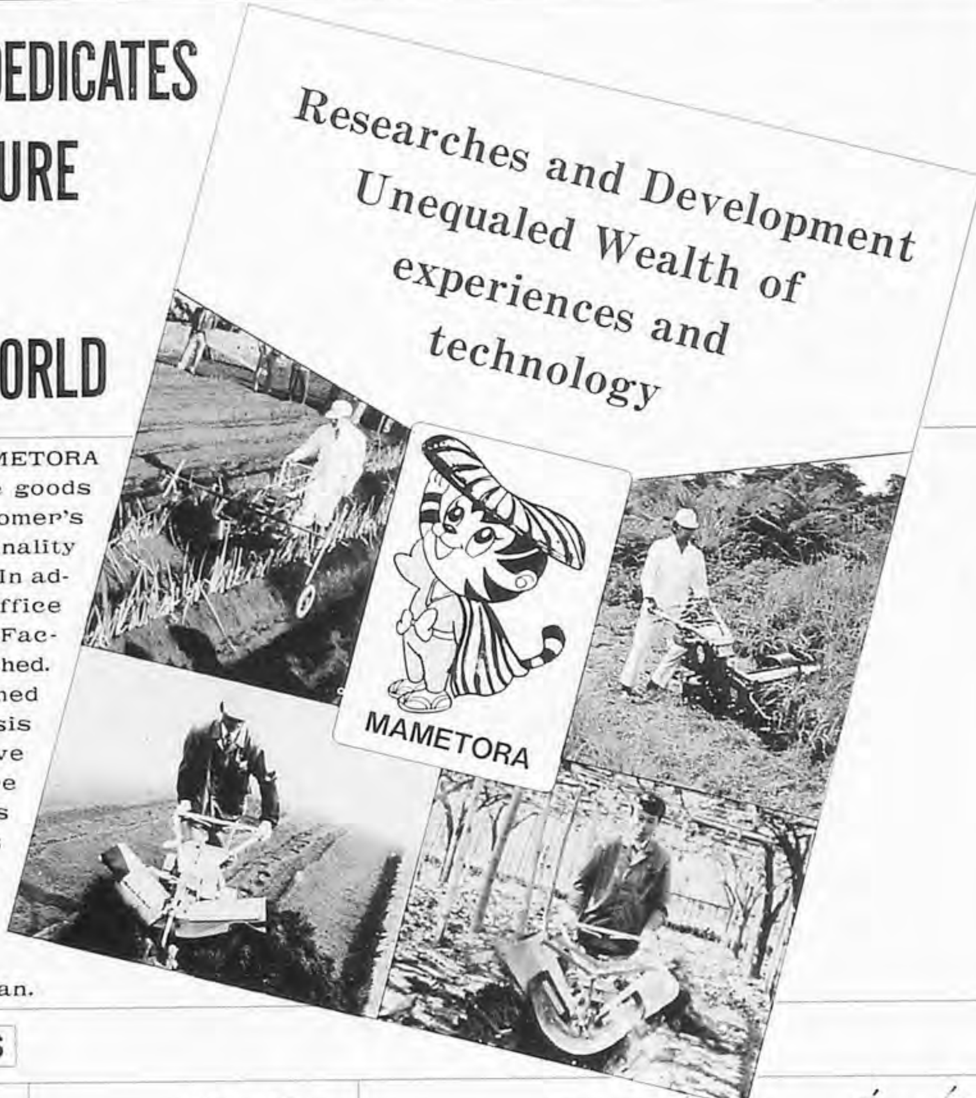

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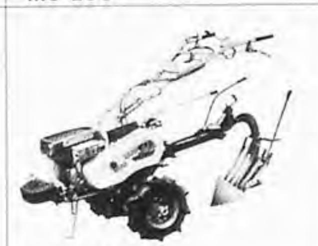
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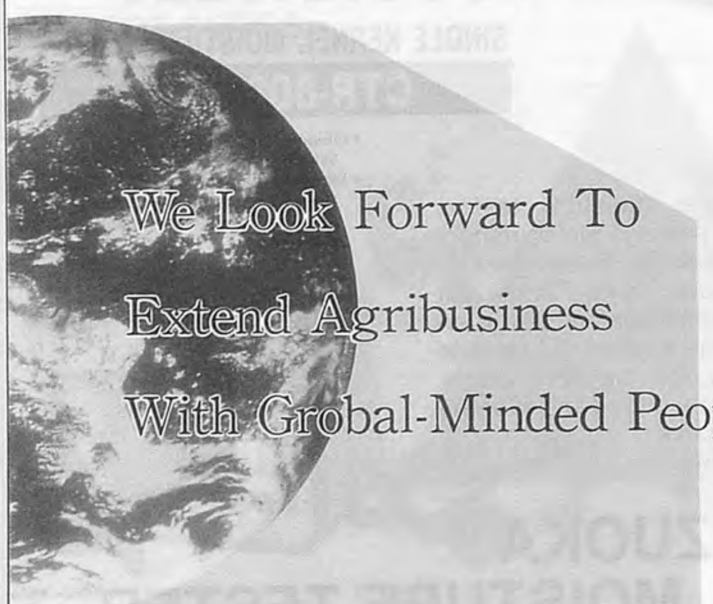

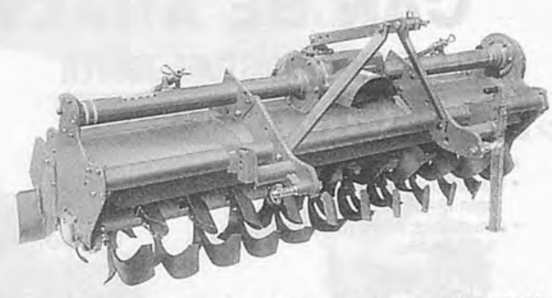

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EDITORIAL

The Race Between Population and Food Supply

Statistics are not necessarily cold: not when they pertain to the world's population which is currently estimated at close to 5.3 billion. It is projected to increase by about a billion for the next 10 years. The Peoples' Republic of China (PRC) has at present a population of some 1.1 billion—roughly equivalent to the world's rate of population increase in the coming 10 years. What this implies is that by the 21st century, something like the other country the size of PRC's population will be added on the face of the earth. One wonders whether there will be enough food to feed such a huge population at the rate the current food supply increases at a very slow phase, particularly in the Third World countries where, ironically, much of the increase in population is found.

Of course, the race between population and food supply is not a new issue except that it is now being brought into sharper focus due to fact that the race is getting to be one-sided, i.e., population is galloping way ahead whereas food supply is lagging far behind. And one does not need to be demographer nor an economist to reconcile the fact that it is imperative for the birth rate to slow down and the food supply to increase at a much faster rate in order for the gap to narrow down to a manageable size.

Population experts and governments are thus being called upon to put more teeth in the enforcement of policies and measures aimed at slowing down population growth whereas agriculturists and food scientists are being challenged anew to step up productivity rates and increase food availability at rates much faster than they have been.

At the expense of being repetitious, the AMA, in this regard, cannot overemphasize the importance of agricultural machineries in increasing food production and food supply availability. It is no longer debatable that mechanized farming increases the economies of scale, hence raises productivity levels. In the same vein, modern food processing equipment and new technologies are indispensable in extending the shelf life and improving the quality of processed products of the farm and the seas.

To be sure, policy makers in both developed and developing countries need to reexamine their policies and programs in terms of rendering them responsive to the common effort to reduce, if not close, the gap in the frightening race between population and food supply.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
July, 1990

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Field Performance Tests of Turtle Tiller and Boat Tractor

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Abstract

Two Asian field vehicles especially designed for wetland conditions were field tested at the Asian Institute of Technology (AIT). These were the "Turtle" tiller from the Philippines and the "Boat" tractor from China. Both were found to work well in these conditions with average field capacities in each case of about 0.2 ha/h. This performance is much better than can be achieved by conventional wheeled walking tractors in the same conditions[1]. Both have the additional advantage of being surface vehicles, not hitting and, therefore, not damaging the paddy field hardpan. Hull drag was high for both machines and depending on whether or not there was standing water on the field surface. Some operational drawbacks were experienced with both machines and suggestions are made for possible improvements.

Introduction

On dryland, tractors both traction and flotation forces are provided by the same device, normally a wheel or track. There has, in addition, to be proper matching of power, weight, speed and slip to ensure optimum power transmission in the frictional-cohesive soils on which these tractors normally work[2]. Until recently vehicles used for wetland cultivation in rice fields were exclusively adaptations of dryland vehicles. However, the requirements for wetland vehicles are quite different from those for dryland vehicles. Wetland vehicles must be kept as light as possible since they are likely to be working on near purely cohesive soils. In these soils each increment of weight added increases motion resistance but does little to increase traction forces[3]. In addition, experiments at the International Rice Research Institute have shown that when continuous cropping of wetland rice is practised, anything which contacts the hardpan during land preparation, including animals, leads to progressive deepening of the hardpan so that, sooner or later, entry into the field becomes impossible.[4] The heavier the device the more rapid is the rate of hardpan deepening. Since the population of Asia is rapidly increasing, cropping intensity is increasing and the tractor population also rapidly increasing, this is a potential future problem of large dimensions.

Recently two new field vehicles have been invented in Asia to try to solve this problem. These are the "Turtle" tiller from the Philippines and the "Boat" tractor from China. Both are radically different from dryland tractors in that each has a large float unit with a separate device for providing traction and soil working forces. Their principle of operation is closer to a ship than to a conventional tractor. Information on their field performance is rather limited, however, and to throw some light on this, the following experiments were carried out at A.I.T.

Methodology

For both machines the relevant data such as engine power, physical dimensions, weight etc were measured in the laboratory. They were then taken into actual paddy fields of roughly 50 m x 50 m size and their field performance measured and operational problems noted. Field conditions such as length of water soaking, depth of hardpan etc were varied to see what effect these had on performance. Modifications were made to the rotor of the Turtle tiller and the cage wheels of the Boat tractor to improve performance. The drag force versus speed characteristics of each device were found by towing them in the field with a four-wheel tractor running in an adjacent dry field. Drag forces were measured with

Fig. 1 The "Turtle" tiller.

Fig. 2 Wet rice paddy after one pass of the turtle tiller.

Fig. 3 Leveling board attached to rear of turtle tiller.

Fig. 4 Weeds and stubble clogging original rotor.

Fig. 5 Modified open-ended rotor compared to original.

and without standing water on the field surface.

Results and Discussion

Turtle Tiller

The specifications of the Turtle tiller are given in **Table 1**[5]. A photograph of the machine is shown in **Fig. 1**. These show that the weight/power ratio of 0.28 kN/kW was quite low which, as mentioned previously, is advantageous for wetland vehicles. Moreover, the nominal contact area of 2.23 m^2 is much higher than can be achieved with wheeled vehicles making the nominal contact pressure of 0.94 kPa very much lower than with these vehicles. One immediate disadvantage that was seen was that, because of the elliptical cross-section of the float, the field was left with a wave-like profile after tilling in which water was left only in the depressions **(Fig. 2)**. This was completely cured by fitting a levelling board **(Fig. 3)**. Another problem noticed was that the original puddling rotor, which had closed ends, tended to clog easily with weeds and stubble **(Fig. 4)**. This was also cured by making a new rotor with open ends. **(Fig. 5)** Field performance was generally very good. However, **Fig. 2** shows that rice stubble of nearly 1 m in height was in the soil after only one pass of the machine. Field conditions and equipment used in the tests are shown in **Table 2** and performance details given in **Table 3**. **Table 4** gives the measured components of drag force of the tiller at 2 km/h forward speed which was judged to be the maximum comfortable walking speed a man could maintain in a paddy field.

The first finding was that, with the original rotor, the field had to be water-soaked for at least one month before the rotor could penetrate into the soil's upper layer. This was reduced to one week using the modified rotor. **Table 3** shows that field capacity increased, rotor slip decreased and fuel consumption decreased as the number of passes increased. Engine speed was set at 2 000 R.P.M. for these tests. On the third pass the machine was moving so fast that

Table 1 Specifications of the Turtle Tiller

Engine: Ruggerini Motori RD901 (diesel)	
max. power	7.5 kW
max. speed	3 000 R.P.M.
Transmission: V-belt tensioning mechanism for primary transmission, chain and sprocket for final transmission to puddling rotor	
Nominal contact area	2.23 m^2
Weight	2.1 kN
Weight/power ratio	0.28 kN/kW
Nominal contact pressure	0.94 kPa
Attachments	Puddling rotor (front-mounted)

Table 2 Field Conditions for Testing of Turtle Tiller

Field	Water soaking (weeks)	Field operations prior to test	Equipment used			Stubble or grass	
			P1	P2	P3	Mean height (cm)	Description
A	8	One puddling after 4 weeks of soaking	R1	R1	R1	40	Non-uniform soft-stalked grasses
B	8	none	R1	R1	R1	80	Uniform hard stalked grasses and rice stubble
C	4	none	R1	R1	R1	60	Ditto
D	4	none	R2	R2	R2+L	80	Ditto
E	4	One puddling after 2 week of soaking	R1	R1	R1	30	Non-uniform soft-stalked grasses
F	1	Freshly harvested area	R2	R2	R2+L	30	Uniform rice stubble

Pn = n^{th} pass of machine; R1 = original rotor; R2 = modified rotor; L = leveling board.

operators rapidly became tired as about half an hour was the maximum time one person could operate the machine continuously. This points to the need for a gearbox on the machine since, at the same engine speed, forward speed increased by about 3:1 on the third pass as compared to the first. Rotor slip was very high during all tests from 70-90%. This further highlights the need for a gearbox since at the engine R.P.M. setting of 2 000, which is close to optimum R.P.M. for a diesel engine, the vehicle, had it been fitted with road wheels would have been travelling at close to 20 km/h on a hard road. This is quite impossible for a person to keep up with. The high rotor slip, however, is the main factor responsible for the very effective incorporation of stubble and weeds into the soil by the machine.

Table 4 shows that the vehicle drag was high for all the conditions tested but that reductions of between 20% and 60% were possible if standing water could be guaranteed over the field surface. The rotor and transmission casing, which penetrates into the soil surface in operation, in addition to the float itself were major producers of drag.

Table 3 Field Performance Details of Turtle Tiller

Field	Field capacity (ha/h)			Rotor slip (%)			Fuel consumption (l/h)		
	P1*	P2	P3	P1	P2	P3	P1	P2	P3
A	0.17	0.23	0.28	87	82	79	1.53	1.34	1.31
B	0.08	0.16	0.21	88	81	80	2.48	1.81	1.42
C	0.09	0.17	0.22	90	78	78	2.47	1.58	1.40
D	0.10	0.16	0.28	91	86	70	2.23	1.89	1.22
E	0.12	0.17	0.23	91	87	80	1.94	1.58	1.38
F	0.11	0.20	0.29	91	83	70	1.95	1.48	1.21

*Pn = n^{th} pass of machine

Table 4 Components of Drag Force of Turtle Tiller at 2 km/h Forward Speed

Condition	Drag force (kN)	Coefficient of drag	% Reduction due to standing water
1. With everything in position but driving belts not connected			
a) with water in field	0.48	0.23	61
b) without water in field	1.22	0.58	
2. Without rotor			
a) with water in field	0.32	0.15	20
b) without water in field	0.40	0.19	
3. Without rotor and transmission casing			
a) with water in field	0.19	0.09	44
b) without water in field	0.34	0.16	
4. Without rotor and transmission casing but with levelling board			
a) with water in field	0.22	0.10	–

Table 5 Specifications of Hubei 12 Boat Tractor

Engine: Yanmar ES 155C (diesel)	
Max. power	11.5 kW
Max. speed	2 400 R.P.M.
Transmission:	V-Belt tensioning mechanism for primary transmission, 3 speed bearbox and differential for final transmission. Skid-steer steering.
Nominal contact area	1.17 m²
Weight (without operator)	7.04 kN
Weight/power ratio	0.61 kN/kW
Nominal contact pressure	6 kPa
Nominal contact pressure	Rotary cultivator (rear mounted)

Boat Tractor

Table 5 shows the specifications of the Hubei 12 Boat tractor tested. A photograph of the machine is shown in **Fig. 6**. This shows that although the engine power of the Boat tractor was slightly higher than the Turtle tiller (11.5 kW compared to 7.5 kW,) its weight, even without an operator seated, was considerably higher (7.04 kN compared to 2.1 kN) Nominal contact-pressing was also much higher (6 kPa compared to 0.94 kPa.) The Boat tractor tested seemed to be over-designed with both rear axle and transmission looking to be much bigger and heavier than they need to be. The engine was removed, no weight to simulate a typical operators weight was added, and a floating test was conducted on a canal. The result is shown in **Fig. 7**. This particular version of the Boat tractor was most definitely not amphibious! Field tests were carried out in gear 1 flooded, puddled, fields with no crop stubble, using the rotory cultivator attached to the machine. Hardpan depth was varied from 4 to 34 cm. The results are given in **Table 6**. This shows that as the hardpan depth increased, fuel consumption (at 2 000 R.P.M. engine speed)

Fig. 6 The "Boat" tractor.

Fig. 7 Floating test of boat tractor.

Fig. 8 Mud blocking on original cage wheels.

Table 6 Field Performance Details of Boat Tractor

Depth of hardpan (cm)	Field capacity (ha/h)	Fuel consumption (l/h)
4	0.21	0.82
23	0.22	0.88
34	0.17	1.06

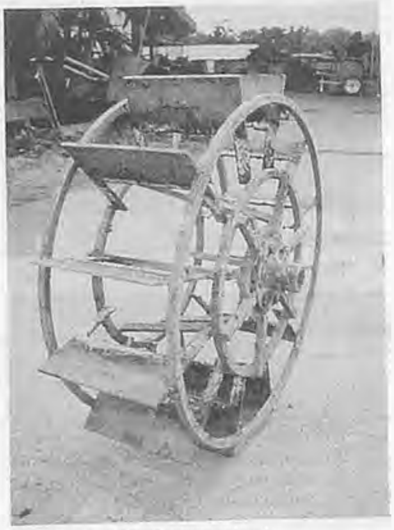

Fig. 9 Modified cage wheels.

Table 7 Drag Force against Speed Characteristics of Boat Tractor Float and Cage Wheels

Hardpan depth (cm)	Standing water condition	Drag force – Speed equation	Comments
0	NSW	D = 2.95 + 0.14 V	Original wheels
0	SW	D = 2.31 + 0.51 V	Original wheels
20	NSW	D = 2.82 + 0.75 V	Original wheels
20	SW	D = 1.90 + 1.12 V	Original wheels
40	NSW	D = 4.15 + 1.74 V	Original wheels
40	SW	D = 3.23 + 1.67 V	Original wheels
40	NSW	D = 3.75 + 1.14 V	New wheels
40	SW	D = 2.94 + 1.04 V	New wheels

NSW = no standing water; SW = standing water; D = drag force (kN); V = forward speed (m/sec).

also increased and field capacity decreased. At 34 cm depth of hardpan the original cage wheels (**Fig. 8**) constantly blocked with mud and hence these were replaced by a pair of re-designed cage wheels (**Fig. 9**). Overall field performance, however, was good with average field capacity in the range of 0.2 ha/h, similar to the results obtained with the Turtle tiller. Since the Boat tractor is a riding-type device unlike the Turtle tiller, the operator has a wider choice of possible speeds to run the machine. Tests were, therefore, conducted at various speeds up to 5 km/h, with the rotary cultivator disconnected to find the drag force of the hull and cage wheels and the effect that standing water on the field surface had on these. The results shown in **Table 7** indicate that although standing water did seem to reduce the drag force at a given speed, the effect was not so strong as observed with the Turtle tiller. The reason may be that the Boat tractor's higher nominal contact pressure has the effect of squeezing out some of the water from the interface between the metal float and the soil, thus reducing the lubricating effect of the water.

Conclusions

The Turtle tiller from the Philippines and the Boat tractor from China were field tested to measure performance. Both worked well in the field with field capacities of about 0.2 ha/h, a much higher performance can be achieved by conventional power tillers.

A levelling board was added to the Turtle tiller to smooth out the wave-like profile of the field caused by its elliptical hull. An improved open-ended puddling rotor reduced the tendency for weeds and stubble to wrap around the rotor. The machine badly needs a gearbox both to be able to adjust field speed properly and to give it a possible on-road capability.

The Boat tractor, in the form tested, was not amphibious and sank in water without engine or operator. It would be much more effective if it was made lighter by, for example, making the transmission and rear axle much lighter than at present.

The use of fibreglass for the hulls of both machines might be a useful thing to investigate.

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Research on Water Saving on Sandy Soil in Drip Irrigation (I)

Assessing Water Use and Growth of Komatsuna through Application of Reduced Water Rates

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Introduction

Aimed at economizing on irrigation water, an experiment was conducted on *Komatsuna** which was planted on sandy soil with low-water holding capacity. The experiment deals with application of reduced water rates in evaluating plant growth, water need at different crop stages and plant parameters in drip-irrigation. It consisted of two treatments of water supply: 10 cc and 20 cc per day.

Materials and Methods

The experiment used 46 plots (individual boxes of 18 cm long, 13 cm wide, and 8 cm deep). The boxes were filled with sand to a height of 7 cm and were perforated at the bottom with 6 holes for drainage. A rectangular mesh was laid at the bottom of each box to hold sand. For each treatment, (10 cc and 20 cc), *Komatsuna* was planted in 18 boxes in two rows with a distance of 1.5 cm between plants. Of the 18 boxes, 9 were covered with white plastic vinyl mulch applied between rows with 2 points provided at 10 cm interval to supply the irrigation water. The remaining 9 boxes did not have mulch. Four additional boxes (2 with mulch and 2 with no mulch) without vegetation on them were also provided for each treatment. Micro-tubes were spaced 10 cm and partitioned in two micro-tubes per box. Fertilizer was dissolved in the irrigation water and was applied 10 cc once every other day in the planted plots. Two control plots, one planted to *Komatsuna* (same way of fertilizing mentioned before) and the other not planted, were always fully supplied with water throughout the growing period.

The treatments were started soon after the seedling emerged in all plots. Moisture budgeting was performed every 10 days until maturity for three days by weighing the boxes before and after irrigation to account for the water derived, evaporation and/or evapotranspiration and water storage. A mean value of these parameters was determined for the three days and represented the value for the period. Crop sampling was taken the last day of moisture budgeting. The growth (weight per plant) was computed from four boxes (equally divided as mulched and non-mulched plots) for each treatment and from six other boxes at the last growing period.

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* The scientific name of Komatsuna is *Brassica cmpestris L. var. perviridis;* a popular leaf vegetable in Japan.

Results

Evaporation and Water Regime in Non-planted Plots

Data on evaporation with mean per period and climatic condition for the control plot in the greenhouse are shown in **Table 1**. The curve of evaporation for the four periods of measurement in the 10 cc and 20 cc treatments are shown in **Fig. 1** for the non-planted mulched plot, non-mulched soil and control plot.

Evaporation was almost similar in the mulched plots but was drastically reduced in those plots for 10 cc and 20 cc. That evaporation represented about 30% of that in the control plot.

In the non-mulched soil, evaporation was also similar for the two treatments representing more than 80% of that in the control plot.

The curves in **Fig. 1** shows very well this point. The curves exhibit the same pattern but much greater amplitudes are shown in the control and non-mulched soil plots showing their sensitivity to high evaporation days (e.g., periods 1 and 3). The mulched plot exhibited a nearly constant trend throughout the growing period. The curves also show that the periods 1 and 3 were high evaporation days (81% relative humidity and 33°C max. temperature, 76% relative humidity and 31°C max. temperature were recorded in the greenhouse, respectively, for the two periods).

These results infer that the use of plastic mulch in the drip-irrigated plots can save more than 70% of the water that would be lost by evaporation in fully water-supplied plots under furrow or flood irrigation. Hence, in desert areas where the initial soil moisture is very low and has to be restored to an adequate level before seeding is resumed, the preceeding results suggest that drip irrigation and mulched-covered rows could be a solution to water shortage.

Table 1 Evaporation in Non-planted Plots with Mean and Percentage of Control Plot, and Climatic Conditions in Greenhouse

Treatment	Daily evap. (g) [a]						Max. temp. (°C) [c]				R.H. (%) [d]			
	Period 1	2	3	4	(mean)	% Cont [b]	Period 1	2	3	4	Period 1	2	3	4
20 ml														
Mulch	14.4	12.6	15.4	11.9	(13.6)	33								
Bare	38.2	34.3	45.2	25.8	(35.9)	88								
							33	25	31	26	81	88	76	78
10 ml														
Mulch	12.1	11.6	16.6	10.4	(12.7)	31								
Bare	32.3	32.2	44.8	20.8	(32.5)	80								
Control	43.6	38.0	51.7	29.4	(40.7)									

a) Mean daily evaporation; b) Control plot; c) Mean daily max. temperature
d) Mean daily relative humidity.

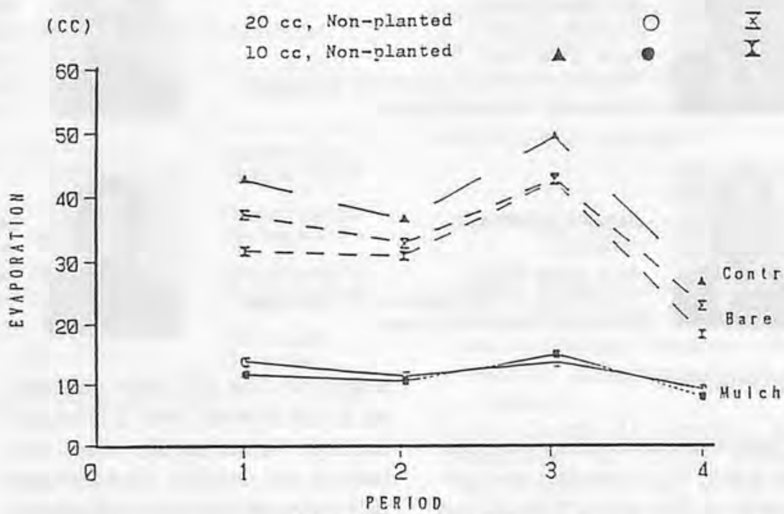

Fig. 1 Daily evaporation.

Evaporation and Water Regime in Planted Plots

Data on evapotranspiration from soil and plants and soil moisture storage and/or depletion are shown in **Table 2**. The curves of evapotranspiration for the four periods of measurement in the two treatments, 10 cc and 20 cc, for the planted and mulched soil and the planted but non-mulched soils are shown in **Fig. 2**. As shown previously in the case of non-planted plots, evaporation from the soil is greatly affected by soil characteristics (i.e., non-mulched or mulched soil and moisture status), and climatic conditions. In planted plots, evaporation or evapotranspiration is greatly affected by the combination of these factors and the rate of development of the plants. Usually, the rate of evapotranspiration is largest for the flowering/reproductive stage relative to other stages, for example, planting and early vegetative stage.

For the control plot, **Fig. 2** shows that evapotranspiration is minimum at period 1 (early vegetative stage); increases at period 2, is maximum at period 3 (reproductive stage); and reaches a second minimum at period 4. The control plot receives a full supply of water sufficient to meet the atmospheric evaporative demand.

Both treatment of 10 cc and

Table 2 Evapotranspiration in Planted Plots and Soil Water Regime

Treatment	E.T. (g)[a]				Water storage (g)[b]			
	Period				Period			
	1	2	3	4	1	2	3	4
20 ml								
Mulch	39.4	69.7	75.0	37.9	1.1	−28.4	−33.9	2.3
Bare	51.3	73.8	62.7	37.6	−11.0	−32.4	−22.2	2.6
10 ml								
Mulch	37.7	51.5	32.0	18.5	−16.0	−30.5	−11.8	1.6
Bare	46.8	34.9	24.0	17.9	−25.7	−14.1	−3.9	2.3
Control	47.1	67.0	107.7	63.3	–	–	–	–

[a] Mean daily evapotranspiration; [b] Mean daily water storage.

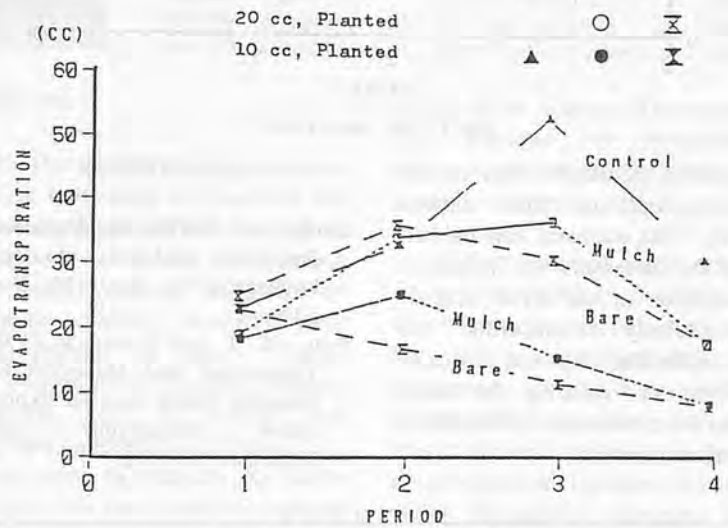

Fig. 2 Daily evapotranspiration.

20 cc irrigation water were not generally sufficient to meet water evaporative demands. Stress conditions were observed at those periods where the initial moisture reserve in the soil and the subsequent irrigation water were insufficient to cover the evaporative demands. This was mainly encountered in i) 10 cc treatment for the non-mulched plots at periods 2 and 3; for the mulched plots mainly at period 2; ii) 20 cc treatment for the non-mulched plots at period 3; in lesser extent for the mulched plots at the same period 3; (periods which corresponded to high evaporation days).

The mulched plots in the 20 cc treatment were the only ones that exhibited normal evaporation pattern–suggesting better moisture regime in those plots.

The obtained results also show that mulch effect on evapotranspiration decreased as the plants reached maturity. At this stage, evaporation from soil is minimal as the plant leaves are large enough to keep light from directly reaching the ground.

Period 4 illustrates well this point. **Table 2** shows that for each treatment, evapotranspiration from the mulched and bare plots was almost identical. Note also that this period corresponded to low evaporation days. Moisture gain was recorded in all treatments.

Stress conditions were also noted. They can be harmful to plant growth, specially if the stress period lasts. Long stress days may be avoided if the frequency of irrigation is increased to meet demands. This can also be done if evaporation rates are properly assessed and water losses are subsequently restored to the soil.

Plant Growth

Table 3 shows the growth data for the four periods in both treatment for mulched and non-mulched soils. Corresponding growth curves are shown in **Fig. 3**. In the same figure the growth rates were identical for all treatments at period 1 where enough moisture was present to satisfy demands.

Plant growth decrease were observed in all treatments at period 3 which had the highest evaporation rates resulting in harmful stress conditions. The overall result indicates a better plant growth in the 20-cc treatment for the mulched plots which is attributed to better soil moisture conditions in those plots.

The final plant growth in the control plot was less than that in the 20-cc treatment for both mulch and non-mulched plots. This observed improvement could be attributed to the difference in soil aeration in the drip-irrigation plots. The advantage of drip-irrigation over flood or furrow irrigation, apart from saving water, is to offer better plant growth due to better soil aeration.

Plant growth was poorest in the 10-cc treatment, specially for the non-mulched plots.

Conclusion and Remarks

In dry agricultural areas, plastic mulch could be a good tool in keeping moisture in drip-irrigated plant rows to an optimum level before seeding is resumed. Mulch could also be used as a thermal regulator to correct the high temperature changes between day and night usually recorded in desert areas. However, the type of mulch used in

Table 3 Growth Given as Weight per Plant for the Four Periods of Measurement

Treatment	Growth (g/plant)			
	Period			
	1	2	3	4
20 ml				
Mulch	0.19	0.91	0.89	1.19
Bare	0.17	0.76	0.74	1.04
10 ml				
Bulch	0.18	0.65	0.51	0.65
Bare	0.17	0.55	0.27	0.51
Control	–	–	–	0.99

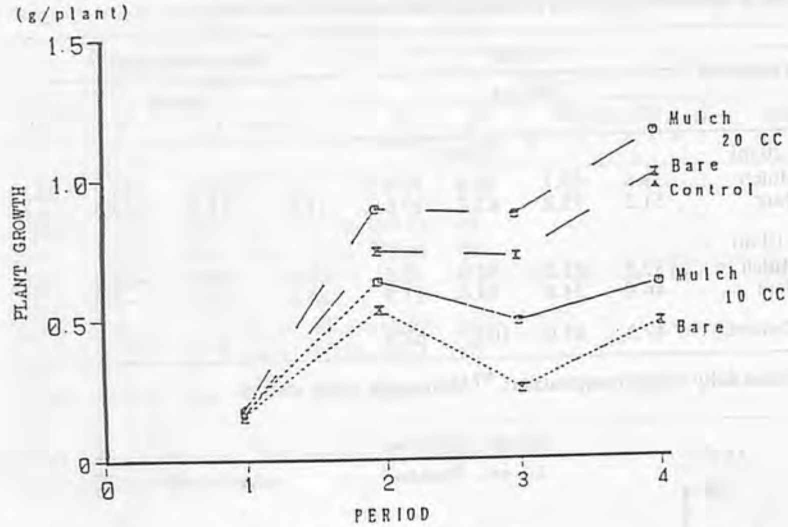

Fig. 3 Daily plant growth.

this study did not contribute much to the thermal regime of the soil, hence raising the necessity of doing similar research on other types of mulch (e.g., black opaque mulch, colored mulch, paper or hay mulch, etc.).

The results further show that the mulch effect on evapotranspiration decreased when the plants were fully developed. However, better moisture conditions were observed overall in mulched plots. Soil moisture budget shows that the reduced rates of the irrigation water was not generally sufficient to cover all the evaporative demands. This caused stress condition that slowed growth. This problem can be corrected by increasing the frequency of irrigation in hot stress days or by correctly monitoring the evaporative demands and gradually supplying or replacing the water loss to keep moisture in the soil at an optimum level.

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Performance of Two Different Types of Combines in Harvesting Rice in Egypt

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Abstract

In the course of mechanization of rice harvesting to overcome the increasing high cost and shortage of labor and to reduce grain losses, two main types of self-propelled German combine harvesters were tried recently in Egypt, namely; the conventional all-crop combine harvester and the special rice combine imported from Japan.

In order to evaluate the suitability of the two types of combine for the Egyptian conditions, they were compared in harvesting two different rice varieties grown in large scale in Egypt. The tests were conducted under different percentages of straw and grain moisture content and harvesting speeds. The two combines were compared as to grain losses, field efficiency and harvesting costs.

Introduction

Rice is a main crop in Egypt where it is grown in 1/6 of the total agricultural area. Manual harvesting is presently prevailing and requires about 133 labor hours per feddan (= one acre = 4 200 m^2) (Bergman et al, 1979).

Rice harvesting became recently a problem due to shortage of labor and, consequently, the increase of wages in the country. The competition between the simultaneous labor requirements for rice and cotton harvesting compounds the problems.

In the course of mechanization of rice harvesting to overcome the increasing high cost and shortage of labor and to reduce grain losses, the performace of two main types of self-propelled combine harvesters was compared recently, namely: i) a conventional combine harvester which is mainly imported from USA and Europe, and ii) special rice combine harvester which was imported from Japan.

The performance of these two combines were evaluated for suitability for the Egyptian conditions in comparative tests conducted in harvesting of two rice varieties which mainly differ in plant length and tendency to lodge.

The objectives of this study were to determine:

i) the grain losses caused by different parts of each combine harvester;
ii) the field capacity and efficiency;
iii) the harvesting costs and;
iv) the optimum operation conditions for each of the two combines as affected by the rice variety, straw moisture content and harvesting speed.

Review of Literature

Grain losses in combine harvesting can be classified as follows:

i) Header losses which represent fallen grain on the ground due to the action of cutting and conveying assembly.
ii) Cylinder losses which represent unthreshed seed discharged with straw from the rear of the machine.
iii) Straw walker losses which represent free seeds carried over the walkers in the straw and discharged behind the conventional combine.
iv) Cleaning (shoe) losses which represent free seeds discharged behind the combine over the cleaning section.
v) Grain damage which does not represent a direct loss of yield but may reduce the quality and value of grain.
vi) Leakage losses.

Several investigators studied factors that affect these loses in the conventional combines. The header losses are affected by the reel peripheral speed (Goss et al 1958) in relation to forward speed, reel height (Griffen 1973) and height of cutting. The cylinder grain losses were affected by feedling pattern (Arnold 1964), cylinder and concave design (Neal et al, 1970) and operating conditions (Johanson

1959, Delfoss et al 1983, Wieneke 1964).

Straw-walker losses were generally affected by walker design, grain/non-grain ratio, feed rate (Reed et al 1970) and kind and condition of crop. Cleaning losses were affected by adjustments of the size of openings and slope of sieves and air velocity from fan, grain/nongrain ratio and crop condition (Goss 1958, Johanson 1959, Feiffer 1969).

The field efficiency is the ratio between the productivity of a machine under field conditions and the theoretical maximum productivity (ASAE 1983). Field efficiency accounts for failure to utilize the theoretical operating width of the machine, time lost due to operator capability and habits and operating policy and field characteristics. Field efficiency is not a constant for a particular machine but varies with the size and shape of the field. Small rice fields prevail in Egypt (Fouad 1984). The field efficiency varies also with pattern of field operation, crop yield, moisture and crop conditions. Turning and idle travel, materials handling, cleaning clogged equipment, machine adjustment, lubrication and refueling and waiting for other machines account for the majority of time lost in the field.

The field capacity and efficiency affect the costs of harvesting. In Egypt, the costs of mechanized rice harvesting are lower than manual harvesting. (Ministry of Agr. 1982, Shepley 1984).

While sufficient information about factors affecting the operation of conventional combine harvesting is available, little information is available about the Asian rice combine. Nevertheless, rice harvesting by both types of combine is new in Egypt. Therefore, such a comparative study was needed for the mentioned objectives.

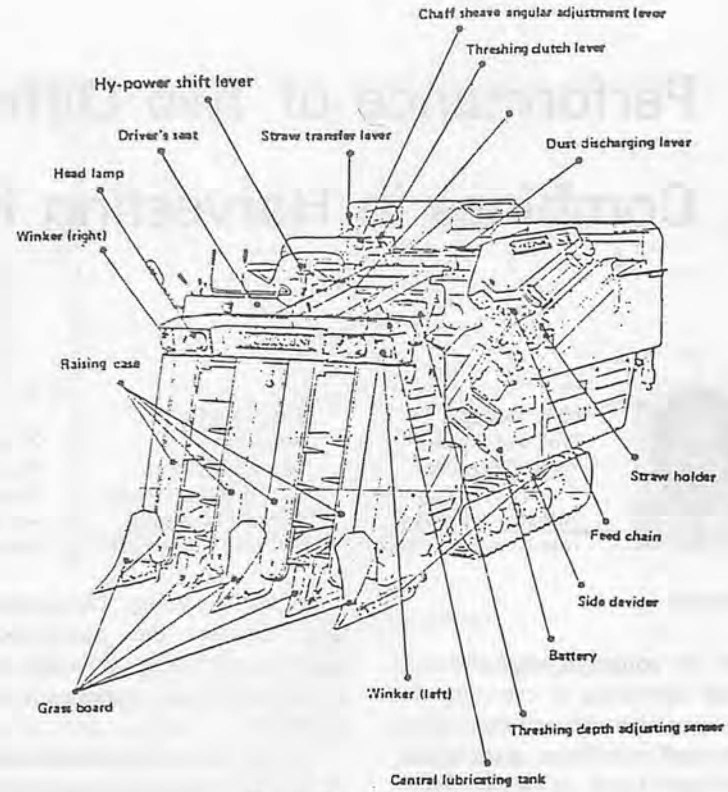

Fig. 1 The rice combine.

Materials and Methods

The conventional combine used in this study was of the trade mark Deutz-Fahr, type M 980, West German make of 54 kW diesel engine and 3-meter cutting width. The peg type drum is 1 030 mm wide and of 560 mm diameter and operated at 800 rpm. Drum-concave clearence was adjusted to 15 mm in front and 7 mm in rear according to the instructions. There are 4 straw walkers of 3.9 m^2 separating area. The machine has a top laminated sieve and an interchangable sieve with a total sieve area of 2.66 m^2. The grain tank capacity is of 2 300 liters. The dimensions of the front and rear tires are 18.4-26 AS and 10-15 Impt, respectively. These tire dimensions enabled trouble-free operation on the soft and moist soil of the rice fields at the time of harvest.

The special rice combine (Fig. 1), Japanese make, was of the trade mark Yanmar TC 3500 K, 23.5 kW diesel engine, crawler type of 400 x 1465 mm ground contact and bagger type. This type of machine is basically designed for rice and less suitable for harvesting other crops (Delfoss, 1983).

The rice combine has fixed divides and plastic tines that move vertically to raise the lodging plants. The machine is equipped with a reciprocating knife of 1 350 mm cutting width. The effective mean cutting width was 1 200 mm representing 4 plant rows of 30 cm spacing. By the help of star wheels, the plants of different rows join together and are then held from the lower part of the stem and carried by a conveying system of chain with triangular tines to the top of the machine where the panicles are fed along a bag type threshing cylinder and concave. The cylinder is 900 mm wide and of 420 mm diameter and was operated at 540 rpm according to the instructions. The position at which the paddy stems are held during threshing is adjustable according to plant length. After threshing, the straw is discharged behind the machine. The threshed

Table 1 Mean Values of Crop Conditions at Time of Harvest

Crop condition	Rice variety	Date of harvest		
		Early 20 to 26 Oct.	Medium 5 to 11 Nov.	Late 10 to 26 Nov.
Straw moisture content (%) (wet base)	Ryho Giza	65.9 64.1	52.3 55.5	31.3 42.9
Grain moisture content (%) (wet base)	Ryho Giza	19.5 22.9	17.2 17.8	14.6 16.0
Plant tilt angle*	Ryho Giza	61.8° 19.8°	62.6° 17.6°	63.6° 16.3°
"Knicked" plant (%)**	Ryho Giza	0.0 –	6.2 –	19.4 –
Preharvest grain losses (g/m²)	Ryho Giza	0.5 0.9	1.2 1.6	1.8 2.4
Soil moisture content (%)	Ryho Giza	30.5 32.7	30.4 31.7	28.5 30.1

* Angle between the level ground and the line extending between the panicle and the base of the plant.
** Mean "knick" location is 13 cm under panicle base.

grains go through a cleaning section and are then conveyed to the bagging device.

Opposite to the conventional combine wiich deals with plants not necessarily planted in rows, the rice combine can harvest crop primarily in rows and the cylinder is fed with the upper part of the plants and does not have straw walkers.

The rice varieties used in the experiment were the Ryho and Giza 172, which differed in mean plant length of 70.4 cm and 100.4 cm, and mean number of seeds per head of 86.5 and 114.6 cm, respectively. They differ also in some other characteristics **(Table 1)** which will be discussed below. On the other hand, the two varieties were nearly similar in mean number of plants per hill of 23.5 and 22.7 and number of plants per m^2 of 426.8 and 421.7, respectively. The average yield amounted 4 266 kg and 5 523 kg per feddan for the Ryho and Giza varieties, respectively.

Measurements of grain losses were conducted in the usual procedure using screen frames and sheets of canvas to receive the different kinds of losses separately while the machine was traveling at constant speed and uniform crop condition (as described by Abdel Mawla 1985). Preharvest grain losses were also determined **(Table 1)** since the two types of combines differ in the width of cut.

Calculation of Harvesting Costs

Due to the actual field capacity for each treatment, the costs of harvesting were calculated as the sum of the fixed costs and variable costs of the combine per feddan plus the monetary value of total grain loss. The service life was considered 1 250 and 2 500 operating hours in five years for the rice and conventional combines, respectively. A salvage value of 10% of original cost, an interest rate of 12% and an overhead of 10% of operation costs were calculated. The labor costs include operators' wage and wages for manual bagging of the grain output from the unloading auger of the conventional combine and grain refilling in larger bags for the grain output of the rice combine. Rice grains in Egypt are delivered in 100-kg bags. Other cost items were calculated according to the recommendations of the American Society of Agricultural Engineers (ASAE 1982).

Procedure

The experiments were conducted in random split design in Kafr El-Sheikh area in the middle of the Nile Delta where the soil texture is clay. The 150-m long fields were transplanted mechanically and treated the same according to the usual practice. The earliest harvesting was about one month after stopping irrigation and draining the fields. The soil moisture content at the time of harvesting ranged between 30.5% and 32.7% **(Table 1)** at which troubles due to slippage were held at minimum during harvest. Straw and grain moisture contents were measured also at the time of harvest **(Table 1)**.

The combines were operated at three-speed treatments, namely; 0.9, 2.3 and 2.8 km/h for the rice combine and 0.8, 2.1 and 2.9 for the conventional combine. Higher speeds caused much troubles due to clogging.

Results and Discussions

Changes in Crop Conditions

One of the objectives of this study was to determine the optimum crop conditions for harvesting. Straw, grain and soil moisture content, plant tilt angle relative to horizontal as a measure for lodging, percentage of "knicked" plants, and preharvest grain losses changed in the course of time. The rice crop was harvested at three dates with about two-week intervals. The dates were from 20 to 26 Oct., from 5 to 11 Nov. and from 20 to 26 Nov. These dates are considered in the region as early, medium and late harvesting, respectively.

Table 1 shows the representative mean values reflecting crop conditions at the time of harvesting. The Giza variety is a typical lodging rice plant. This characteristic may be correlated with the mean length of plants (114.6 cm). On the other hand, the Ryho plants resist lodging (mean plant length 86.5 cm) but tend to "knick" at about 15 cm below the panicle by the decrease of straw moisture content. The Ryho plant tilt angle tends to increase with an increase in "knicking" percentage. The center of gravity of the plant is transferred through "knicking" so that the moment affecting tilting becomes less and causes the tilt angle to increase. The moisture content of straw, grain and soil decrease by time and remains higher in case of the Giza variety than the Ryho variety, probably due to lack of aeration as a result of lodging. Preharvest grain losses are less for the Ryho variety and increase by a decrease in grain moisture content in the course of time.

Grain Losses

Figs. 2 and 3 show the mean values of the four mentioned types of grain losses in addition to the total grain losses versus average operation speed, crop conditions and type of combine used.

Grain Losses of Ryho Variety

Effect of harvesting speed – Header, drum and cleaning grain losses tend, in general, to increase with the increase of harvesting speed for the rice combine. The total grain losses increased insignificantly by an increase of harvesting speed from 0.92 to 2.31 km/h but increased significantly with an increase of the speed from 2.3 to 3.2 km/h. This observation is valid for all experimented crop conditions.

There is a highly significant increase in the total grain losses due to the increase of speed from 0.77 to 3.1 km/h for the conventional combine. All kinds of grain losses increased at varying rates as affected by increase in harvesting speed.

Effect on harvest data – The total grain losses by the rice combine increased by the delay of harvesting from medium to late. The largest increase was due to the rapid increase in drum losses. The drum losses which constitute about 66% of the total grain losses is about 10 times those of early harvest. The high drum losses are due to the increased percentage of "knicked" plants as the straw moisture content of the Ryho plants decreases. The panicles of the knicked plants could not be reached by the drum. The late harvest nearly doubled the header losses but reduced cleaning losses to about one-third.

Opposite to the rice combine, the total Ryho grain losses of the conventional combine decreased from early to medium harvesting. The change in total grain losses between middle and late harvesting was insignificant. From early to late harvesting, the header losses of the conventional combine increased at similar rate as the rice combine, but drum, straw walker and cleaning losses decreased significantly.

Grain Losses of Giza 172 Variety

Effect of harvesting speed – The increase of the average harvesting speed of the rice combine from 0.89 to 2.83 km/h caused at least significant increase of total grain losses. This increase in total grain losses is mainly due to the increase of header and drum losses which are attributed to the lodging condition of the crop. A relatively low speed offers gentle handling of the lodging crop in cutting and delivering to the drum in the required way. In early harvesting, the increase in total grain losses was only due to drum losses. Cleaning grain losses were not affected by the harvesting speed at all times.

The increase of harvesting speed of the conventional combine from 0.75 to 2.08 km/h and 2.9 km/h caused highly significant and significant increase in total grain losses, respectively. All kinds of grain losses increased with the increase in speed. The highest rate of increase was of straw walker losses in early and medium date harvesting and of header losses in late harvesting.

Effect of harvesting date – There is a highly significant increase in total grain losses due to the delay in harvesting date and, consequently, the crop conditions. The total grain losses in late harvest were 2.5 times those of early harvest. Only the header and drum losses contributed to this increase.

In this respect, the header losses showed the highest rate of increase. As it was observed in the case of the Ryho variety, the Giza cleaning losses of the rice combine decreased due to the delay in harvesting, probably due to decrease in straw and grain moisture content.

There was a general decrease in drum, straw walker and cleaning losses but a sharp increase in header losses by the conventional combine due to later harvesting. Accordingly, the medium date of harvest showed the least total grain losses. Total grain losses of early harvest were insignificantly higher than late harvesting.

From **Figs.** 2 and 3 it can be concluded that the total grain losses per feddan of the rice combine were less than the conventional combine in early and medium dates but higher in late harvest for both rice varieties.

Field Efficiency

Another criterion of comparison between the two types of combines are the field capacity and efficiency. The two machines cannot be compared in field capacity since they differ in the width of cut. Hence they are compared here in the field efficiency which is mainly affected by time losses in turning, grain emptying and removal of straw clogging. **Fig.** 4 shows that both combines were almost similar in field efficiency in harvesting the Ryho variety, but the conventional combine showed significantly higher field efficiency in harvesting the Giza variety due to smooth operation without clogging. In harvesting the lodging Giza crop, the conventional combine was less affected by the time of harvest compared with rice combine.

Effect of combine speed –

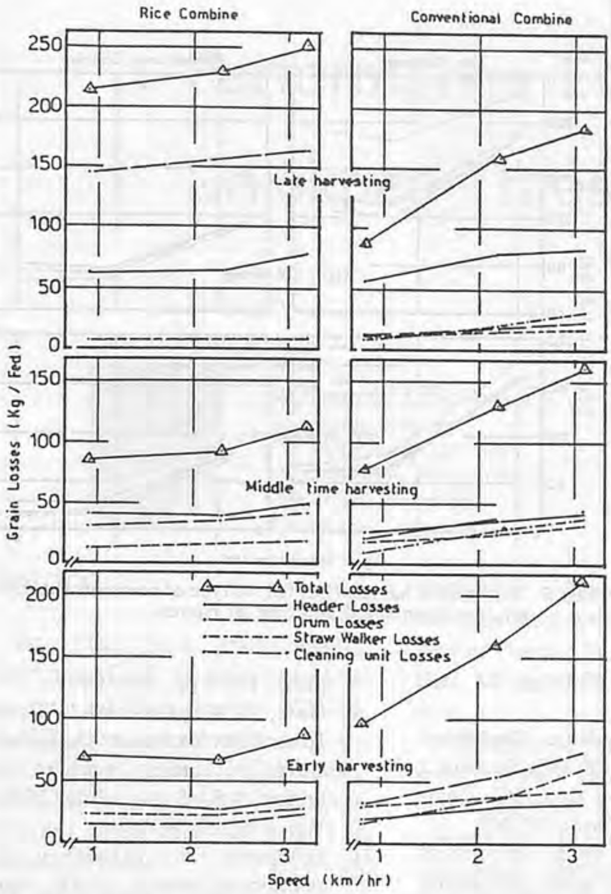

Fig. 2 Grain losses per fedan 94200 m^2) vs average operation speed, type of combine and date of harvest of the Ryho variety.

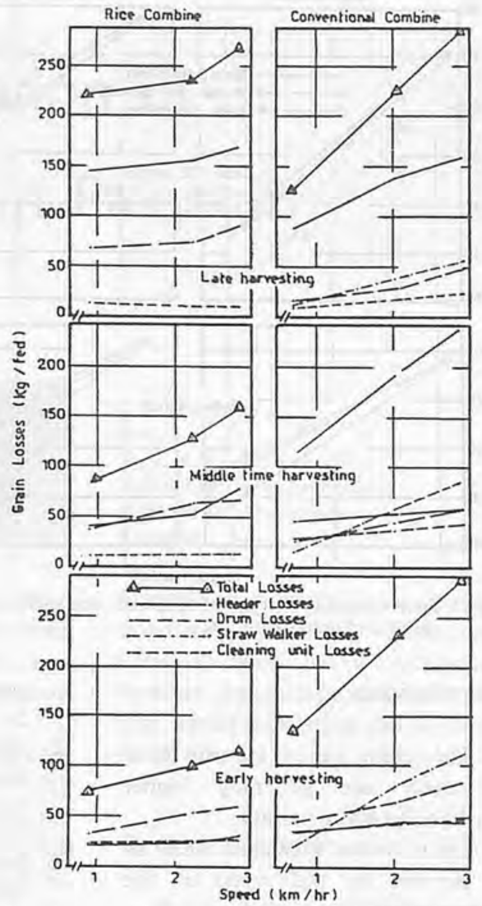

Fig. 3 Grain losses per fedan vs average operation speed, type of combine and date of harvest of the Giza 172 variety.

Although the field capacity increased, the field efficiency decreased with the increase in speed for both types of combines due to the percentage of time losses at higher speeds (Fouad 1976).

Effect of rice variety – Due to lodging, the Giza rice variety showed a lower field efficiency than the Ryho variety for both types of combine.

There was almost no effect of the date of harvest on field efficiency at the lowest combine operation speed. However, for the Giza variety, by the rice combine, late harvest showed the lowest field efficiency. Except this case, early harvest showed the highest rate of decrease in field efficiency due to the increase in speed. For the Ryho variety, the highest efficiency was at late harvest. In case of the Giza variety, the highest efficiency was at early harvest for the rice combine, and at medium time harvest for the conventional combine.

Cost of Harvesting

As mentioned in the methods, the operation cost per feddan is calculated on the operation cost per hour and the field capacity, feddan per hour. The total harvest cost per feddan is calculated here as the sum of the operation cost per feddan and the cost of grain loss per feddan. Thus, the total harvest cost is affected by the harvest speed and date of harvest, which reflect the crop conditions and the rice variety.

In general, the total harvesting costs of the Giza variety were higher than the Ryho variety in all cases. (Fig. 5).

The total harvesting costs of the rice combine were highly significant than the conventional combine in all cases.

For both rice varieties there was a highly significant decrease in the total harvest costs with an increase in operation speed from 0.9 and 0.8 km/h to 2.3 and 2.2 for the rice and conventional combine, respectively.

The rate of cost decrease differed slightly due to the date of harvest. The change in total costs due to further increase in speed to the third speed was insignificant.

Early harvest by the conventional combine showed the highest total costs for both rice varieties.

The total costs for late harvest by the rice combine were greater than the other dates of harvest of the Ryho and Giza varieties, respectively.

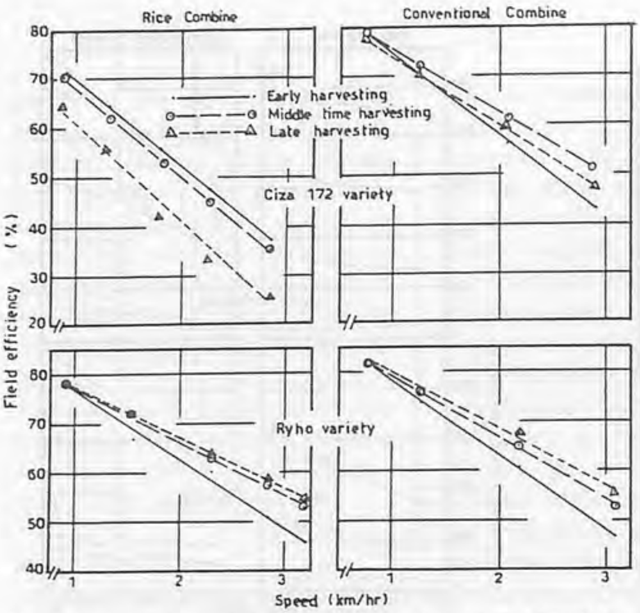

Fig. 4 Field efficiency vs type of combine, rice variety, operation speed and date of harvest.

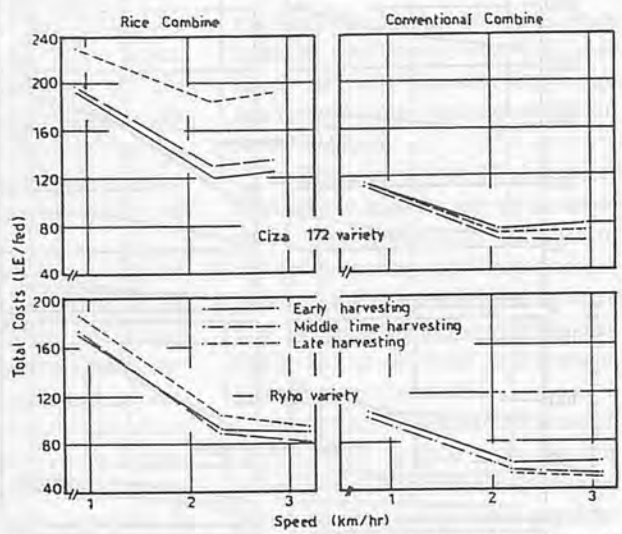

Fig. 5 Total cost of harvest (LE/fed) vs type of combine, rice variety, operation speed and date of harvest.

Conclusions

1. The grain losses for the Giza variety are generally higher than the Ryho variety.
2. Grain losses increased with an increase in the speed of the combines.
3. Grain losses in the conventional combine are relatively higher than for the rice combine.
4. Grain losses were affected by the time of harvest which reflect field and crop conditions.
5. Although the field capacity increased with an increase in combine speed, field efficiency decreased in comparison.
6. The total harvest cost per feddan, which includes cost of grain loss, is higher for the Giza variety than the Ryho variety but decreased with an increase in the combine speed.
7. Under conditions and limilations of the experiments, the total costs of harvest for the conventional combine are less than for the rice combine.

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Performance Evaluation of Chickpea Thresher in Pakistan

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Abstract

An axial flow grain legume thresher (AGAD Model C) was tested on chickpea variety CM-72. Modifications were made to improve its performance. The thresher worked best with cylinder speed 580 rpm, feed rate 430 kg/h and concave clearance 3 cm, at which the thresher capacity was measured to be 190 kg/h with a threshing efficiency of 93% and fuel consumption of 5.7 lit/h. The total machine loss and grain damage was 9.1% and 2.2%, respectively. The field performance of the thresher was directly compared with conventional threshing using bullock and tractor treading, in terms of grain losses, labour requirement and economics of operation.

Introduction

Chickpea or gram (*Cicer arietinum* L.) is a ready source of protein for the diet of masses in many Asian countries. It is cultivated as a winter crop in the tropics and a spring or summer crop in the temperate climate. The annual world production of chickpea is about 7 million t of dry grain from an area of 10 million ha. Some 85% of production stems from South Asia but the cropping area extends westwards from Afghanistan, through West Asia and the Mediterranean basin, into Ethiopia and East Africa, the Americas and Australia.

Chickpea is grown as a postmonsoon "winter" crop in Pakistan. By land area planed to chickpea, the country ranks second in the world. The total production of grain legums in 1984-85 was 725 500 t, out of which chickpea alone contributed about 72%. In 1984-85, the national average yield was 517 kg/ha. The maximum potential yields are obtained in India or winter sown crops in the Mediterranean —more than 5000 kg/ha dry seed in 160-170 days, during which temperature of zero degree C or less are recorded.

Traditionally, chickpea harvesting and threshing is done manually. After harvest, plants are left in the field in small piles and are later gathered into large heaps in the threshing yard. Almost 100% of the chickpea crop is threshed by animals, tractor treading or flailing by poles. In comparison, mechanical threshers are not used anywhere in Pakistan.

The optimum time of chickpea harvesting and threshing in Pakistan is March-April immediately followed by wheat harvesting and threshing. The threshing with bullock or tractor treading and subsequent manual winnowing, is a labour-intensive operation. Therefore, there is need for a mechanical thresher for chickpea threshing, so that wheat harvesting can be started on time.

Review of Literature

Madan et al (1985) developed and tested an axial flow threshing system for the threshing of groundnut. The comparison between existing threshing system (spike tooth type) and axial flow threshing system under study reveals that total pod losses and specific power consumption were low in the case of axial flow threshing system in addition to better straw quality.

Majumdar (1985) designed a multicrop thresher by incorporating IRRI axial flow arrangement on traditional tooth thresher for threshing major crops. The machine was operated by a 5-hp electric motor and output capacities were 348, 276, 200, 540, 1635 and 392 kg/h for gram, wheat, soybean, sorghum, maize and paddy, respectively. Gram was threshed by feeding the whole crop. The threshing efficiency of the machine was about 99% in most cases. The total grain losses were below 2% for wheat, gram, sorghum and paddy. For maize and soybean, the losses were 2.2 and 4%, respectively.

Vas et al (1969) investigated into the effects of mechanical threshing parameters on kernel damage and threshability of small grains. It was indicated that cylinder speed is the primary influencing parameter while concave clearance, although of less significance, is an important factor as well.

Amjad et al (1986) tested the AGAD thresher imported from the Philippines for its perfomance on CM-72 chickpea variety for limited hours of operation. Performance testing variables were two different threshing drum speeds (480 and 580 rpm), and three different crop feed rates. The average value of grain loss, threshing and cleaning efficiencies were recorded at 5.58%, 95.78% and 91.35%, respectively. The average grain output of 119.03 kg/h was observed. Grain breakage was insignificant. Gasoline consumption of the thresher was 0.92 *l*/h.

Objectives

The study was undertaken with the following objectives:

1. To measure and evaluate the field performance of AGAD thresher (Model C); and

2. To make recommendations for possible modifications of the thresher to improve its performance.

Materials and Methods

Description of Thresher

The AGAD thresher model C (Fig. 1) is an engine-powered machine, mainly comprising of threshing drum, concave, blower, rotary sieve, auxiliary cleaner and feed table. The machine is provided with two pneumatic wheels, leaf springs to absorb shocks and vibrations and two removable pipes bolted on the frame for field transport using animals.

The thresher operates on the principle of axial flow movement of material. The threshing mechanism consists of a peg-tooth cylinder which rotates inside a two-section cylinder concave (Fig. 2). The upper concave has inclined louvers which moves the threshing material axially between the threshing drum and the concave. The material is loaded onto the feeding tray and fed into the opening between the cylinder and lower concave. The pegs on the threshing cylinder fit the material, separating the grain from the pod and the straw, and at the same time accelerating them around the cylinder. The majority of the grain is threshed during the initial impact but further threshing is performed while the material moves axially until the straw is discharged by the straw paddles at the opposite end.

Power is transmitted through a series of V-belts to the five major components – the threshing cylinder, delivery auger, centrifugal blower, rotary screen and auxiliary cleaner (Fig. 3).

The thresher separates and cleans the grain in four stages. In the first stage, preliminary grain and straw separation occurs at the concave. In the second stage, threshed crop is exposed to a blast of air from the adjustable air control blowers located beneath the drum. It blows the lighter impurities, such as chaff and unfilled grains from good grains. In the third stage, the remaining un-

Fig. 1 AGAD thresher in operation.

Fig. 2 Inner view of thresher.

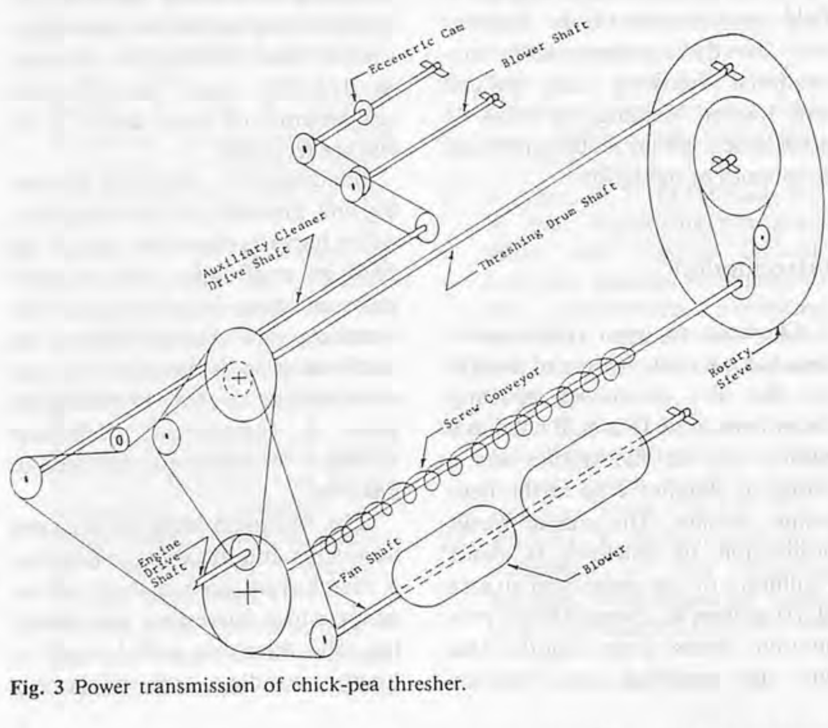

Fig. 3 Power transmission of chick-pea thresher.

cleaned grains and straw mixture fall onto the bottom of the inclined tray where there is a delivery auger which directs the mixture towards the rotary screen for separation of grains. As the grains sieve down through its perforations, still smaller pieces of straw may come along with the grain, which are consequently picked up by the fins of the rotary screen and are dropped onto the reciprocating sieve of auxiliary cleaner unit. In the fourth stage, the mixture is again exposed to an air blast from the blower. The reciprocating screen also helps in cleaning the grains. The cleaned grains are then collected from the main grain outlet underneath the auxiliary cleaner.

Modifications

The clearance between the threshing cylinder and concave was made adjustable by inserting or taking off rectangular shim each of 0.5 mm thickness.

During the preliminary testing, it was observed that a major portion of the material is threshed during the first impact of pegs. This caused accumulation of the material on delivery auger. To overcome this problem the peg length was increased from 5 cm to 7 cm. The modified cylinder was installed on the thresher to ensure better and even threshing of the material.

Two centrifugal blowers are mounted underneath the concave to separate the chaff and unfilled grains from good grains. It was observed that the blowers were not performing effectively, because of lower speed of fans. Therefore, the blower speed was increased by replacing the pulley of smaller size on the blower shaft and the blade width was increased from 52 mm to 102 mm to get more air for winnowing operation (**Fig. 4**).

Modifications were also made to supply power to the thresher from tractor P.T.O. shaft (**Fig. 5**).


Fig. 4 Modified blower.


Fig. 5 PTO-drive for thresher.

Field Performance Evaluation Tests

The variables considered for field testing of the thresher were three threshing cylinder speeds (480, 530 and 580 rpm), three cylinder-concave clearances (3.0, 3.5 and 4.0 cm) and three feed rates (370,400 and 430 kg/h). The moisture contents (db) of about 8.8% for grain and 11.9% for straw was kept constant during testing. Only one chickpea variety, CM-72, was used.

The performance index (PI) was used to compare the relative threshing performance of thresher under different conditions or to determine the values of optimum operating conditions.

$$PI = C_a \times (1 - \frac{W_L}{W_i}) \times \eta_T (1 - \frac{W_d}{W_i})$$

where,

C_a = threshing capacity kg/h
W_L = weight of grains lost, kg
W_i = total grain input, kg
W_d = weight of damaged grains, kg
η_T = threshing efficiency in decimal

The field performance of the thresher was directly compared with the conventional methods (threshing using bullocks and tractor treading) in terms of grain losses, labour requirement and economics of operation.

Results and Discussion

Table 1 presents the thresher performance at different combinations of variables. The percentage of grain damage increased with an increase in clinder speed for all feed rates and concave clearance combinations (**Figs. 6 and 7**). This increase was due to higher impact levels imparted to the crop during threshing process at equally high cylinder speeds. Grain damage was in the range of 1.6% to 2.6%. The mean grain damage decreased with increasing concave clearance and feed rate.

The percentage of total machine

Table 1 Performances of Thresher at Various Cylinder Speeds, Concave Clearances and Feed Rates

Cylinder speed (rpm)	Clearance (cm)	Breakage (%)			Total machine loss (%)			Threshing efficiency (%)			Capacity (kg/h)		
		F1	F2	F3	F1	F2	F3	F1	F2	F3	F1	F2	F3
480	3.0	2.1	2.0	1.9	9.0	9.2	9.8	93.0	92.7	91.9	161.0	173.9	183.8
	3.5	1.6	1.8	1.8	9.7	9.5	9.8	92.3	92.4	91.9	157.4	171.1	179.2
	4.0	1.7	1.8	1.8	9.7	9.9	9.8	92.3	92.0	91.9	154.7	170.2	177.3
530	3.0	1.7	1.8	2.1	10.0	10.4	9.9	92.5	91.9	92.2	163.7	177.6	186.7
	3.5	1.7	1.7	1.9	10.4	10.5	10.5	92.1	91.8	92.6	161.0	174.8	170.8
	4.0	1.7	1.6	1.8	10.1	10.6	10.8	92.4	91.7	92.3	158.3	173.0	180.2
580	3.0	2.6	2.4	2.2	10.0	10.0	9.1	92.8	92.4	92.9	162.9	176.6	189.7
	3.5	2.4	2.2	1.8	9.7	9.5	9.1	93.1	92.9	92.9	162.8	175.8	187.0
	4.0	2.4	2.0	1.6	9.7	9.6	8.9	93.1	92.8	93.1	162.8	176.7	188.0

F1, F2, F3 = feed rates 370, 400 and 430 kg/h, respectively.

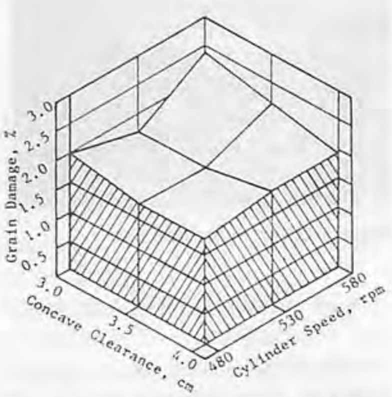

Fig. 6 Effect of cylinder speed and concave clearance on grain damage.

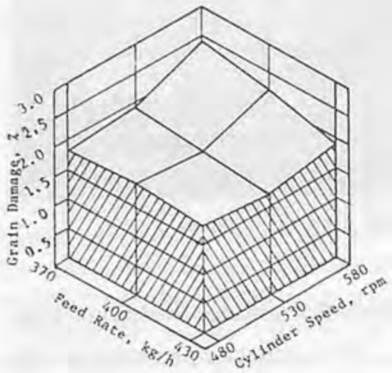

Fig. 7 Effect of cylinder speed and feed rate on grain damage.

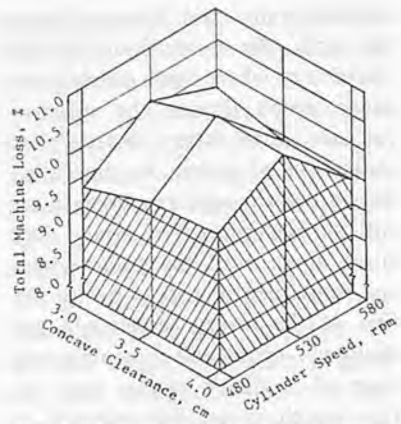

Fig. 8 Effect of cylinder speed and concave clearance on total machine loss.

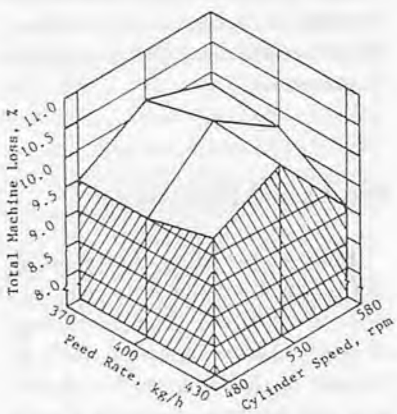

Fig. 9 Effect of cylinder speed and feed rate on total machine loss.

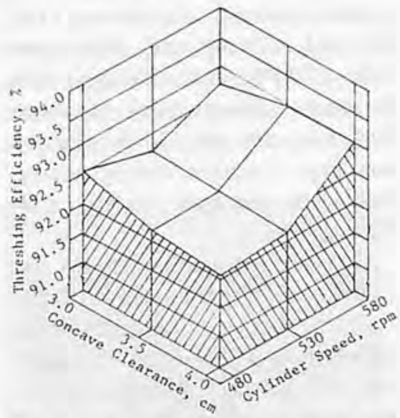

Fig. 10 Effect of concave clearance and cylinder speed on threshing efficiency.

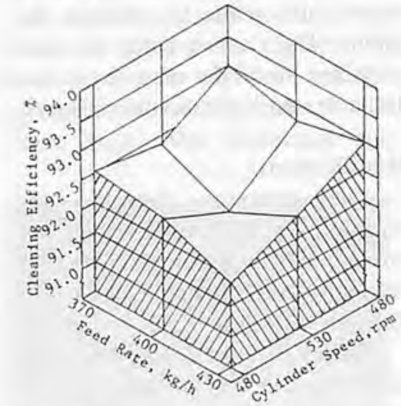

Fig. 11 Effect of cylinder speed and feed rate on threshing efficiency.

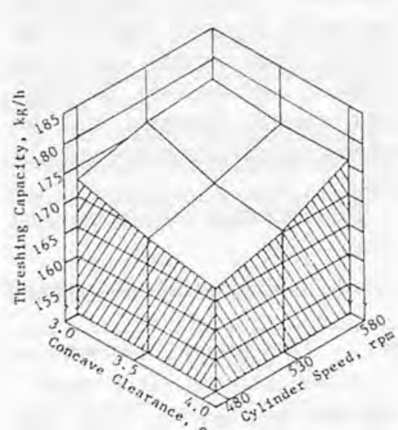

Fig. 12 Effect of concave clearance and cylinder speed on threshing capacity.

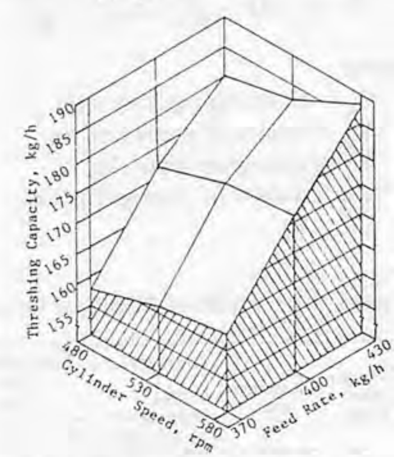

Fig. 13 Effect of cylinder speed and feed rate on threshing capacity.

loss increased from 480 to 530 rpm cylinder speed and decreased at 580 rpm for all combinations of independent variables (**Figs.** 8 and 9). The total machine loss was in the range of 8.9% to 10.8%. The variation in total machine loss at different cylinder speeds was statistically significant at 1% level (**Table** 2), whereas, the effect of concave clearance and feed rate on total machine loss was statistically non-significant.

The mean threshing efficiency increased with an increasing cylinder speed, and decreased with increasing concave clearance and feed rate (**Figs. 10** and **11**). Threshing efficiency was in the range of 90% to 93.1%.

The threshing capacity increased with the increase in cylinder speed for all combinations of independent variables (**Figs. 12** and **13**). The threshing capacity was in the range of 155 kg/h to 190 kg/h. At 480, 530 and 580 rpm, for all three feed rates, the threshing capacity decreased as concave clearance increased. The feed rate of 430 kg/h gave the maximum capacity in all the tests.

The thresher required 3 labour-

Table 2 Analysis of Variance for the Effect of Cylinder Speed, Concave Clearance and Feed Rate on Total Machine Loss

Source of variance	Sum of squares	Degrees of freedom	Mean squares	F calculated	F (0.05)	F (0.01)
Clearance (C)	0.2784	2	0.1392	2.97	3.18	5.05
Feed rate (F)	0.1837	2	0.0919	1.96		
Speed (S)	10.8693	2	5.4347	116.07**		
C*F	0.3299	4	0.0825	1.76	2.55	3.70
C*S	2.8448	4	0.7112	15.19**		
F*S	2.7236	4	0.6809	14.54		
C*F*S	1.2036	8	0.1505	3.21		
Error	2.5385	26	0.0468			
Total	20.9619	80				

* Significant at 0.05 level, ** Significant at 0.01 level.

Table 4 Labour Requirement for Traditional Threshing Systems (Bullock and Tractor Treading)

Operations	Labour requirement (man-h/t)	
	Bullock treading	Tractor treading
Spreading of crop on threshing floor	1.49	1.48
Treading	17.91	2.96
Winnowing and cleaning	8.96	8.89
Collecting and bagging	2.99	2.96
Total	31.35	16.29

Table 3 Performance Index of Thresher at Different Cylinder Speeds, Feed Rates and Concave Clearances

Concave clearance (cm)	Cylinder speed (rpm)	Feed rate (kg/h)	Damaged grain (decimal)	Grain loss (decimal)	Threshing efficiency (decimal)	Threshing capacity (kg/h)	(1-GD)	(1-GL)	Performance index
3.0	480.0	370.0	0.021	0.050	0.930	161.000	0.979	0.950	139.256
3.0	480.0	400.0	0.020	0.047	0.927	173.850	0.980	0.953	150.513
3.0	480.0	430.0	0.019	0.048	0.919	183.820	0.981	0.952	157.766
3.0	530.0	370.0	0.017	0.057	0.925	163.730	0.983	0.943	140.390
3.0	530.0	400.0	0.018	0.061	0.919	177.600	0.982	0.939	150.500
3.0	530.0	430.0	0.021	0.061	0.922	186.660	0.979	0.939	158.209
3.0	580.0	370.0	0.026	0.060	0.928	162.890	0.974	0.940	138.398
3.0	580.0	400.0	0.024	0.062	0.924	176.640	0.976	0.938	149.422
3.0	580.0	430.0	0.022	0.061	0.929	189.720	0.978	0.939	161.858*
3.5	480.0	370.0	0.016	0.051	0.923	157.430	0.984	0.949	135.691
3.5	480.0	400.0	0.018	0.049	0.924	171.110	0.982	0.951	147.652
3.5	480.0	430.0	0.018	0.051	0.919	179.190	0.982	0.949	153.433
3.5	530.0	370.0	0.017	0.060	0.921	161.000	0.983	0.940	137.015
3.5	530.0	400.0	0.017	0.065	0.918	174.800	0.983	0.935	147.485
3.5	530.0	430.0	0.019	0.063	0.926	180.770	0.981	0.937	153.867
3.5	580.0	370.0	0.024	0.061	0.931	162.840	0.976	0.939	138.940
3.5	580.0	400.0	0.022	0.063	0.929	175.750	0.978	0.937	149.620
3.5	580.0	430.0	0.018	0.063	0.929	187.000	0.982	0.937	159.848
4.0	480.0	370.0	0.017	0.052	0.923	154.700	0.983	0.948	133.062
4.0	480.0	400.0	0.018	0.054	0.920	170.170	0.982	0.946	145.437
4.0	480.0	430.0	0.018	0.053	0.919	177.300	0.982	0.947	151.525
4.0	530.0	370.0	0.017	0.061	0.924	158.300	0.983	0.939	135.012
4.0	530.0	400.0	0.016	0.066	0.917	172.960	0.984	0.934	145.766
4.0	530.0	430.0	0.018	0.066	0.923	180.180	0.982	0.934	152.534
4.0	580.0	370.0	0.022	0.063	0.931	162.840	0.978	0.937	138.928
4.0	580.0	400.0	0.020	0.066	0.928	176.700	0.980	0.934	150.092
4.0	580.0	430.0	0.016	0.065	0.931	188.000	0.984	0.935	161.033

* Maximum value of performance index; GD=damaged grain (decimal); GL=grain loss (decimal).

ers to operate in the field. The average labour required for threshing operation was 8.52 man-h/t.

The performance indices of the thresher at various cylinder speeds, feed rates and concave clearances are shown in Table 3.

The higher value of performance index was achieved at 530 rpm cylinder speed, 430 kg/h feed rate and 3.0 cm concave clearance. At this combination, the threshing capacity, threshing efficiency, grain damage and grain loss were 190 kg/h, 93%, 2.2% and 6%, respectively.

Traditional Threshing

Fig. 14 Threshing of chickpea by tractor treading.

Fig. 15 Manual winnowing of threshed material.

Bullock treading and tractor treading (Fig. 14) followed by manual winnowing (Fig. 15) are the two traditional threshing methods used in Pakistan. The labour requirement for these two traditional systems are compared in Table 4. The total grain losses of 11.9% and 12% were recorded for bullock and tractor treading, respectively. The maximum grain loss was in winnowing and cleaning operation.

9.9% and 9.5% for bullock and tractor treading, respectively.

Economics of Threshing Operation

The cost analysis of mechanical and traditional threshing was undertaken with a view to assessing the economic feasibility of the mechanical threshing. **Fig. 16** shows the relationship between the total cost of threshing in US$ per ton and annual use of thresher per year.

At present wage level in Pakistan, the thresher with gasoline engine has a break even point at 30 t (58 ha) and 55 t (106 ha) per year as compared to bullock and tractor treading. The thresher powered from tractor has a break-even point of 65 t (126 ha) per year as compared to bullock threshing, whereas, the tractor treading followed by winnowing operation is economical up to 80 t (155 ha) per year as compared to thresher powered from the tractor PTO. The horizontal line depicted the cost of bullock and tractor treading which would rise in direct proportion to the wage rate.

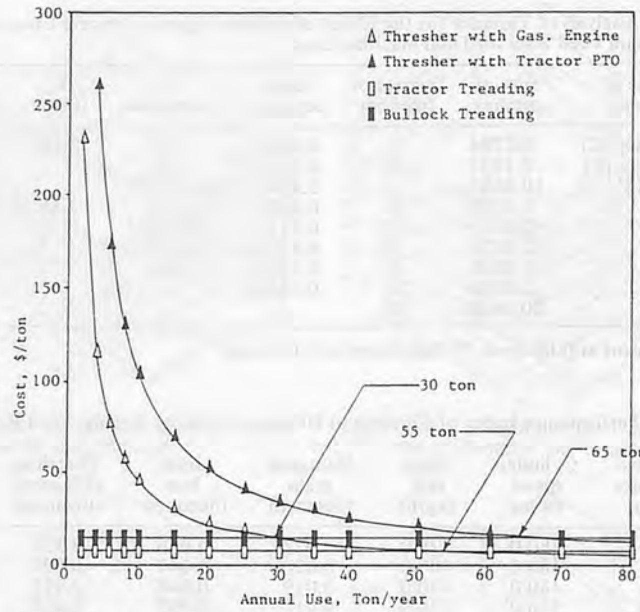

Fig. 16 Total cost vs annual use.

Recommendations

1. A study should be conducted on the cleaning units of thresher for separating good grains from unthreshed pods and straw.

2. Different types of threshing cylinder should be tested to ascertain their work performance on chickpea.

3. To reduce the machine losses, the inclined louvers and concave clearance should be made adjustable.

4. To increase thresher capacity, improve safety and ease of crop feeding, the feeding mechanism should be modified.

5. The machine should be extensively tested for varying crops and machine conditions to compare its performance and economics of operation with other existing threshing systems.

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Development and Performance Evaluation of Pedal-operated Sunflower Thresher

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Abstract

A sunflower thresher was designed, developed and evaluated by the Agricultural Engineering Research Centre, Pune. It is a hold-on type, pedal-operated, light weight, and a low-cost machine based entirely on a new concept. The threshing efficiency and cleaning efficiency are 100 and 96 to 98%, respectively. The output capacity of the machine is about 40 kg seed per hour. The threshing cost is Rs. 13 per quintal as against Rs. 30 to 35 per quintal for other local methods. The thresher is named as 'Phule sunflower thresher.'

Introduction

Because of uncertainty of rains, land planted to groundnut in Maharashtra decreases in area year after year: from 8.24 ha in 1981-82 to 6.63 ha in 1985-86. The area planted to sunflower, however, has increased from 1.43 ha in 1981-82 to 4.15 ha in 1985-86 (Anonymous, 1987-88). Sunflower is attracting farmers because it is a short-duration, hardy crop, that grows in any season and on any type of soil under adverse conditions. It contains 45 to 50% oil that is light yellow coloured with good flavour and high nutritional value. The crop needs less inputs (seed, fertilizer, chemicals, irrigation, etc) compared to other oil seed crops (Salunkhe et al, 1982). The only problem with this crop is threshing. There is no suitable machine for sunflower threshing. The prevalent threshing methods like beating with sticks, rubbing the earheads face to face, rubbing the earheads on bricks, stones, wire mesh, etc, trampling earheads under bullocks feet or tractor tyres are tedious and labour and time consuming. Use of a conventional type of thresher poses separation problems (Pacharane, 1987). The Agricultural Engineering Research Centre, Pune, therefore, designed and developed a hold-on type pedal-operated sunflower thresher based entirely on a new concept. Its performance has been evaluated (Anonymous, 1987).

Materials and Methods

Design Considerations

All local methods of sunflower threshing were carefully studied and the following points were given due consideration in the design of the sunflower thresher.

1) Crushing of sunflower heads during threshing requires more energy than detaching the seeds without crushing the heads.

2) It involves more material handling and that the crushed particles of the receptacle of the head which are of the size and weight of the seed escape both the mechanical as well as the aerodynamic separations in the conventional type of threshers.

3) Threshing of sunflower by such threshers necessitates drying of heads below 12% moisture content (Pacharane, 1986) which means 15-20 days sundrying of the heads after maturity.

4) Ripe sunflower heads shade the petals of the ray florats. The bracts of involucre become yellow and little loose but remain attached to the head. The bracteoles covering the seeds become little separated from seeds but remain attached sufficiently rigidly to the receptacles of the head.

5) The ripe seeds become dark, little hard and loose in the bracteoles. A gentle impact is adequate to detach these seeds without removal of other components of the florats.

6) The shape of the sunflower heads does not change appreciably after maturity up to 10-12% seed-moisture-content. Below that they

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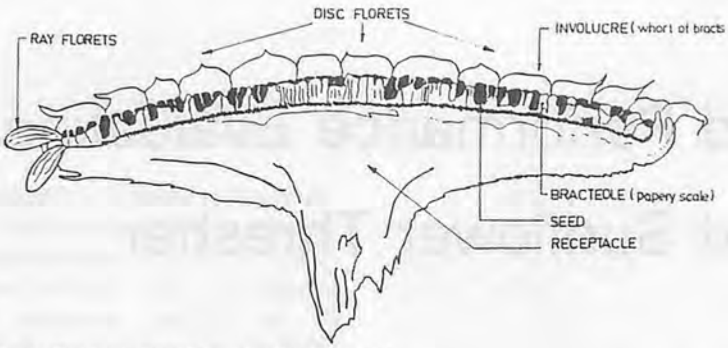

Fig. 1 Sunflower head (longitudinal section).

tend to take any irregular shape.

7) The average range of sunflower head diameter is 5 to 28 cm.

8) Threshing immediately after maturity yields monetary benefits to the farmers.

9) The seedless sunflower heads are of use as feed for cattle, as fuel, for manufacturing packing materials and hard-boards, for pectin extraction, etc.

Machine Description

The manually-operated hold-on type sunflower thresher consists mainly of three units: a) threshing unit made of threshing wheel, top cover and grain mixture collector; b) cleaning unit made of separation passage; and blowing fan; and c) power transmission unit.

Threshing Wheel

This is made of 660 mm dia and placed horizontally at a convenient height on a main shaft of 20 mm dia. The wheel rim is of 20 mm dia pipe and is connected to a central bi-flanged bush with 50 small dia rods.

Top Cover

This is a 26-gauge thick metal sheet 700 mm in diameter that covers the threshing wheel from the top. It is convex in shape and is supported from the concave side by a wooden cross. When in position this wooden cross divides the top of the threshing wheel in 4 compartments. Each compartment is accessible through a hole of 250 mm in dia in the top cover. The convex shape of the top cover makes it possible to accommodate sunflower heads larger than the dia of the feeding holes. Each hole in turn is half covered with a semi-circular cap. The cap prevents grains from spilling out while being detached. It also determines the direction of feeding the heads for threshing on threshing wheel. The heads are necessarily fed in the direction of rotation so that the fingers of the operator never get into the spokes of the threshing wheel. The wooden cross, besides giving support to the metal sheet of the top cover, prevents sunflower heads from escaping into the next compartment while being held on the wheel for seed separation.

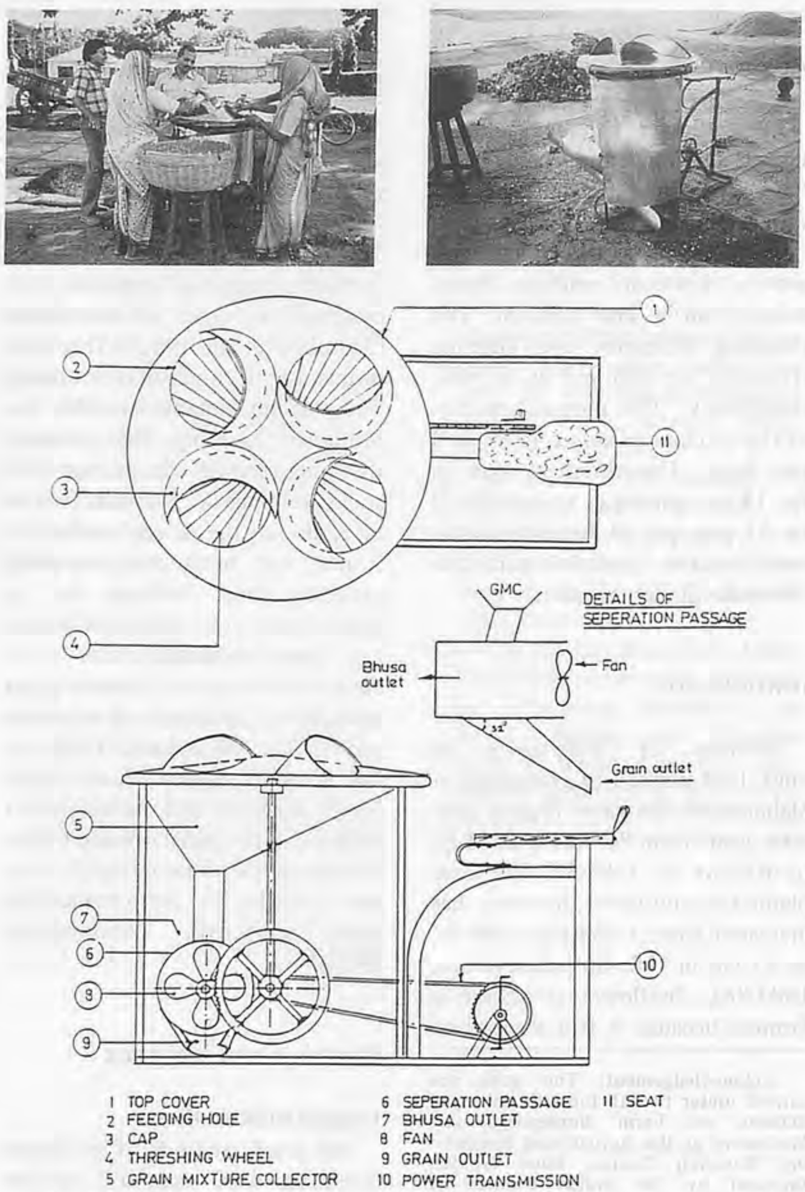

Fig. 2 Phule sunflower thresher.

Grain Mixture Collector

This is a funnel-shaped part that forms the bottom of the threshing unit. It collects the grain mixture and discharges it through the bottom opening into the cleaning unit.

Separation Passage

This part is the cleaning unit which receives grain mixture from the grain mixture collector. It is a circular space of 240 mm diam. and 400 mm in length. The outer end is the straw outlet. At the inner end is provided a fan. The bottom of the passage from straw outlet to centre is made sloping (32° with horizontal) rearwards and the slope is extended down to end as grain outlet. The grain mixture enters into the separation passage from the top, nearly halfway between the fan and the straw outlet. While falling across the passage and sliding down the inclined bottom of the passage, the grain mixture is subjected to separation by blowing air of the fan. The "bhusa" consisting of bracteoles, bracts, little scrappings of the receptacle and very light seed blows away through the straw outlet. The clean grain slides down along the bottom of the passage to the grain outlet.

Blowing Fan

This is made of 215 mm diam. that generates an air blast of nearly 3.5 m/sec. adequate for the aerodynamic separation of grain and straw in this thresher.

Power Transmission

Power from the pedal is transmitted through chain and sprocket to a horizontal shaft. A small bevel assembly at the centre on the horizontal shaft rotates the vertical main shaft on which the threshing wheel is mounted. At the other end of the horizontal shaft a spur gear assembly rotates, the fan to create the necessary air blast.

Working of the Thresher

Four persons are required on this thresher for threshing operation. One of them in addition to feeding of sunflower heads, operates the thresher by pedaling while sitting. These persons feed sunflower heads through the feeding holes on the top cover. A sunflower head is held with its seed-face gently on the revolving threshing wheel, at times it is slowly rotated, till all the grain is detached. When done with, fresh head is taken for threshing.

Results and Discussion

The sunflower thresher was tested for its performance under the conditions given in **Table 1**. The performance test data are given in **Table 2**. Referring to this table it is seed that: 1) the feedrate obtained in trial II was 43.55 kg/h whereas they were 48, 48 and 65 kg/h in the I, III and IV trials, respectively. This is because the sunflower heads used in the II trial had the smallest diam (13 cm). Consequently, the output capacity of II trial was least (24.68 as against 28.25, 27 and 37.20 kg/h); 2) for trials I and IV, the sunflower heads used were of the same diam. i.e. 17 cm, however, the output capacities were 28.25 and 37.20 kg/h, respectively. This difference is due to the difference in the moisture content. It is observed that the sunflower heads take up any irregular shape below nearly 10% seed-moisture-content. Such heads need more time for detachment of all seeds as the operator has to manually bring every face of the head in touch of the revolving threshing wheel. The feed rate and, hence, the output capcity in trial IV was maximum owing to the higher moisture content (12%) and larger diam. (17 cm) heads; 3) the maximum blown grain percentage observed was 3%. It is noted that this grain collected from bhusa is empty, light and has

Table 1 Test Conditions Data of Sunflower Thresher Trials

Test number date of test location of test	I 12.11.87 College farm	II 13.11.87 College farm	III 18.11.87 College farm	IV 8.12.87 College farm
1. Condition of crop				
Crop variety	Morden	Morden	Morden	Morden
Grain ratio	0.61	0.59	0.59	0.59
Head diam. (cm)	17	13	16	17
Seed moisture content (%)	8	8	8	12
2. Condition of machine				
Average RPM pedal	68	68	68	68
Threshing wheel	166	166	166	166
Blower	2 379	2 379	2 379	2 379
Velocity (m/s)				
Threshing	1.5 to 5.2	1.5 to 5.2	1.5 to 5.2	1.5 to 5.2
Air blast	3.33	3.33	3.33	3.33
3. Condition of operation				
Labour required	4	4	4	4
Period of test (h)	2	1.02	1	1
Man-h required	8	4.08	4	4
Feed-rate (kg/h)	48	43.55	48	65
Operator change	No	No	No	No
4. Condition of labour				
Skilled/unskilled	Unskilled	Unskilled	Unskilled	Unskilled
Male/female	M	M	F	M
Wage rate (Rs/ha)	1.25	1.25	1.25	1.25
5. Ambient conditions				
Temperature (C)	29°	29°	32°	27°
Wind velocity	NA	NA	NA	NA

Table 2 Performance Test Date of Sunflower Thresher

Item	Test I	Test II	Test III	Test IV
Grain ratio	0.61	0.59	0.59	0.59
Flower head dia, (cm)	17	13	16	17
Moisture content, (%)	8	8	8	12
Feed rate, (kg/h)	48	43.55	48	65
Broken grain (%)	Nil	Nil	Nil	Nil
Blown grain (%)	1.72	3	3	1.51
Spilled grain (%)	1.29	1.5	1.76	1.41
Threshing efficiency (%)	100	100	100	100
Cleaning efficiency (%)	97.6	96.4	97.2	98.8
Output capacity (kg/h)	28.25	24.62	27	37.20
Corrected output capacity, (kg/h)	30.12	27.20	29.76	38.38
Cost of operation (Rs/h)	5.23	5.23	5.23	5.23
(Rs/Q)	17.36	19.22	17.74	13.63

no seed value; 4) the spilled grain percentage observed was between 1.29 and 1.76. (The design of the cap of the feeding hole is being improvised in the commercial prototype to reduce this loss to minimum); 5) the manual feeding of sunflower heads results in 100% threshing efficiency. Practically no grain was kept undetached on the heads; 6) the cleaning efficiency was between 96.4 and 98.8%. Threshing of earheads at higher moisture contents removed mostly all seeds and very little of other materials from the earheads. Very dry (and smaller) heads needed more care while holding on the threshing wheel. Otherwise, even a little more pressure removes the scrappings of the receptacles and the cleaning efficiency is reduced; 7) in all the trials no visual grain breakage was observed; and 8) to avoid variations in the moisture content of grain and grain ratio, the output capacities are corrected by the formula (Anonymous, 1983).

Corrected output capacity

$$= Wc = \frac{(100 - M)\, Gs_W}{(100 - Ms)\, G}$$

where,

W = output capacity obtained

M = observed moisture content of grain

Ms = standard moisture content, 14%

G = observed grain ratio

Gs = average grain ratio

The cost of operation of the thresher was Rs. 5.23/h i.e., nearly Rs. 13 to 20/quintal of seed. The local rates of threshing of sunflower prevalent in most of the districts of Maharashtra are Rs. 30 to 35 /quintal of seed. This means that the threshing with this thresher is cheaper. The seed-less earheads which remained intact after threshing of seeds were used as fuel. For this purpose they were sold at Rs. 70 to 100/quintal. These earheads are also used for manufacturing packings and hardboards. In that case the by-product of threshing of sunflower with this thresher would be a bonus to farmers. The machine was observed to be easy to transport (weight nearly 50 kg), simple and easy to operate without any undue vibrations. There were no breakages or any other problems during all these trials.

Thus this low cost (maximum cost would be Rs. 800) of the manually operated sunflower thresher has shown a best quality operation. The threshing and cleaning efficiencies were of high order. The losses were minimum with no visual damage to the grain. It allowed threshing immediately after maturity i.e., at 22% moisture content, requiring no rigorous sun-drying. Because of this, the crop involves no risk of theft, damage from birds or rain. It allows fields to be harvested early and early field operations for the next crop. It reduces labour, time and expenditure of the farmers on sunflower threshing.

Conclusions

1) The pedal-operated hold-on type 'Phule sunflower thresher' is a low cost (Rs. 700-800) technology most suited to medium, small and marginal farmers.
2) The threshing and cleaning efficiencies of the machine are 100 and 96 to 98%, respectively.
3) All grain losses in the thresher are within permissible limits.
4) The output capacity is low i.e., about 40 kg. But the thresher permits threshing right after harvesting, without any sun-drying. This avoids losses due to theft, rain, birds, rodents, etc. and no watching charges.
5) The thresher reduces per quintal threshing cost. It is Rs. 13 to 15 as against Rs. 30 to 35 per quintal of the prevailing local methods.

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Development and Performance Evaluation of a Sorghum Thresher


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Abstract

The physical properties of sorghum grain such as moisture content, bulk density, straw-grain ratio, size, angle of inter-granular friction and angle of repose were studied. A sorghum thresher with a capacity of 3.7 q**/h was designed on the basis of physical properties. The thresher was fabricated and evaluated for its performance in-terms of threshing efficiency, cleaning efficiency, visible damage, germination percentage and sieve loss. The results of the test indicate that for optimum performance, the thresher should be operated at a cylinder speed of 400 rpm (10.05 m/s) with cylinder - concave clearance of 7 mm and feed rate of 6 kg/min. The power required for operating the thresher at this combination was 5 kW and the maximum output was 3.2 g/h.

Introduction

Sorghum is grown in every part of the world where the average summer temperature exceeds 20°C and the frost free season is 125 days or more. Indigenous threshing of sorghum crop is one of the most time-consuming, laborious and uneconomical. The existing methods do not encourage high output and often results in low quality product. There is a growing need to provide the farmers with an appropriate sorghum thresher. Keeping a portable microscope with a sorghum thresher was undertaken with the following objectives :

i) To study the physical properties of sorghum grain.
ii) To develop a sorghum threasher.
iii) To test the performance of the thresher in respect of threshing efficiency, cleaning efficiency, visible damage, normal germination and sieve loss at varying feed rates, cylinder speed and cylinder concave clearances; and
iv) To study and recommend the best combination of operating parameters such as feed rate, cylinder speed and cylinder-concave clearance for the capacity and power requirment of the thresher.

Previous work done – The major physical factors limiting the design of a sorghum thresher have been reported in many test reports. Stahl (1950), Stewarts (1968), Hussain et al (1968), Wratten et al (1969), Bhattacharya (1972) and others studied the effect of moisture content on different physical properties of food grains. Nawab Ali (1972), Bist et al (1976), Choudhury (1980), Surya Nath et al (1982) and Murthy and Shri Kant (1983) conducted an experiment to determine the influence of cylinder speed and cylinder-concave clearance affected threshing efficiency.

Equipment and Experimental Procedure

Physical Properties of Sorghum Grain

Before fabricating the thresher it was necessary to develop certain design parameters based on engineering properties of the sorghum grain. These include moisture content, bulk density, straw-grain ratio, size, angle of intergranular friction and angle of repose.

The moisture content of grain was determined on wet basis using oven dry method and heating the samples at 130°C for 18 h (ASAE, 1972). The bulk density was found by weight volume method under natural filling condition. The average straw-grain ratio was determined by weighing the straw and grain after separating the grains from ear heads manually. The size of the grain was obtained by

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* Research Paper No. 5466.
**q = 112 lbs UK

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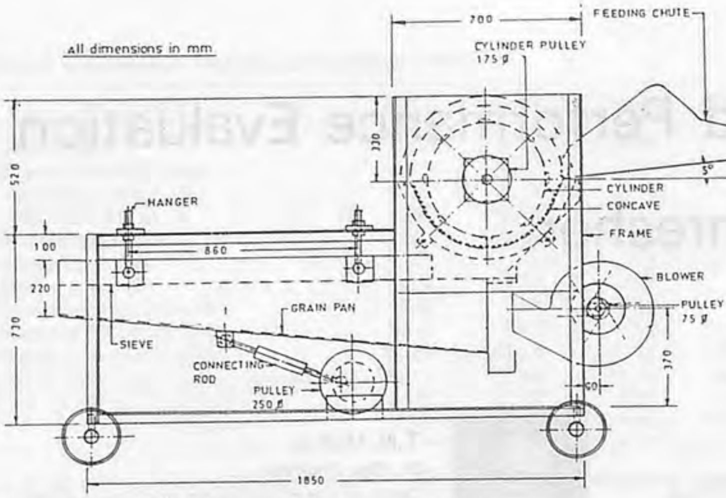

Fig. 1 Functional components of sorghum thresher.

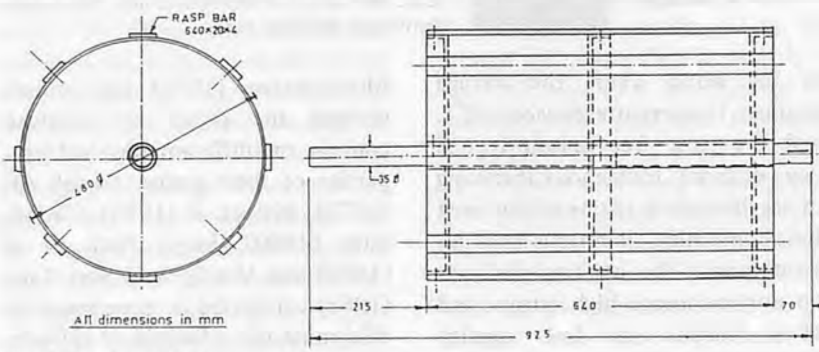

Fig. 2 Raspbar cylinder assembly.

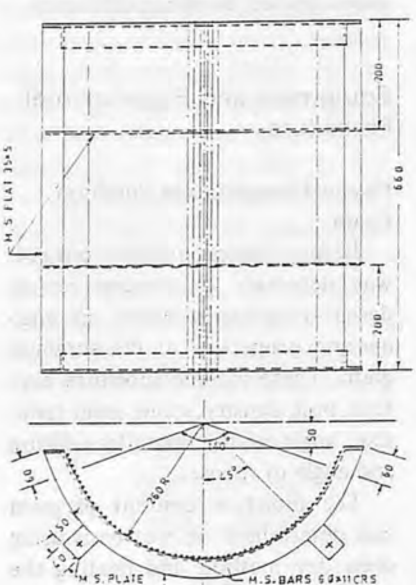

Fig. 3 Concave.

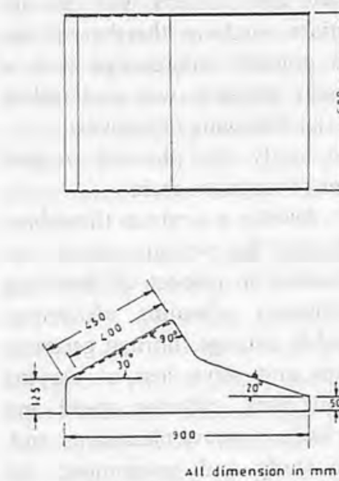

Fig. 4 Feeding chute.

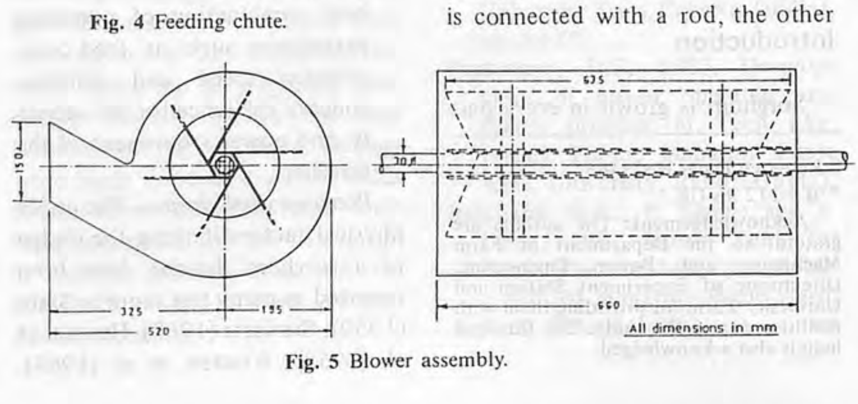

Fig. 5 Blower assembly.

measuring length, width and thickness of the grain from tip to tip using a portable microscope with a magnifying power of ten times. The angle of intergranular friction of the grain was found using direct shear test method. The angle of repose was determined by pouring the grains in a funnel.

Fabrication of Sorghum Thresher

An open concave type of sorghum thresher shown in **Fig. 1** was fabricated in the Department of Farm Machinery and Power Engineering, G.B. Pant University of Agriculture and Technology. The cylinder **(Fig. 2)** is a rasp bar type of 64 cm in length and 48 cm in diameter. It is used with appropriate make of open type semi-circular adjustable concave shown in **Fig.3** covering 140° of cylinder circumference fabricated from angle irons of 35 x 35 x 5 mm size and 6 mm size metal rods with a clearance of 5 mm between metal rods. The feeding chute **(Fig. 4)** was fabricated according to Indian Standard Institution specification using mild steel sheet of 1.6 mm thick which is located 5° above the horizontal cylinder shart axis towards the cylinder. A blower **(Fig. 5)** consisting of six fan blades mounted on a shaft with 30 mm diam. and supported in a roller bearing of length 680 mm and width 480 mm was fabricated from mild steel sheet. The separating section consists of sieve with 6 mm diameter and grain pan inclined at 35° from the horizontal. The bottom side of the pan is connected with a rod, the other

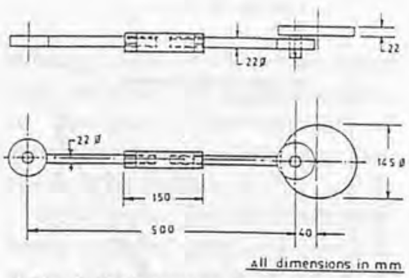

Fig. 6 Reciprocating connecting rod.

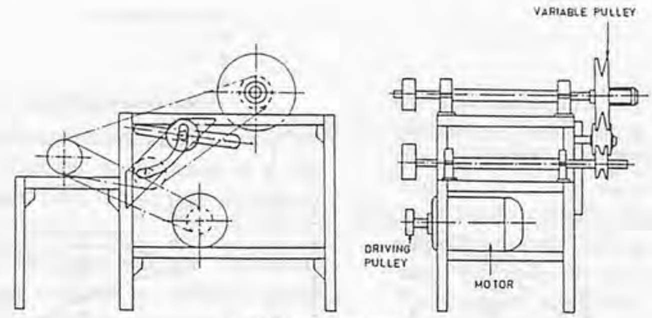

Fig. 7 Speed variator.

and being connected to an eccentric wheel with a diameter of 150 mm made of 15 mm thick mild steel sheet with a hole of 20 mm diameter (Fig. 6). A speed variator shown in Fig. 7 was used for changing the cylinder speed without changing the pulley. Measuring devices like stop watch for time measurement, revolution counter (tachometer) for measuring speeds, triple beam balance and electronic balance were used for weight measurement.

Testing of Sorghum Thresher

A combination of feed rate, F, at 3 levels (6, 8, 10 kg/min), cylinder-concave clearances, C, at 2 levels (7 and 11 mm) and cylinder speed, S, at 3 levels (300 rpm (7.5 m/s), 400 rpm (10.05 m/s), 500 rpm (12.6 m/s) were selected. In all, 18 combinations of F, C and S were formed with each combination replicated thrice. Sorghum ear heads were fed into the threshing unit and the threshed material was collected at the outlets which was cleaned and weighed. The portion of the material containing unthreshed grain was separated from straw and weighed after hand-threshing and cleaning in order to determine the threshing efficiency in terms of percentage of total grain recovered. The formula used for calculating different parameters are as follows:

Threshing efficiency (%) = 100 – (Quantity of unthreshed grain in sample/Total grain in sample) x 100

Cleaning efficiency (%) =

$$\frac{W - w}{W} \times 100$$

where,

W = Total mixture of grain and chaff received at the main outlet (kg)

w = Weight of chaff at the main outlet of the thresher (kg)

Visible damage (%) = (Quantity of broken grains in sample (g) / Total quantity of grain in sample (g)) x 100

Sieve loss (%) = (Free, clean grains collected from sieve sample per unit time / Total grain input per unit time) x 100

Non-visible damage was obtained by applying normal germination test.

Results and Discussion

Physical Properties of Sorghum Grain

The bulk density and straw-grain ratio were determined in order to find the theoretical capacity of the thresher. The size of the sorghum grain was used to decide the distance between two circular rods on the concave assembly and the diameter of the hole on the sieve used for cleaning. The angle of intergranular friction and angle of repose were used to decide the angle of grain pan with respect to the horizontal axis. Based on the laboratory studies the following were found: bulk density, 0.22 g/cc; straw-grain ratio, 1:3; size of sorghum grain, 4.333 mm; angle of intergranular friction and angle of repose, 32° and 33°42′.

Sorghum Threshing

Threshing efficiency – It is shown in Fig. 8 and Table 1 that threshing efficiency increases with an increase in cylinder speed for all feed rates and cylinder-concave clearances. The maximum threshing efficiency of 99.9% was obtained at the lowest feed rate of 6 kg/min, cylinder-concave clearance of 7 mm and cylinder speed of 500 rpm (12.6 m/s). Minimum threshing efficiency of 98.3% was found at lowest cylinder speed of 300 rpm (7.5 m/s), cylinder-concave clearance of 11 mm and feed rate of 10 kg/min. This is because at a higher speed the energy imparted to the ear head and grain increases causing higher threshing efficiency. The reason for lower threshing efficiency at higher feed rate, cylinder-concave clearance and at lower speed is because of the cushioning effect between the cylinder-concave clearance and the low impact force at a low cylinder speed.

Cleaning efficiency – Fig. 9 shows the effect of feed rates and cylinder-concave clearance on cleaning efficiency. It generally appears that cleaning efficiency decreases as the feed rate and cylinder-concave clearance increases for all combinations of feed rate cylinder-concave clearance except at high feed rate coupled with higher speed, i.e.; treatment T_9 ($F_2 C_1 S_3$) and T_{13} ($F_3 C_1$, S_3). This is because with increasing feed rate and cylinder-concave

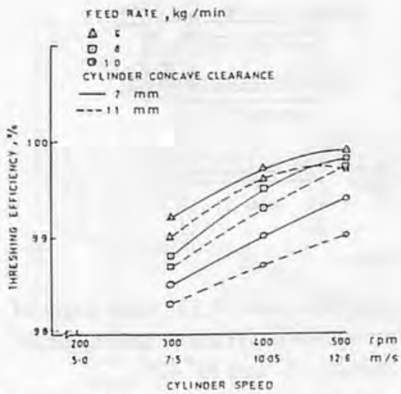

Fig. 8 Effect of cylinder speed, feed rate and cylinder concave clearance on threshing efficiency.

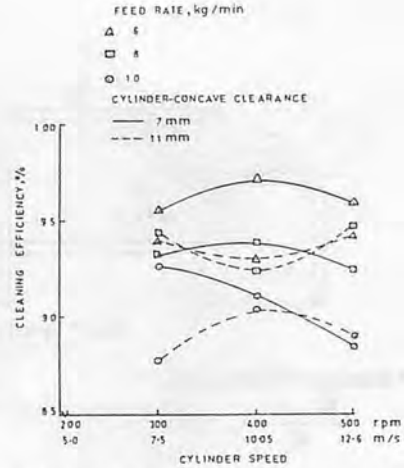

Fig. 9 Effect of cylinder speed, feed rate and cylinder concave clearance on cleaning efficiency.

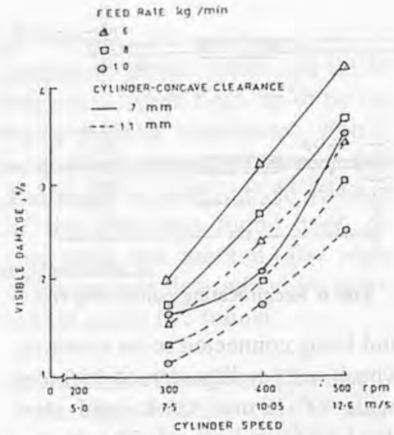

Fig. 10 Effect of cylinder speed, feed rate and cylinder concave clearance on visible damage.

Table 1 Performance Data of Sorghum Thresher at Different Combination of Feed Rate, Concave Clearance and Cylinder Speed

Treatment	Threshing efficiency (%)	Cleaning efficiency (%)	Visible damage (%)	Normal germ. (%)	Sieve loss (%)
$F_1C_1S_1$ (T_1)	99.20	95.60	1.92	90.00	3.82
$F_1C_1S_2$ (T_2)	99.63	97.20	3.24	88.60	4.21
$F_1C_1S_3$ (T_3)	99.90	96.00	4.20	85.30	3.95
$F_1C_2S_1$ (T_4)	99.00	94.30	1.56	92.00	3.69
$F_1C_2S_2$ (T_5)	99.60	93.00	2.40	89.30	3.02
$F_1C_2S_3$ (T_6)	99.70	95.50	3.42	89.30	3.34
$F_2C_1S_1$ (T_7)	98.80	93.20	1.74	93.30	2.85
$F_2C_1S_2$ (T_8)	99.50	94.00	2.64	90.00	3.75
$F_2C_1S_3$ (T_9)	99.80	90.00	3.66	89.30	3.00
$F_2C_2S_1$ (T_{10})	98.70	93.00	1.32	94.70	2.90
$F_2C_2S_2$ (T_{11})	99.30	92.50	1.98	91.30	2.40
$F_2C_2S_3$ (T_{12})	99.70	94.70	3.06	90.06	2.50
$F_3C_1S_1$ (T_{13})	98.50	92.70	1.62	95.30	2.65
$F_3C_1S_2$ (T_{14})	99.00	91.20	2.04	92.00	2.42
$F_3C_1S_3$ (T_{15})	99.40	88.50	3.48	90.00	2.07
$F_3C_2S_1$ (T_{16})	98.30	87.80	1.14	95.30	2.30
$F_3C_2S_2$ (T_{17})	98.60	90.40	1.74	93.30	1.90
$F_3C_2S_3$ (T_{18})	99.00	89.00	2.50	92.00	2.15

clearance, the stream of sorghum ear had passing through the clearance is increasing which burdens the cleaning system. This in turn results into decreased cleaning efficiency. The deviation from the general trend in case of treatments T_9 ($F_2C_1S_1$) and T_{15} ($F_3C_1S_3$) may perhaps be attributed to variation in crop and operating conditions.

Visible damage – **Fig. 10** shows that the percentage visible damage was in the range of 1.12 to 4.22%. The minimum of 1.12% was at feed rate of 10 kg/min, cylinder-concave clearance of 11 mm and cylinder speed of 300 rpm (7.5 m/s). The maximum breakage of 4.21% was at feed rate of 6 kg/min., cylinder concave clearance of 7 mm and cylinder speed of 500 rpm (12.6 m/s). It is evident from the figure that with increase in speed, the visible damage increased. Also, with an increase in cylinder-concave clearance, the visible damage increased. The reason for this is in line with the finding explained in the section above.

Normal germination – **Fig. 11** shows the relationship of the effect of feed rate, cylinder-concave clearance and cylinder speed on sorghum seed normal germina-

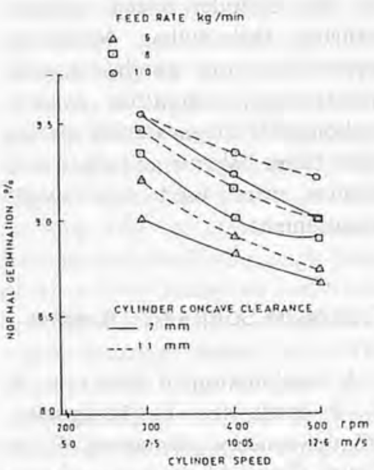

Fig. 11 Effect of cylinder speed, feed rate and cylinder concave clearance on normal germination.

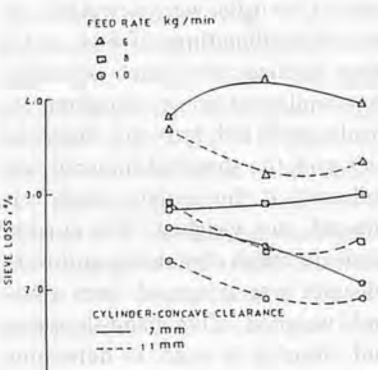

Fig. 12 Effect of cylinder speed, feed rate and cylinder concave clearance on sieve loss.

tion percentage. The germination rate decreased with an increase in speed. The reason for low germination rate at high speed is that the grain is subjected to impact and rubbing forces which in turn cause both external and internal injuries to the grain. The variation of germination percentage was between 85.3 to 95.3.

Sieve loss – The relationship between cylinder speed and sieve loss at varying feed rates is shown in **Fig. 12**. The data are presented in **Table 1**. The curve indicates that the decrease in sieve loss corresponds to the increase in feed rate and cylinder-concave clearance. The sieve loss varied from 1.90% to 4.21% for different levels of feed rates. The minimum loss was observed at feed rate of 10 kg/min and cylinder-concave clearance of 11 mm whereas the maximum loss was at feed rate of 6 kg/min and cylinder-concave clearance of 7 mm. It is because at a lower feed rate, the volume of the material handled by the sieve is low as compared to high feed rate. Thus, the material has a tendency to bounce on the sieve and taken out of the sieve easily whereas at high volume of material, this action is reduced and dwell period is increased. This results in lower sieve loss.

Combination for best performance – The best combination for maximum threshing efficiency, cleaning efficiency and germination percentage with a minimum visible damage and sieve loss was obtained at feed rate of 6 kg/min, cylinder-concave clearance of 7 mm and cylinder speed of 400 rpm (10.05 m/s).

The maximum output (capacity) and power requirement for operating the thresher at the best combination was 3.2 q/h and 4.95 kW, respectively.

Conclusion

1. Threshing efficiency increased with an increase in cylinder speed for all feed rates and cylinder-concave clearances. The threshing efficiency was found in the range of 98.3 to 99.9%.
2. Cleaning efficiency and sieve loss were observed to increase at a decreasing feed rate and cylinder-concave clearances.
3. Visible grain damage decreased with an increase in cylinder speed and with the decrease in feed rate and cylinder-concave clearance. It was observed in the range of 1.12 to 4.22%.
4. Germination percentage increased with a decrease in cylinder speed and increase in feed rate and cylinder-concave clearance. The germination percentage ranged between 85.3 and 95.3%.
5. The best combination of feed rate, cylinder-concave clearance and cylinder speed in order to obtain the higher threshing efficiency, cleaning efficiency and normal germination percentage was treatment T_2 ($F_1 C_1 S_2$), with a combination of 6 kg/min feed rate, 7 mm cylinder-concave clearance and 400 rpm (10.05 m/s) cylinder speed. The thresher is, therefore, recommended to work at the above combination for its best performance.
6. At the recommended speed for 400 rpm (10.05 m/s), the power required for operating the thresher was 4.95 kW. Therefore, it can be operated by a 5 kW electric motor.
7. The maximum output of the thresher was 3.2 q/h.

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Development of Power-operated Groundnut Sheller

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Abstract

The design of power-operated groundnut sheller developed at AIT, Bangkok in 1984 was modified to increase shelling efficiency and capacity and to reduce breakage of kernels and power consumption. The best performance of the sheller was achieved at 180 rpm shelling cylinder speed and 18 mm concave clearance with feed rate of 400 kg/h of pods at 13% moisture content (db). The shelling capacity, shelling efficiency and breakage were 280 kg/h, 98.05 and 4.53%, respectively. The power consumption with one motor was 0.75 kW. The minimum planted area to own the machine should be 7.4 ha. The manual sheller should be replaced by power operated one when annual shelling is more than 6.25 tons.

Introduction

The groundnut shellers can be classified as manually-operated or power-operated depending on their power source. Based on shelling action, the shellers can be divided into reciprocating type and continuous or rotary type.

Manually-Operated Groundnut Shellers

A semi-rotary type groundnut sheller (Fig. 1) was originally developed at the Tropical Products Institute and is now produced in many countries. It consists mainly of a hopper, wire mesh, shelling bar and reciprocating arm. The hopper is a semi-cylindrical trough. The wire mesh is attached to the bottom of the hopper. The shelling bar is attached to the lower end of the reciprocating arm. It can be activated from the centre within the hopper.

A hand-operated groundnut decorticator (Fig. 2) was originally developed by Dandekar Brothers, Maharashtra (India). It consists of a shelling cylinder which is rotated by hand. It has been modified by the Department of Agricultural Engineering, Khon Kaen University, Thailand.

The UPLB peanut sheller (Fig. 3) was developed at the University of Philippines at Los Baños, Laguna. The shelling unit consists of a stationary hopper with built-in spring-loaded shelling bar and underneath it is a reciprocating slotted screen. It is fitted with a bicycle chain drive and a blower to separate the shells from the kernels. Its capacity is about 40-80 kg/h.

A foot operated groundnut sheller (Fig. 4) was developed by Hindsons Private Ltd., Punjab (India). It is fitted with a fly wheel for easier operation and a blower to separate shells from kernels. It is operated by one person and has a capacity of 25 kg/h.

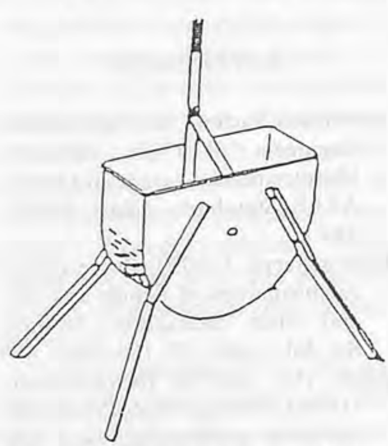

Fig. 1 Manually-operated semirotary peanut sheller.

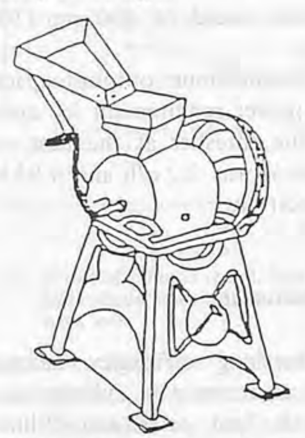

Fig. 2 Hand-operated groundnut decorticator.

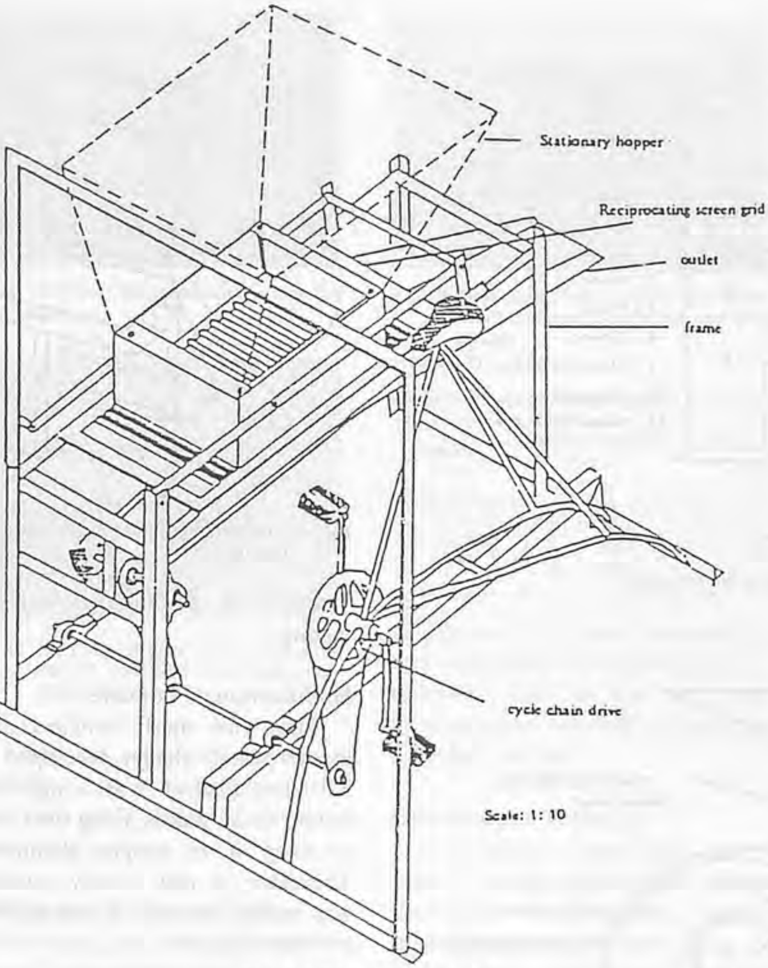

Fig. 3 UPLB peanut sheller.

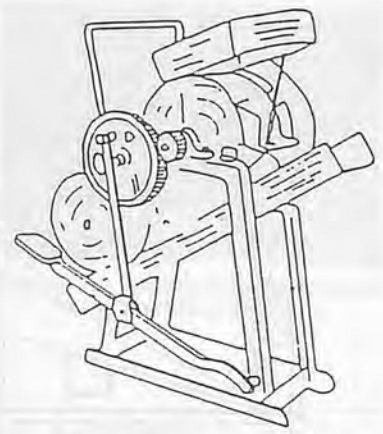

Fig. 4 Foot-operated groundnut sheller.

Power-operated Groundnut Shellers

The TNAU groundnut decorticator (Fig. 5) was developed by the Tamilnadu Agricultural University, Coimbatore, India. The machine consists of a hopper, double crank lever mechanism, oscillating unit and a blower assembly, all fitted to a frame. In the oscillating unit a number of cast iron pegs are fitted. The groundnut pods are shelled between the oscillating unit and a perforated concave sieve. The husk is blown away by a blower and clean kernels are collected through a spout at the bottom. The clearance between the oscillating unit and the concave is adjustable. It has a capacity of 400kg/h of pods or 260 kg/h of kernels. The percentage of breakage, threshing efficiency and cleaning efficiency were 4.5%, 95% and 98%, respectively.

An automatic groundnut decorticating machine (Fig. 6) was manufactured by Harrap, Willinson Ltd., Salford, U.K. It consists of a hopper, beating chamber and cleaning fan. A ribbed feed roller feeds the pods into the beater chamber below. From the feed roller, the pods fall into the beater chamber where these are struck by rotating flexible beaters. The broken shells and kernels are forced out through the perforated cylindrical steel shelling screen. After leaving the beater chamber, the kernels and broken shells fall into a duct which has a wire mesh delivery chute at its lower end. A fan mounted below the mesh blows air up the duct. The draft is sufficient to blow the shells upward and out of the shell outlet spout but will not lift the kernels which continue to fall into the wire mesh delivery chute.

The BPI groundnut sheller with cleaner (Fig. 7) was developed at the Bureau of Plant Industry, Metro Manila, Philippines. It is powered by a 2.2 kW electric motor and has a capacity of 30 kg/h. It has an assembly of three oscillating screens. The groundnuts are fed through a hopper and pass between two rollers with just enough clearance to crack the pods. The shelled and unshelled groundnuts move down the oscillating inclined trough, passing below a suction duct. The kernels radially drop into a secondary trough and then into the container. The shells of the groundnut are sucked upwards by the suction fan and blown into the duct for discharge. This machine could perform shelling without causing damage to the nut.

Kittichai (1984) developed a power-operated groundnut sheller at AIT, Bangkok. The sheller cylinder consists of 12 sets of 10 x 20 cm rubber tire shoes which are 30 degrees apart. The diameter and width of shelling bar are 54 cm and 22 cm, respectively. For the optimum performance of shelling, the blower settings were 1 000 rpm blower shaft speed and 30 degree blower chute angle. The best performance of the sheller was achieved at 20 mm clearance and shelling bar speed of 180 rpm. At these settings capacity, shelling efficiency and percentage breakage were 210.5 kg kernels/h, 98.0% and 5.3%, respectively. The power consumption of the sheller was about 1.0 to 1.1 kW.

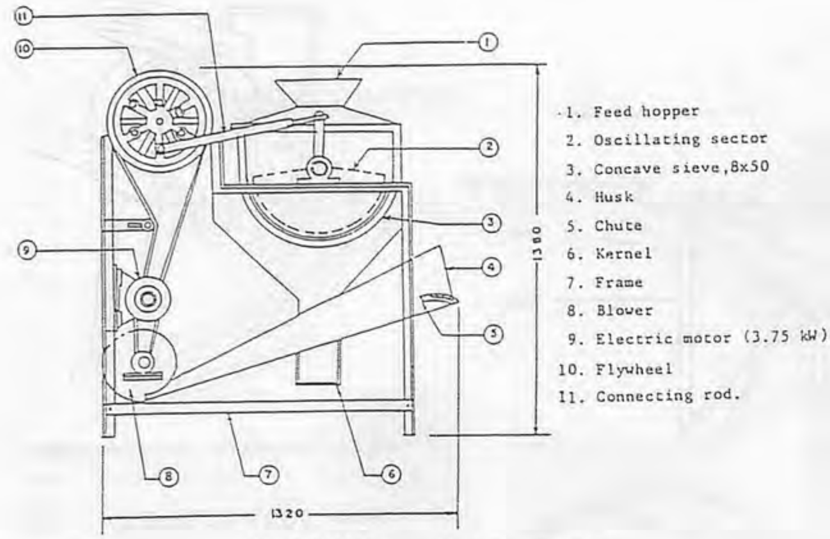

Fig. 5 TNAU groundnut decorticator.

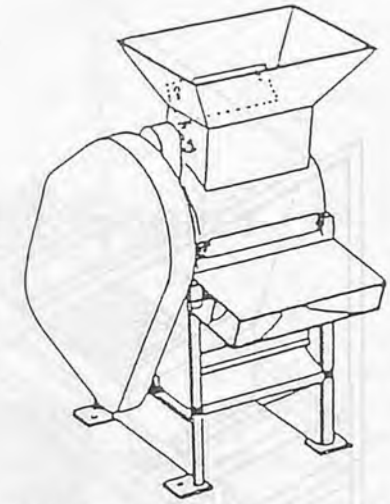

Fig. 6 Automatic groundnut decorticating machine.

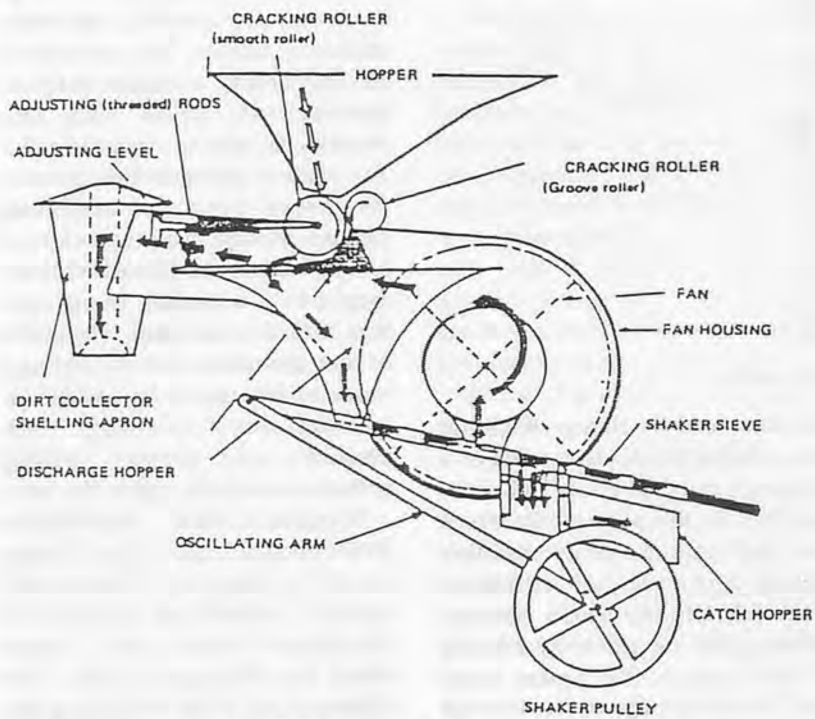

Fig. 7 BPI peanut sheller with cleaner.

Objectives

The research project was undertaken with the following objectives:

1. To modify the components in the peanut sheller developed by Kittichai (1984) for better performance.

2. To design and develop a power operated groundnut sheller with mechanism to separate good, broken and immature kernels and unshelled pods; and

3. To make comparative cost analysis of the power-operated sheller with a manual sheller.

Materials and Methods

The average size of groundnut pods used in the shelling test was 27 mm in length and 12 mm in diam. The distribution of large, medium and small size of the groundnuts were 51, 37, and 22 percent of the total pods, respectively. **Fig. 8** shows different varieties of groundnut used for testing.

Modification of Concave

The wire mesh concave used in the peanut sheller developed by Kittichai (1984) was rough and bolted at 32 places along the frame to keep it in proper alignment. Therefore, a new sturdy concave was made with radial bar spacing of 9 mm (**Fig. 9**).

Development of Sieve Assembly

Screens with slots along the direction of oscillations were tried (**Fig. 10**). Slot size were 85 x 5 mm. The G.I. sheet used was of 1.5 mm thickness. Blockade was found to be reduced as the oscillating motion pushed the seeds forward. But still the seed separation or grading was not efficient due to mesh load on the screens. To reduce the load, a set of three trays of size 62 x 30 x 3.7 cm were made. The screens were then fitted into the trays. The screens are replaceable to suit various varieties of groundnut. The first screen scalps the unshelled pods and other impurities more than 9 mm to the left outlet. The second screen grades good kernels from 9 to 5 mm in dia. from the rest of the mass to the front outlet while the third screen isolates broken and immature kernels with less than 5 mm diam. from the remaining mass. Trials were taken

Fig. 8 Varieties of groundnut used for testing.

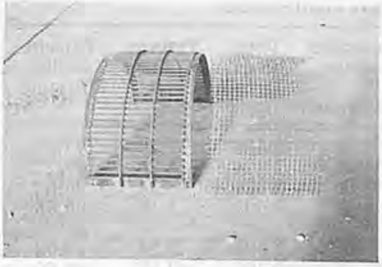

Fig. 9 New radial bar concave and wire-mesh concave used in the previous design.

Fig. 10 G.I. sheet screens with slot along the direction of oscillation.

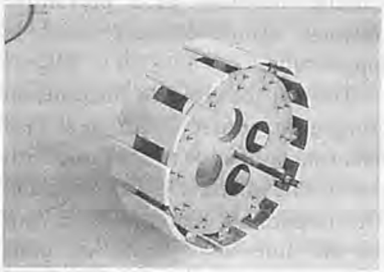

Fig. 11 Shelling cylinder fitted with shoe rubber sole pad with cushoning material.

Table 1 Levels of Independent Parameters

Serial No.	Shelling cylinder speed (rpm)	Cylinder concave clearance (mm)	Kernel moisture content (%)	Feed rate (kg/h)
1	S_1 = 160	C_1 = 14	M_1 = 7	F_1 = 340
2	S_2 = 180	C_2 = 16	M_2 = 13	F_2 = 400
3	S_3 = 200	C_3 = 18	M_3 = 20	F_3 = 460

for optimum range of speed of oscillation and, accordingly, the belt size and pulley sizes were determined.

Modification of Blower Chute

The width of blower chute was greater in the original design, which resulted in the loss of air volume and needed higher rpm of the blower speed, requiring more power for the same cleaning. The width of the blower chute was reduced and a wire-mesh 10 x 10 mm was fitted inside to control the blower loss.

Shelling Cylinder Rasp Bars and Hopper

Air cushioning pad was placed between shoe rubber sole and rasp bar plate. The curvature to the rasp bars was made uniform to facilitate better shelling action (Fig. 11). This type of rasp bar worked satisfactorily as shoe rubber sole had adequate elasticity and rough surface for breaking the pods without slipping. A new hopper with 5 kg capacity and 57° inclination with the horizontal was made.

Screw Mechanism for Clearance Adjustment

For proper and easy adjustment of clearance, a screw mechanism was developed. By screwing or unscrewing, one can vary the clearance between concave and shelling cylinder rasp bars.

Experimental Technique

Performance trials were undertaken after incorporating the abovementioned modifications. In the shelling mechanism test, 4 kg of groundnuts were filled into the hopper in each test in three continuous runs. The feed rate was varied by· the flap arrangement inside. The shelling bar speed was adjusted by a variable speed motor and clearance by a screw mechanism. Power and time for shelling were recorded. For these tests, the product was analysed for shelling efficiency, percentage of breakage and shelling capacity. The moisture content of the pods was varied by natural drying in the sun and shade.

In the cleaning mechanism test, 4 kg of groundnuts were fed in three continuous runs. A sample was taken aftter finishing each run. Blower speed and blower chute inclination were set and power consumed was recorded in every test.

The shelling cylinder speed (S), cylinder concave clearance (C), kernel moisture content (M) and feed rate (F) were taken as independent parameters for the study (Table 1).

Percent shelling efficiency, percent breakage of the kernels, capacity and power consumption were taken as dependent parameters for the study in order to determine the optimum values for better performance.

Shelling Performance Index (SPI)

This measure was used to compare the relative shelling performance of various shellers under identical conditions or to determine the overall performance of a particular sheller under various operating conditions.

$$\text{SPI} = \text{Shelling efficiency} \times \text{capacity} \times \left(1 - \frac{\text{Percentage breakage}}{100}\right) / \text{Power (kW)}$$

Results and Discussion

Table 2 shows that after modifying the concave and hopper, the shelling efficiency increased considerably, the power consumption was also reduced but the breakage was not much affected. Moreover, as the rear end clearance was reduced to 1/2 of the front end, shelling improved. Figs. 12 and 13 show the shells blown with wire mesh and radial bar concave. The

Table 2 Shelling Performance Tests after Concave Modification

Shelling speed (rpm)	Clearance (mm)	Good seeds (g)	Broken seeds (g)	Immature seeds (g)	Unshelled seeds (g)	Total seeds (g)	Percent breakage	Percent shelling efficiency
160	16	2 488	206	52	79	2 825	7.29	97.20
	18	2 429	169	50	76	2 724	6.20	97.21
	20	2 479	179	55	112	2 825	6.34	96.04
	22	2 414	139	49	90	2 692	5.16	96.66
180	16	2 325	249	52	68	2 694	9.24	97.48
	18	2 388	290	48	70	2 796	10.37	97.50
	20	2 309	222	67	95	2 693	8.24	96.47
	22	2 243	212	77	81	2 613	8.11	96.90
200	16	2 285	336	60	52	2 733	12.29	98.10
	18	2 072	483	75	65	2 695	17.92	97.59
	20	2 052	339	44	65	2 500	13.56	97.40
	22	1 997	268	35	70	2 370	11.31	97.05

Fig. 12 Shells blown with wire mesh-type concave.

Fig. 13 Shells blown with radial bar type concave.

quantity of shelled pods in unit time was greater. For unit mass of pods, the power consumption and time of shelling were low.

Fig. 14 shows the general view of sieve assembly. It will be shown that for the 180 rpm of the shelling cylinder, 280 rpm of sieve assembly shaft was satsifactory for separation and grading. The proper angle of inclination for top, middle and bottom screens were 8°, 5°, 13°. Small broken hulls, soil particles and very immature kernels passed easily through the third screen which had round holes of 5 mm diam.

The cross-belt arrangement from shelling cylinder shaft to sieve assembly was effective for uniform movement of the material along the screens. Alternatively, the cross belt arrangement may be replaced by an intermediate shaft, pulley, belt and bearing assembly as a preventive measure against excessive wear in longer runs.

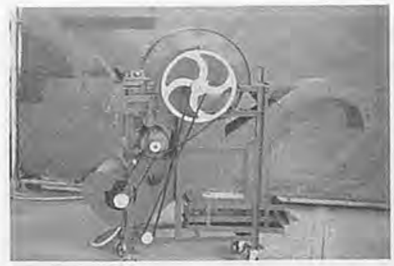

Fig. 14 Power-operated groundnut sheller.

The impact given to the pods on coming in contact with new rasp bars (made of shoe rubber sole with cushioning material) was minimal. The cushioning material took care of the uneven layering of pods while crushing and enabled to shell at lower clearance, resulting in higher capacity and higher feed rate. In general, breakage was low as compared to rasp bars made of rubber tyre material used in the prototype model.

Maximum shelling efficiency was found at 200 rpm at 14 mm clearance **(Table 4)**. **Fig. 15** shows that as the clearance increased, shelling efficiency decreased. Similarly, shelling efficiency was significantly affected by feed rate and moisture content.

Shelling efficiency decreased, in general, with the increase in moisture content **(Table 4)**. With increasing moisture content, shelling

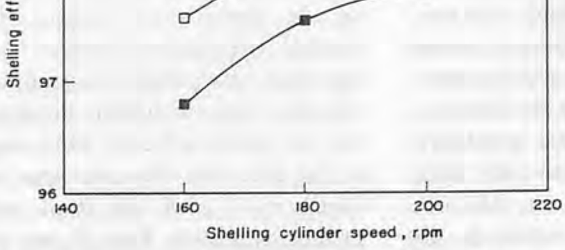

Fig. 15 Shelling efficiency vs shelling cylinder speed at different concave clearances.

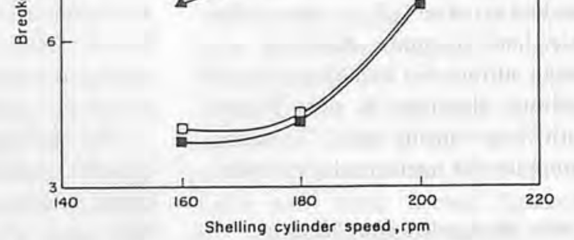

Fig. 16 Effect of shelling cylinder speed on breakage of kernels at various concave clearances.

became difficult because much of the energy received is used for elastic deformation of the pods, hence there was a tendency for low breakage of pods with increased moisture content.

Fig. 16 shows that as shelling speed increased, breakage increased for the same clearance, feed rate and moisture content. The increase was due to the high impact force imparted to the pods during shelling process at high speeds.

With increased clearance, the percentage breakage was reduced at all speeds. In general, higher feed rate resulted in higher breakage percentage at all clearances and shelling bar speeds and moisture contents. The higher breakage may be due to clogging of the material in the cylinder concave assembly at higher feed rates and greater bruising of kernels by rubbing between the layers of unshelled and shelled pods in the concave (Table 3).

Fig. 17 shows that shelling capacity, in general, increased with increasing feed rate at the same clearance and shelling speed. Fig. 18 shows that power consumption has increasing trend with increases in feed rate at all combinations of the other parameters. At 180 rpm and feed rate of 400 kg/h for con-

Table 3 Relationship between Shelling Cylinder Speed and Percent Breakage for Various Levels of Concave Clearances, Feed Rates and Moisture Contents

Shelling cylinder speed (rpm)	Clearance = 14 mm			Clearance = 16 mm			Clearance = 18 mm			Clearance = 20 mm		
	F1	F2	F3	F1	F2	F3	F1	F2	F3	F1	F2	F3
	Moisture content = 7% (w.b.)											
160	11.67	11.86	11.90	8.51	8.68	9.14	8.03	8.11	8.13	7.04	7.25	7.75
180	12.36	12.93	13.26	9.55	9.86	10.22	7.93	8.59	9.41	7.82	7.75	8.38
200	12.83	13.32	13.82	11.58	11.65	11.90	9.62	10.36	11.32	8.18	9.23	10.30
	Moisture content = 13% (w.b.)											
160	8.25	8.74	9.33	5.88	6.75	6.79	4.05	4.24	4.54	3.40	3.95	4.21
180	8.69	9.89	10.82	7.24	7.66	8.24	4.16	4.53	4.89	3.98	4.40	4.64
200	9.78	10.65	12.16	8.15	8.63	10.27	6.78	6.87	7.20	6.59	6.75	6.99
	Moisture content = 20% (w.b.)											
160	11.33	12.17	13.26	11.07	11.41	12.46	9.26	10.49	11.41	9.09	10.15	10.62
180	13.65	13.76	14.27	12.45	13.53	13.65	9.64	12.72	13.41	9.31	11.72	11.87
200	14.59	14.63	15.73	13.55	13.74	14.55	11.32	13.04	14.45	10.61	11.61	12.80

Table 4 Relationship between Shelling Cylinder Speed and Percent Shelling Efficiency for Various Levels of Concave Clearance, Feed Rates and Moisture Contents

Shelling cylinder speed (rpm)	Clearance = 14 mm			Clearance = 16 mm			Clearance = 18 mm			Clearance = 20 mm		
	F1	F2	F3	F1	F2	F3	F1	F2	F3	F1	F2	F3
	Moisture content = 7% (w.b.)											
160	98.35	98.29	98.22	98.17	98.14	97.91	97.85	97.71	96.42	97.30	96.90	96.64
180	98.38	98.33	98.24	98.32	98.23	97.93	98.25	98.15	97.58	97.68	97.59	96.98
200	98.56	98.53	98.45	98.37	98.25	98.20	98.32	98.19	97.78	98.28	98.10	97.57
	Moisture content = 13% (w.b.)											
160	98.38	98.22	98.17	98.15	98.13	97.84	97.78	97.65	97.32	96.94	96.79	96.43
180	98.37	98.34	98.16	98.26	98.21	98.90	98.07	98.05	97.51	97.67	97.53	96.86
200	98.47	98.37	98.25	98.28	98.23	98.12	98.20	97.96	97.67	98.11	97.82	97.47
	Moisture content = 20% (w.b.)											
160	98.28	98.19	98.10	98.11	98.04	97.74	97.32	97.56	97.25	96.76	96.65	96.39
180	98.29	98.23	97.97	98.24	98.10	97.78	97.89	97.79	97.35	97.45	97.23	96.77
200	98.41	98.29	98.17	98.26	98.15	98.02	98.14	97.87	97.56	97.86	97.62	97.38

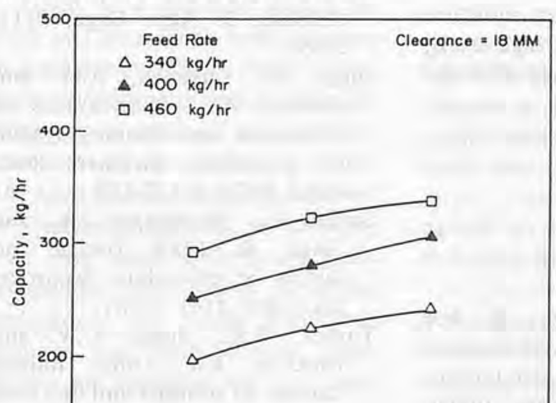

Fig. 17 Capacity variations with shelling cylinder speed for different feed rates at 18 mm concave clearance.

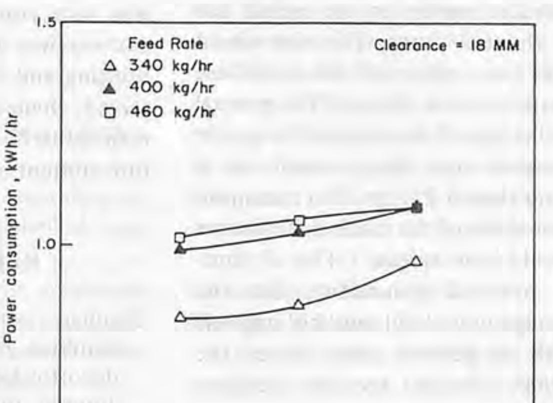

Fig. 18 Power consumption variation with different feed rates and at 18 mm concave clearance.

cave clearance 18 mm, the power consumption was 0.75 kW.

Comparative Cost Analysis

The cost of shelling using power-operated sheller was compared with that of the manual sheller. The shelling capacity of both shellers, 280 kg (kernel)/h for power-operated sheller and 40 kg (kernel)/h for manual sheller were used in the calculations of operation cost. The manual sheller was assumed to be operated in conjunction with a winnower which had a cleaning capacity of about 280 kg (kernel)/h.

A survey of farmers in Thailand indicates that the average planted area per household was 0.48-0.64 ha, with an average yield of 1 200 kg/ha.

For the manual sheller and winnower, the labour requirement were one and two men, respectively. The labour requirement for the power-operated sheller was two men, one for feeding groundnuts into the hopper and another for packing the kernel output.

Fig. 19 shows the relationship between the total cost of shelling per ton and annual use in tons per year. The operation cost of manual sheller with winnower was approximately double that of the power operated sheller at the annual use of about 23 tons. The cost would have been reduced if the annual use was more than 23 tons. The manual sheller should be replaced by power operated one when annual use is more than 6.25 tons. For minimum annual use of the sheller, the farmer should have at least 7.4 ha of planted area of groundnut. But the average household land holding was 0.48 to 0.64 ha only, hence the farmer should try for custom-renting or cooperative ownership.

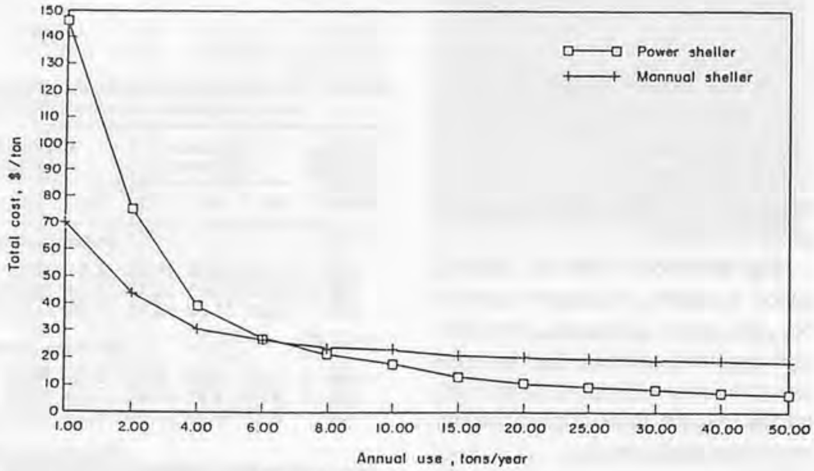

Fig. 19 Total cost vs annual use.

Conclusions

1. The performance of the sheller was improved by using the grate type round bar concave instead of wire mesh concave.

2. The concave front and rear end clearances kept in the ratio of 2:1 had considerable effect for better shelling.

3. The slotted screen assembly was worked well at 280 rpm, when shelling cylinder shaft speed was 180 rpm. Kernels were graded according to whole, broken and immature kernels.

4. The rubber shoe sole pod with cushioning material pasted on the rasp bar gave the best result by reducing breakage.

5. As the moisture content decreased below 10% or increased more than 15%, the breakage was considerable. Splitting of kernels was very common when moisture content was low but at high levels, bruising and hull damage were observed, hence shelling is recommended to be done at 10-15% moisture content range.

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Bin-drying Shelled Corn with Natural Air in Beijing, China

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Abstract

Bin-drying shelled corn with natural air in Beijing, China was simulated by using a computer utilizing weather records as input. Minimum airflow rates which dry grain to a moisture equal to or less than 15.5% with a maximu dry matter loss of 0.5%, were determined at initial moisture contents of 18%, 20%, 24%, and 26%, harvest dates of September 10, 20, and 30, and grain bed depth of 3.6 m and 5.2 m.

Introduction

Grain is a primary source of food in China. With rapid increase in grain production in recent years, grain spoilage and germination in storage as a result of poor and inadequate drying and storage facilities have become a major problem in Chinese agriculture. In the past, grain was sold to the state grain companies after being harvested and dried, but today individual farmers and some private grain dealers are searching for their own grain drying and storage systems for surplus grains. Unfortunately, until recently proper systems have not been used on small country farms or by private grain dealers. The predominant method of drying grains is still to spread the grains on the ground and dry by sunlight and natural wind. It has risk of spoilage and germination due to rain or humid weather. About 5 to 10% of total corn yield is lost each year because of spoilage and germination (Cao 1984, Rannfelt 1982).

Fossil fuels such as coal, gas and oil are expensive in China. In the northern part of the country, the weather is relatively dry and cool so that a natural-air in-bin drying system may be better adapted than drying systems which use fossil fuels. Natural-air systems may simplify the drying equipment, reduce initial investment, lower operation cost and save energy.

Objectives

The specific objectives of this study were:

1. To evaluate the feasibility of natural air bin-drying shelled corn in Beijing, China; and
2. To determine the minimum airflow rates at different initial moisture contents, harvest dates and grain depths of corn.

Computer Simulation

Natural air corn drying is widely used the U.S. corn belt. Data for design of systems is available (MWPS 1980). Design data was developed through the use of computer simulation utilizing weather records as input. A state-of-the-art natural air drying simulation program (NADWIS) is available on the mainframe computer at Iowa University (Wilcke 1985). NADWIS was used to simulate natrual air bin-drying shelled corn in Beijing, China.

Weather Data

Average daily dry bulb temperatures and average relative humidities of each 10-day period over years from 1951 through 1980 in Beijing area were obtained from the Beijing Weather Bureau. The weather data was used as input to NADWIS. Because data was the average of 30 years, simulation results would be generally applicable to describing the drying process in this area, although it would not simulate variations among years.

Corn Harvest Data and Initial Moisture Content

Corn is usually harvested in September in Beijing City and Hebei Province. Therefore, Sept. 10, 20 and 30 were assumed as three harvest dates in the computer simulation. Corn initial moisture content is dependent on harvest date, temperature and relative humidity. The usual range of corn moisture content at harvest is between 20% and 24% (wet basis is used). In unusual years the harvest moisture could be as low as 18% and as high as 26%. These four initial moisture contents were used in the simulation.

Bin Diameter

A 5.5-m (18-ft) diameter bin, as used in Wilcke's field experiment, was selected because it is a common size.

Corn Bed Depth and Quantity

Grain bed depth has a large influence on fan input power requirement. 3.6-m (11.8-ft) and 5.2-m (17.2-ft) bed depths were used to match the 5-ring and 7-ring bins which Wilcke used in his experiment. Dry matter metric tons of corn in bin were predicted from bulk density and initial moisture content. Bulk density was estimated from Wilcke's work (Wilcke, 1985).

Initial Airflow Rate and Fan Input Power

To evaluate the effect of airflow rate on the drying process, several intial airflow rates were simulated: 0.3, 0.7, 1.3, 2.1, 2.6, 3.2, 3.7, 4.6 and 5.3 m^3/min/t (0.2, 0.5, 1.0, 1.6, 2.0, 2.4, 2.8, 3.5 and 4.0 cfm/bu). Airflow was assumed to vary during the drying process, according to Wilcke's observed results.

It was assumed that any size of fan was available. Electric power input to the fan was estimated from Wilcke's field experiment 1982 to 1983 (**Table 1**).

If the airstream passes over the fan and the motor prior to entering the corn, it will be heated due to fan and motor inefficiencies. It was assumed that the overall efficiency was 0.425, which was used by Wilcke (1985). Air temperature rise was based on the efficiency (1-0.425) and the electric input power.

Table 1 Fan Input Power Requirement (kW)

MC_i*	Airflow** (m^3/min/t)	3.6-m bed Power (kW)	3.6-m bed Dry matter (t)	5.2-m bed Power (kW)	5.2-m bed Dry matter (t)
18%	0.3	0.02	46.9	0.06	68.4
	0.7	0.17		0.62	
	1.3	0.94		3.46	
	2.1	2.99		11.04	
	2.6	–		–	
	3.2	–		–	
	3.7	–		–	
	4.6	–		–	
	5.3	–		–	
20%	0.3	0.02	46.1	0.06	67.2
	0.7	0.17		0.62	
	1.3	0.92		3.41	
	2.1	2.95		10.90	
	2.6	–		–	
	3.2	–		–	
	3.7	–		–	
	4.6	–		–	
	5.3	–		–	
24%	0.3	–	44.7	–	65.2
	0.7	–		–	
	1.3	–		–	
	2.1	2.64		9.76	
	2.6	4.58		16.94	
	3.2	7.19		26.58	
	3.7	10.52		38.91	
	4.6	–		–	
	5.3	–		–	
26%	0.3	–	44.1	–	64.3
	0.7	–		–	
	1.3	–		–	
	2.1	–		–	
	2.6	–		–	
	3.2	6.39		23.63	
	3.7	9.35		34.58	
	4.6	16.22		60.02	
	5.3	22.56		83.45	

*Initial moisture content of grain corn, wet basis; **Initial airflow in m^3/min/t of grain

Final Moisture Content and Drying Period

The usual market moisture content of 15.5% was used. Drying simulation continued until the moisture content of the wettest layer was equal to or less than 15.5%, or until Dec. 16, the winter shutdown date, whichever occurred first. After winter storage and if the grain was not dried, drying restarted on March 1 and continued until moisture criteria was met or until June 1. Weather becomes warm after June 1 and dry matter decomposition would increase rapidly if wet grain dries with low airflow.

Layers Simulated and Time Length

Ten layers were selected for sufficient accuracy. A great number of layers increases computer time and cost. A time period of 24 h was used in the simulation.

Stirring Option

To lower investment, it was assumed that the grain drying system was not equipped with a stirring device so that no grain mixing occurred throughout the drying process.

Simulation Results and Discussion

During the process of natural air bin-drying corn, moisture content decreased and dry matter decomposition increased simultaneously. The criteria for determining minimum airflow rate was that all the grains in the bin were dried to a moisture equal to or below 15.5% with maximum dry matter loss of 0.5%.

Without stirring, the maximum moisture and maximum dry matter decomposition happened in the top layer. As drying began, the bottom grain layer gave up moisture first and quickly became in equilibrium with entering air temperature and relative humidity. The moisture content varied through grain layers in a pattern as shown in **Fig. 1**. It indicated a drying zone moving up during the drying process.

Minimum airflow rate varied with initial moisture content, bed depth and harvest date of grain. From simulation outputs, minimum airflow rates and energy consumption were estimated by interpolation or extrapolation and recommended as shown in **Table 2**.

Bin with grain bed depth of 5.2 m required fewer days of finish the drying than bin with a bed depth of 3.6 m. However, this was achieved with higher fan input power and energy cost. Selection of grain bed depth would be dependent on the availability of fans and bins and the initial moisture content of the grain. Deep beds of high moisture grain have the disadvantage of requiring very high fan input power to provide sufficient airflow to avoid spoilage; therefore, energy costs are high.

For deeper grain beds, higher fan input power is required to provide the same airflow. The air temperature rise is higher due to more electric energy input and the fan and motor inefficiencies and the air will take more moisture of the grain. It is then possible that minimum airflow rates of deep beds are lower.

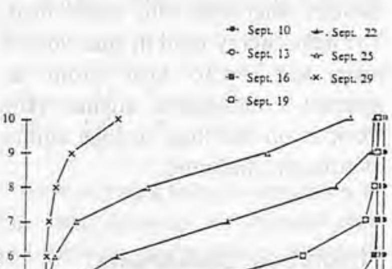

Fig. 1 Natural-air bin-drying corn simulation (corn harvested on Sept. 10 with MCi = 24%; initial air flow = 3.7 m^3/min/t).

Table 2 Recommended Minimum Airflow Rates and the Estimated Eenrgy Costs

MC_i	Harvest date											
	Sept. 10 Bed depth				Sept. 20 Bed depth				Sept. 30 Bed depth			
	3.6 m		5.2 m		3.6 m		5.2-m		3.6 m		5.2 m	
	AR*	EC**	AR	EC	AR	EC	AR	EC	AR	EC	AR	EC
26%	6.2	219	5.9	387	6.1	213	5.7	358	5.1	190	5.0	344
24%	4.5	143	4.2	263	4.1	126	4.0	243	3.2	98	3.0	200
20%	1.5	25	1.3	55	0.9	15	0.9	36	0.7	11	0.7	26
18%	0.7	7	0.7	17	0.7	8	0.7	19	0.7	9	0.7	21

Remark: AR = airflow rate, m^3/min/t; EC = energy cost, kWh/t.

Late harvested grain required a relatively longer drying time. However, the grain spoilage risk was low due to lower outdoor and grain temperatures so that minimum airflow rate was lower. Generally, late harvested grain has lower moisture because natural drying starts in the field. But this may delay the planting of succeeding season crops such as wheat. Also dry matter decomposition starts in the field.

High initial moisture grain required high air flow rates. Increasing airflow resulted in decreasing drying time and deterioration but increasing fan input power and energy cost.

Airflow rates in **Table 2** are recommended. However, deep beds of wet grain make energy costs much higher. Selection of drying systems would depend upon both equipment investment and energy cost of drying.

The minimum airflow rates for relatively dry and late harvested grain might be slightly lower than 0.7 m^3/min/t, which is recommended. In usual humid years, grain may not be dried by June 1 with airflow below 0.7 m^3/min/t. The grain would decompose quickly because of warm weather and insufficient airflow. The recommended airflow 0.7 m^3/min/t would make the drying more safely.

Conclusion

The computer simulation provided a range of data **(Table 2)** for a successful design of bin-drying shelled corn with natural air in Beijing, China. The simulation results indicate that:

1. The deeper grain bed requires fewer days to finish drying process but requires higher fan input power and energy cost.

2. The minimum airflow rate increases as initial moisture content increases.

3. Late harvest lengthens the drying time but lowers spoilage risk and minimum airflow rate.

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Thermal Energy Storage in Concrete and Mud for Crop Storage

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Part I Insulated Concrete and Mud Heat Storage Units

Abstract

Insulated concrete and mud heat storage units in the form of tubes and slabs have been investigated theoretically and experimentally. Solar-heated air and air blown around a hot internal combustion engine were passed through the tubes and slabs.

Fluid exit temperature of up to 90°C was recorded at the end of 5 h. The concrete temperature varied from 116°C to 80°C for the tube and 116°C to 72°C for the slab. Corresponding values for mud tube and slab were 120°C to 92°C and 120°C to 88°C, respectively. The heat stored after 5 h in the concrete tube and slab were 5.75×10^4 and 4.75×10^4 kJ, respectively, while those for the mud tube and slab were 6.20×10^4 and 5.25×10^4 kJ, respectively. The heat stored(Q) with time(t) was found to be related by a formula:

$$Q = A^* e^{-bt}$$

where A* and b are constants. The effectiveness of heat storage increased with increasing time and decreasing storage length.

Introduction

Since the energy crisis of the 1970s energy storage has become important both in developed and developing countries. In the United States of America, state and federal committees studied the energy crisis and recommended means of storing energy and reducing the country's reliance on imported energy. Similar steps were taken in Europe. In the developing world, countries like Ghana responded to the energy crisis by rationing petrol. Research work in other energy and fuel alternatives like solar, wind, geothermal, coal, nuclear and ocean temperature gradients increased. Most research work in the developing countries focused on solar, wind and organic energy.

Most of the studies in the developed countries indicate that energy storage could partly alleviate the energy problem. It is obvious that energy storage will help the developing countries, too. Solar energy and waste heat are available in most developing countries and either a short term or a long term storage of these energies will obviously be beneficial to these countries.

Energy storage units depend on whether the energy is chemical, electromagnetic, kinetic, potential or thermal. The present study is focused on thermal energy storage in concrete and mud slabs and tubes. Thermal energy normally includes steam under pressure, sensible heat of a liquid or a solid, heat of fusion or evaporation, reversible chemical heat of absorption, heat of hydration, heat of chemical change, solar heat and waste heat. The heat energy used in this work is solar and waste heat from an internal combustion engine. The work is on the heat storage ability of concrete and mud.

Theoretical Background

Two types of heat storage units were considered. These are shown in **Fig. 1. Fig. 1(a)** comprises of two rectangular cross-sectioned slabs of concrete or mud separated by a rectangular-sectioned gap through which heated air can pass. Although only two slabs and a gap are considered, it is possible to

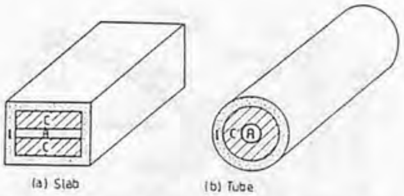

Fig. 1 Heat storage systems: C-concrete or mud, A—air flow, I—insulator.

utilize a series of slabs and gaps as storage unit. **Fig. 1(b)** is composed of a concrete or mud tube through which heated air can pass. The arrangements in **Fig. 1** were insulated as shown.

The energy balance on any of the storage units when the temperature gradients within the concrete or mud is small, may be written as:

$$\frac{R_c d\theta_c}{dt} = HA(\theta_{f1} - \theta_c) \qquad (1)$$

The concrete or mud is then at an approximately uniform temperature. Q_m is obtained when the concrete or mud temperature equals the air temperature. The maximum storable heat, Q_m is:

$$Q_m = R_c(\theta_{f1} - \theta_c) \qquad (2)$$

The actual heat stored is

$$Q = R_c \int_0^t \frac{\partial \theta_c \, dt}{\partial t} \qquad (3)$$

The non-dimensional heat storage or storage effectiveness is defined as:

$$Q^* = \frac{Q}{Qm} = \frac{\theta_{mc} - \theta_o}{\theta_{f1} - \theta_o} \qquad (4)$$

In analyzing the configuration in **Fig. 1(a)**, consider one storage slab and half the gap width as shown in **Fig. 2(a)**. The slabs and gaps (if a series is used), must be identical for the analysis to hold.

Assume constant air density, perfectly insulated concrete or mud, uniform heat transfer coefficient, constant air and material properties, uniform initial temperature distribution in the concrete and mud and a step change in inlet temperature. Then the two dimensional transient heat conduction equation for the concrete or mud and the one dimensional energy conservation equation for the moving air will govern the transient response of the storage unit. The energy equation for the concrete or mud is then:

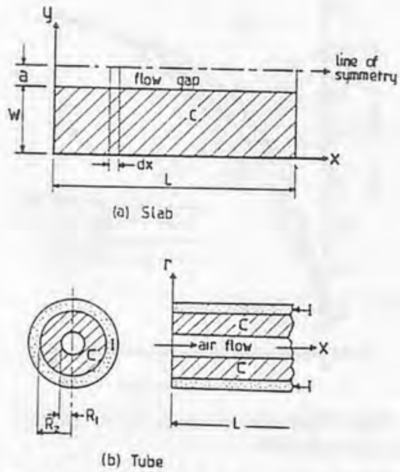

Fig. 2 Cross-section of storage unit: C—concrete or mud, I—insulator.

$$\frac{1}{a_c}\frac{\partial \theta_c}{\partial t} = \frac{\partial^2 \theta_c}{\partial x^2} + \frac{\partial^2 \theta_c}{\partial y^2} \qquad (5)$$

The transformed equations for the concrete or mud and air, using the results of Kays and London (1964) and Schmidt and Szego's (1976) non-dimensional entities, are then respectively:

$$U^2 \frac{\partial^2 T_c}{\partial x^2} + \frac{\partial^2 T_c}{\partial y^2} = \frac{\partial T_c}{\partial E} \qquad (6)$$

and

$$\frac{\partial T_f}{\partial x} + \frac{GB}{U}(T_f - T_u) = 0 \qquad (7)$$

Heat energy lost by the fluid in passing between the slabs is.

$$Q = R_f \int_0^t (\theta_{f1} - \theta_{fo}) dt \qquad (8)$$

Heat energy in concrete or mud is.

$$Q_c = R_c(\theta_{mc} - \theta_o) \qquad (9)$$

In the tubular storage system showin in **Fig. 2(b)**, the concrete or mud and air differential equations, with the assumptions mentioned earlier, are respectively:

$$\frac{1}{a_c}\frac{\partial \theta_c}{\partial t} = \frac{\partial^2 \theta_c}{\partial r^2} + \frac{1}{r}\frac{\partial \theta_c}{\partial r} + \frac{\partial^2 \theta_c}{\partial x^2} \qquad (10)$$

$$\text{and} \quad \frac{R_f L}{HA}\frac{\partial \theta_f}{\partial x} = \theta_c = \theta_f \qquad (11)$$

The non-dimensional equations become (see reference 7).

$$\frac{\partial T_c}{\partial E} = \frac{\phi(1 + U^*)}{2U^*}\frac{\partial^2 T_c}{\partial Z^2} + \frac{1 + U^*}{2U^*B}\left[\frac{\partial^2 T_c}{\partial R^2} + \frac{1}{R}\frac{\partial T_c}{\partial R}\right] \qquad (12)$$

for the concrete or mud, where:

$$\phi = \frac{N^2 V^{*2}}{B}$$

$$\text{and} \quad \frac{\partial T_f}{\partial Z} = T_c - T_f \text{ for the air.} \qquad (13)$$

Work Done

Concrete and mud heat storage models in both slab and tubular forms were simulated with solar heated air and air heated by blowing around an internal combustion engine and its coiled exhaust pipe. The exhaust pipe was coiled to increase its surface area and, consequently, its heat transfer area. The heated air was passed between the slabs and through the tubes to study their heat storage properties.

The concrete and mud slabs measured 550 mm wide by 50 mm thick by 10 m long with a 25 mm gap between the slabs. The slabs were strengthened in the middle with a 25 mm by 25 mm wire mesh, the wires being 3 mm diameter. The inner and outer diameters of the concrete and mud tubes were 50 mm and 250 mm, respectively. These were also

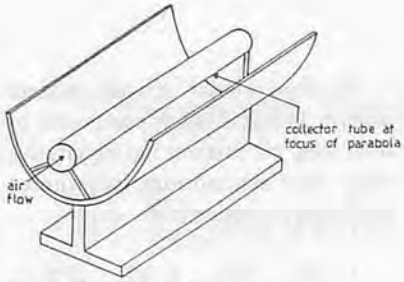

Fig. 3 Parabolic collector.

Table 1 Concrete and Mud Properties Used (Baryeh 1985)

Property	Concrete	Mud
Density (kg/m^3)	2 150.0	1 850.0
Specific heat (kJ/kg°C)	0.825	0.885
Thermal conductivity (W/m°C)	1.082	0.955
Thermal diffusibility	5.966×10^{-7}	5.025×10^{-7}

strengthened as mentioned above. The tubes were 10 m long. Normal concrete composition (Baryeh 1982) and tropical reddish semi-argilous mud (Baryeh 1985) were used for the mud slabs and tubes. Copper-constantan thermocouples were used for temperature measurements.

A parabolic solar collector with reflective metal foil was used (**Fig. 3**). Air inlet temperature was 120°C. Ambient temperature was commonly 27 to 32°C during the tests. The properties of concrete and mud used are shown in **Table 1**. Properties of air used are those given by Weast, Astle and Beyer (1984) and Perry and Chilton (1973).

The air was heated in the collector in **Fig. 3** and was made to flow between the slabs or through the tubes by a centrifugal fan. Fresh air was blown around an internal combustion engine with coiled exhaust pipe to heat up. The heated air was passed between the slabs or through the tubes. Air flow of 5.0 m/s was used. The temperatures and heat stored by the concrete and mud slabs and tubes were measured and calculated. Tables and graphs of non-dimensional parameters presented by Klinkenberg (1954) were used.

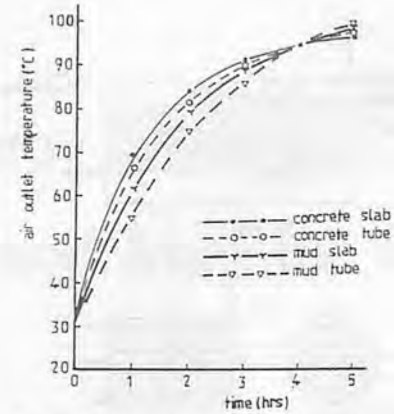

Fig. 4 Experimental air-outlet temperature vs time.

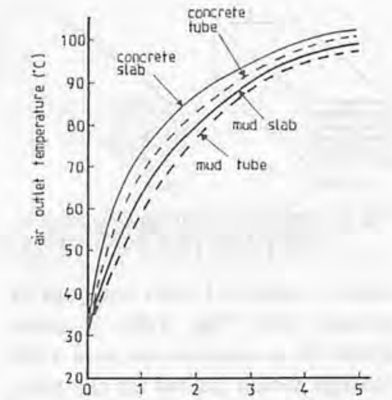

Fig. 5 Theoretical air-outlet temperature vs time.

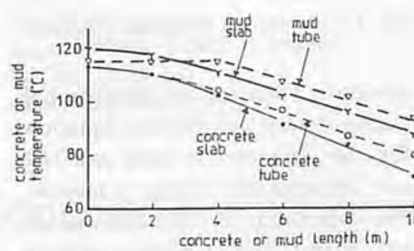

Fig. 6 Concrete and mud temperature vs length after 5 h (experimental).

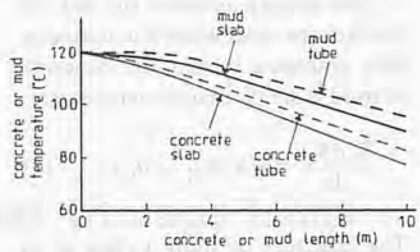

Fig. 7 Concrete and mud temperature vs length after 5 h (theoretical).

Results and Comments

The air outlet temperature as a function of time are shown in **Figs. 4** and **5** for the experimental and theoretical cases, respectively. In both figures, the air outlet temperature increased with time. Initially, the concrete and mud slabs and tubes absorbed heat from the hot air since they are at a lower temperature than the hot air. As they stored heat, less and less heat was absorbed from the air resulting in increasing outlet temperatures. In general, air leaving the concrete slabs and tubes had higher temperatures than those leaving the mud. This suggests, as will be seen again later, that the mud was absorbing more heat than the concrete. At any given time and for both concrete and mud, the theoretical outlet temperatures were higher than the experimental ones. This is because the theoretical curves assume no heat losses. About 4 h after starting, the pattern for the experimental curves changed. The outlet air temperature of the mud storage unit became higher than the concrete temperature. Presumably after 4 h, the mud was then absorbing less heat from the hot air than the concrete. This phenomenon was not demonstrated in the theoretical curves. For both storage systems, the air outlet temperatures for slabs were higher than those of the tubes. This indicates that the slabs absorb less heat than the tubes. This could be due to the smaller surface areas of the tubes. Smaller areas loose less heat than larger areas under the same conditions.

The concrete and mud temperature distributions along their lengths after 5 h are shown in **Figs. 6** and **7** for the experimental and theoretical observations, respectively. Here the mud tube and slab showed higher temperatures than the concrete indicating again that the mud stored more heat than the concrete. The temperatures of the tubes were higher than those of the slabs for both storage materials. After 5 h of operation, the temperatures of the concrete slabs, concrete tube, mud slabs and mud tube were 75°C, 80°C, 88°C and 92°C, respectively. The theoretical curves show slight-

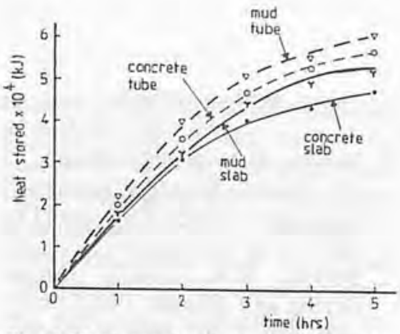

Fig. 8 Heat stored vs time (experimental).

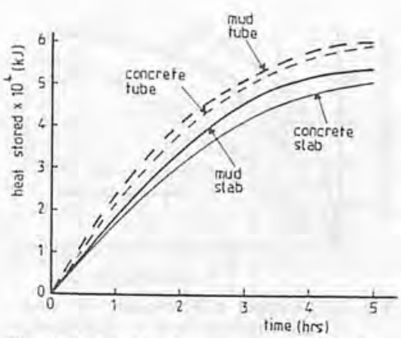

Fig. 9 Heat stored vs time (theoretical).

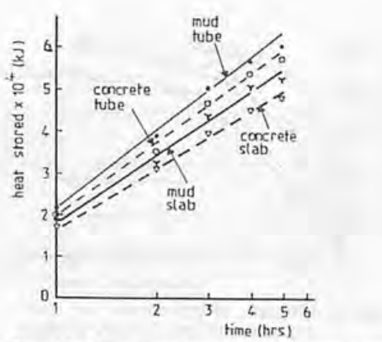

Fig. 10 Heat stored vs time in semi-log scale.

ly higher temperatures than the practical or experimental ones at all stages for both slabs and tubes. This is so because the theory assumes a perfect insulation for both slabs and tubes. For the first 3 m, the concrete slabs and tube had the same temperature. After that, the tube showed higher temperatures up to the end of the length. The mud tube, however, showed lower temperatures than the mud slabs for the first 3 m. Thereafter, the tube demonstrated higher temperatures. This phenomenon was not revealed by the theoretical results. The phenomenon suggests that for some unclear reason, the mud slab rises in temperature more than the tube for short lengths while for the concrete, it appears that for short lengths there is no difference between slabs and tubes as far as temperature rise is concerned. The theoretical values are generally 2°C to 6°C higher than the experimental values.

The heat stored in the systems over a 5 h period are shown in **Figs.** 8 and 9 for the experimental and theoretical situations. Both figures show increases in heat stored with time. At the end of 5 h the mud tube, concrete tube, mud slabs and concrete slabs had stored 6×10^4, 5.75×10^4, 5.25×10^4 and 4.75×10^4 kJ of heat, respectively. The tubes retained more heat than the slabs. This could again be due to the smaller surface area of the tubes which resulted in less heat losses compared to the slabs. In general, the mud retained more heat than the concrete for the same configuration and conditions. This could be due to the lower thermal conductivity, higher specific heat and lower thermal diffusibility of the mud. This type of mud is also used extensively in Ghana for oven construction for baking bread and cakes (Baryeh 1985) In the first 1 or 2 h, the heat stored were not high, yet the air outlet temperature was low. This is because the heat content of the storage systems were so low during this period that although warm fluid passed through them, it took some time for the heat stored to show up.

The heat stored in all the systems in 5 h were very substantial while the hot air passing through the systems still existed with substantially high temperatures. The hot air leaving the system can be used for drying meat, fish and crops while the system stores heat for further drying later or for other usage. The energy storage in such systems may also be used to satisfy other energy requirements. Energy storage devices used in satisfying peak demands (load levelling), for example, have been used extensively in residences and business establishments in Europe (Schmidt and Szego 1976). These systems usually use ceramic storage materials that are electrically heated during off peak periods at a much cheaper energy charge rate.

The heat storage curves in **Fig.** 8 plot linearly on semi-logarithmic sheet as shown in **Fig.** 10. This reveals that the amount of heat stored can be estimated with a formula:

$$Q = A^* e^{-bt}$$

where Q is the heat stored and A* and b are constants depending on the properties of the storage material. A* and b can be determined experimentally.

Figs. 11 and 12 show the respective tube and slab variation of heat storage effectiveness with the non-dimensional time for different values of the non-dimensional concrete or mud heat storage length. It is clear from the figures that the heat storage effectiveness increases with increasing non-dimensional time. The increase was rapid for low non-dimensional time. The heat storage effectiveness increased rapidly up to some point and became assymptotic while it increased with decreasing heat storage length. This shows that short storage lengths are more effective than long ones in the sense that they store a lot of heat in a short time. For both the tube and slab, the heat storage effectiveness for the mud storage units were higher than those of the concrete units for a given length. This again indicates the superiority of the mud over the concrete in storing heat. In general, the heat storage effectiveness for the tubes were higher than those for the slabs for a given length. For a non-dimensional length of 20, the slab storage units displayed a linear relationship between heat storage effectiveness and non-dimensional time up to a non-dimensional time of 20 for both concrete and mud.

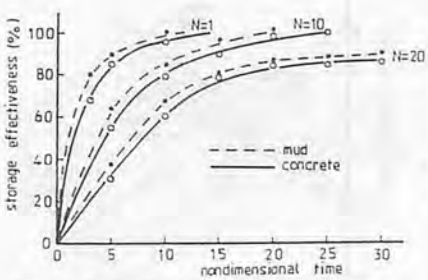

Fig. 11 Storage effectiveness vs non-dimensional time for tube storage.

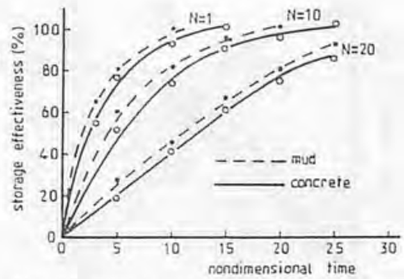

Fig. 12 Storage effectiveness vs non-dimensional time for slab storage.

Nomenclature:

- a_c thermal diffusibility of concrete or mud (m^2/s)
- A heat transfer surface area (m^2)
- B Biot number
- E non-dimensional time
- G non-dimensional quantity
- H convective film coefficient ($W/m^2 {}^\circ C$)
- L length of concrete or mud (m)
- N non-dimensional concrete or mud length
- Q heat stored (W)
- Q_m maximum heat stored (W)
- Q^* heat transfer effectiveness or non-dimensional heat storage
- r radius (m)
- R non-dimensional radius
- R_c flow stream capacity rate ($kJ/{}^\circ C$)
- R_f flow stream capacity rate ($kJ/s^\circ C$)
- t time (s)
- T_c non-dimensional temperature of concrete or mud
- T_f non-dimensional air temperature
- T_{fo} non-dimensional initial fluid temperature
- T_u non-dimensional temperature of contact surface
- U non-dimensional length
- U^* non-dimensional radius ratio
- V^* non-dimensional quantity
- Z non-dimensional radial distance
- θ_c concrete or mud temperature (°C)
- θ_f air temperature (°C)
- θ_{fo} initial air temperature (°C)
- θ_{f1} air temperature at entrance to concrete or mud storage unit (°C)
- θ_{mc} mean concrete or mud temperature (°C)
- θ_o initial temperature (°C)

Conclusion

The experiment has demonstrated that up to 6.0 kJ and 5.75 kJ of heat energy can be stored in tropical semi-argillous mud and concrete over a 5 h period. Air exit temperatures of up to 95°C were recorded in 5 h. This heat is high enough for drying meat, fish or crops or for water heating. The mud was superior to concrete as a heat storage unit. Moreover, the mud is cheap and locally available.

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Part II Storage Set-up for Pepper and Chopped Okro

Abstract

In part I of this study, the thermal energy storage properties of concrete and mud were analyzed. From the results, concrete and mud tubes were selected and used together with storage chambers to study the storage effectiveness of okro and pepper. The results indicate that okro and pepper can be stored up to a period of one year without any serious deterioration.

Introduction

Food storage in developing countries is not as developed and effective as in developed countries. As a result, when many food items become abundant during and shortly after the rainy season, those that are not consumed or stored perish. Consequently, there is scarcity of food in the dry season and food prices go up. There is, therefore, an obvious need to store food for the lean and dry season.

The annual loss of grain from

harvest to use of grain in Africa is as high as 30% of the production (Baryeh 1983). This is more than twice the figure for a developed country like the U.S.A. The loss of fruits and vegetables is as high as 75% (Baryeh 1983). Consequently, the fruit and vegetable intake of the average African is low leading to low vitamin and protein intake. In order to curb this problem, fruits and vegetables need to be stored and made available to consumers in the lean season.

Fruits may be stored by converting them into bottled or canned fruit juices or canned chopped fruit pieces. Vegetables may be steamed and frozen for storage. Electrical power is, however, not available in most rural communities in the developing countries. The common method of preserving certain vegetables is by drying and storing. Such dried vegetables are often not stored properly and they mould and some even germinate during the humid rainy season. An effective storage method is, therefore, necessary for these vegetables. The study presented here looks into the storage of dried okro and pepper.

Okro is used to make soup and other dishes while pepper appears in about 70% of the local dishes in West Africa. More than 60% of the West African population eat okro and pepper. Both crops are cultivated in the humid tropics of West Africa. The annual rainfall at the location of the investigation is 2 800 mm (Gwanfogbe and Melingui, 1988). There are two peaks in the rainfall pattern as shown in Fig. 1.

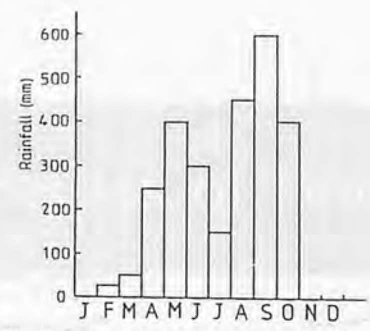

Fig. 1 Rainfall at location of investigation.

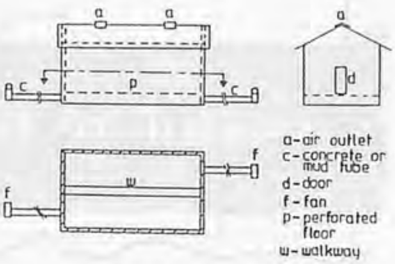

Fig. 2 Storage bin.

Table 1 Characteristics of Tasters

Taster	Age (years)	Height (m)	Weight (kg)	Sex	Occupation
1	25	1.65	65	F	Farmer
2	18	1.60	63	F	Student
3	28	1.75	72	M	Teacher
4	12	1.25	40	M	Student
5	30	1.70	70	F	Typist
6	50	1.62	61	F	Teacher
7	25	1.66	68	M	Mechanic
8	40	1.77	78	M	Farmer
9	27	1.80	75	M	Trader
10	26	1.58	64	F	Trader

Methodology

Pepper harvested in September was dried whole to a storage moisture content of 10% (wb). Some okro was harvested at the same time, chopped and dried to a storage moisture content of 10% (wb). Okro is usually chopped before cooking. Hence the use of chopped okro. Chopping the okro also makes it dry faster. The dried pepper and okro were put in separate jute bags. In mid October, the bags were put in storage bins like those designed and tested by Baryeh (1981, 1985). The bins were connected from the fan to the plenum by mud and concrete tubes (Fig. 2). Tubes were used instead of slabs due to the results obtained in part I of the study.

The crops were aerated in the night from 6:00 PM to 6:00 AM during the rainy season when dew forms on the surfaces of objects more easily. In the dry season, the aeration was done from 9:00 PM to 6:00 AM. The heat stored in the concrete and mud tubes during the day warmed the aerating air. Dried pepper and okro were put in similar jute bags and stored in an ordinary room without any aeration for comparison purposes.

The crops were sampled at ½-week intervals at 10:00 AM and tested for their moisture content, deterioration, germination and taste. Moisture content was evaluated by the oven method. Deterioration, mould growth and germination were determined by observation under a microscope. The samples were used to prepare okro soup and pepper soup for 10 people selected at random to taste. The tasters were medically examined and certified to be normal and healthy and to have normal taste buds and appetites. Their characteristics are shown in Table 1.

Results and Discussion

The moisture content variations for a year are shown in Figs. 3 and 4 for pepper and okro, respectively, for mud tubes. The results for concrete tubes, in general, are 5 to 7.5% higher. This conforms with the conclusion in part I of the study that mud tubes store more heat than concrete tubes.

In general, the moisture content for both pepper and okro did not vary greatly from the initial storage moisture content of 10% throughout the year. During the rainy season when humidities are high, the moisture content was a bit above the initial value of 10%. During this period, the okro had slightly higher moisture contents than the pepper reaching a maxi-

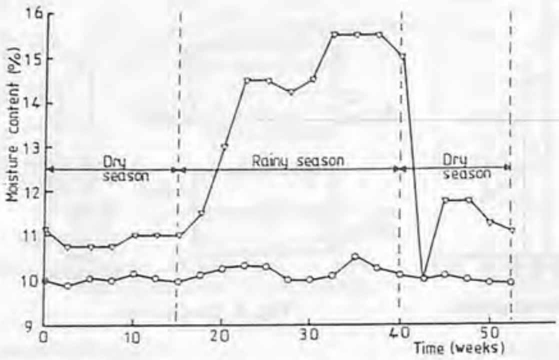

Fig. 3 Moisture content variation for pepper.

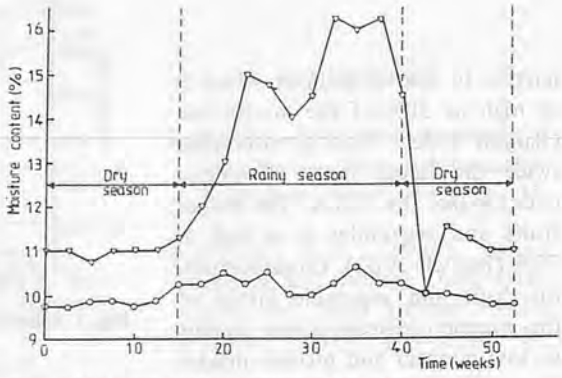

Fig. 4 Moisture content variation for okro.

mum of 10.6% in the second peak of the rainy season. At this same time, the pepper had 10.5% moisture content. The corresponding figures for the first peak of the rainy season are 10.5% and 10.3%, respectively. This may be due to the fibrous nature of the okro and the presence of voids in the okro which could have trapped more moisture in the rainy season. These moisture content values could, however, not promote mould growth and germination as indicated by the samples when they were inspected under a microscope. In the dry season, the moisture content was steady, falling a shade below the initial value at certain times. The okro was noticed to have stayed more below the initial value than the pepper showing that just as the okro easily absorbs moisture into its pores, it easily releases the moisture when aerated. Thus, there was no sign of moulding or germination throughout the year for both aerated crops.

In contrast, the moisture content of the non-aerated crops increased appreciably in the rainy season. The non-aerated okro reached the highest moisture content of 16.25% while the pepper reached 15.5% during the second peak of the rainy season. The okro had a higher moisture content for the reason given earlier. The corresponding values for the first peak are 16.0% and 14.5%. During this period, inspection under the microscope showed mould growth on more than 50% of the crops with the onset of germination on more than 25%. This is a situation which renders the products useless for human consumption. This is obviously due to the humid atmosphere which promotes both mould growth and germination.

Insect attack was negligible. Insects do not usually attack pepper. Only 1.5% of the okro showed signs of the presence of some insects. For other vegetables, like groundnuts, care should be taken to reduce the activities of rats and mice in areas infested by these animals since they feed on such vegetables.

The tasters indicated that the aerated crops tasted good and normal throughout the year. The non-aerated crops, too, tasted good and normal for the first three months of storage. Tasting tests were discontinued on the non-aerated crops in the rainy season when moulds and germination started appearing. This decision was taken due to health reasons. Besides, none of the tasters was prepared to taste a dish prepared from moulded food items. Two of the tasters remarked during the last three tests that the okros had developed a slight flavour which is different from the normal flavour. This, they indicated, did not change the taste. The tasters did not have any differences that could be related to sex, age or profession. The tasters underwent frequent medical check-ups during the tasting period and up to two months after the tasting tests.

Conclusion

The storage set-up presented here has been used successfully to store pepper and chopped okro up to a period of one year without deterioration. It is believed that this storage system can be used to store other crops for use during lean seasons as well as in the harvest season. In this way, the vegetable intake of people in the developing countries will increase and the availability may reduce the prices of vegetables.

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Physical Properties of Peanut in Turkey

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Abstract

A rational approach to the design of peanut processing machinery requires, among others, a knowledge of its physical properties. Foremost among those that affect the design are the properties associated with its geometry. Within such a context this paper deals with the determination of the dimensional properties of peanut as one aspect. This part involves geometric shape, size parameters, size distributions, probability versus dimension, correlation between dimensions, dimensional classification, shell thickness and void. The resulting data of interest for peanuts grown in Turkey is presented and discussed.

Introduction

According to Mohsenin (1970), especially since the 1960s, there has been a growing interest in applying engineering principles in the development of agricultural machinery. A consequence of this trend is that contemporarily more theory is being put into the area of agricultural practice, which has, by tradition, long been heavily empirical in nature. This is most likely to bring about not only a substantial reduction in the time and money spent for the emergence of new types of agricultural machinery but also to contribute to the better operation of the existing machinery already used in the processes of agricultural mechanization. Therefore, a rational approach to the design of agricultural machinery, equipment and facilities will involve a theoretical basis laying down the mathematical and physical foundations which will enable the coupling of the physical properties of the agricultural product with the characteristics of the machinery, equipment, facilities and so forth. This, then, brings foremost the question of determining the physical properties of the agricultural product. Which of the physical properties are of relevance to a particular machine depends on its function. However, there is one property almost inelastic to the variations in the function of the machinery, constantly needed for the processing of the product: this is the geometric property.

In this paper, some essential geometrical properties of peanut grown in Turkey are discussed. This background information is necessary both for establishing geometrical relations between processing machinery and peanut material, and for having a convenient ground in the determination of other physical properties of peanut as well. For instance, the form and dimensions of the holes in sieves which may be used in the cleaning and grading of peanuts are functions of its geometry. Likewise, the ability of peanut to move, the form of its motion, such as sliding and/or rolling and physical properties associated with these such as specific masses, inertias, coefficients of friction are all again functions of its geometry. Behaviour under static and dynamic loading, aerodynamic properties like drag coefficients, projected areas and terminal velocities depend also on the peanut geometry.

In what follows will be given materials and methods in connection with the geometrical properties of peanut, which will involve geometric shape, basic dimensions, size distributions, correlations between dimensions, classification, shell thicknesses and voids. Data resulting therefrom will be presented.

Materials

Peanut materials investigated here are those specified in the Turkish Standards No: 310 (TS-310, 1972), and are of the so-called Anamur, Antalya, Osmaniye and Silifke types.

Geometric Shape

The simplest method of determining the geometric shape of the peanut is direct observation. By this way, Agrawal et al (1973) noted six forms of describing it. Although cassinoid and ellipsoid seem most realistic forms, a much more simpler form is needed in order to provide convenience for theory. Commensurate with most functions of machinery, there is a geometrical model which is both necessary and sufficient to describe peanut and this is that form whereby a peanut is considered as being composed of a cylinder of finite length in the middle and two hemispheres of the same cylinder radius in the ends. One advantage of this model is that it applies equally well to shell and kernel. To what extent this model may be valid will be reviewed after laying down basis for classification.

Size Parameters

For agricultural materials similar to peanut it is suggested that three basic dimensions defined on the axes of an orthogonal reference system be taken as a basis to represent the material quantitatively (Mutaf, 1961). However, measurements and observations have shown that from among the basic dimensions, the width and thickness of the peanut exhibit only slight differences. Therefore, width and thickness are reduced to a single parameter, which is also in good interaction with the solid model chosen, thus making it possible to represent peanut geometrically with length and diameter parameters. Either of width or thickness, whichever is larger, is to be defined as the diameter.

Size Distributions

Without referring to the classical laws of distribution, density functions associated with length and diameter of peanut in the shelled and unshelled (kernel) cases will be determined, based on a sufficient number of measurements from several sets of peanuts.

To this end, let y_i represent frequency corresponding to the measured quantity x_i of the ith item in the set. In order to fit a polynomial of the form $\sum_{j=0}^{n} a_j x^j$ to the frequencies observed, N_i denoting the number of different x_i's, the sum $\sum_{i=1}^{N_i} (y_i - \sum_{j=0}^{n} a_j x_i^j)^2$ will be required to assume a least value. Thus differentiation of the sum with respect to the coefficients a_j and setting the resulting derivatives to zero will lead to the following set of linear equations:

$$\sum_{k=0}^{n} a_{n-k} \sum_{i=1}^{N_i} x_i^{n-k+j-1} = \sum_{i=1}^{N_i} y_i x_i^{j-1} \quad j=1,....,n-1 \qquad (1)$$

By solving the equation set (1) for a_0,..........., a_n coefficients through some suitable means such as Gauss-Jordan Elimination Method, frequencies will be expressed as a function of the size parameter in question.

The procedure to obtain density functions as outlined above has been computerized. Experiments with the program using Antalya-type shelled peanuts have shown that variation in the density function is negligible after the tenth power of the dimensional variable. Therefore, it has been concluded that frequency polynomials of degree n=10 will be sufficient to approximate the measurements in the closest form.

Probability Versus Dimension

One of the basic motives for formulating size distributions is the demand to know the chance of meeting a given size in a random set. Thus determination of size distributions is an end in this respect. Yet it is also a means and a necessary foundation for estimating the probability of encountering those items with size less than a given value. This information is of vital importance to deciding on the appropriate dimensions of the processing machinery, especially for instance, in grading and cleaning.

If P (x) designates the probability of coming across with the peanuts the dimensions of which are less than a given x value defined on the integral $x_0 \leqslant x \leqslant x_n$, then it is evaluated by means of the density function y (x) as such:

$$P(x) = \int_{x_0}^{x} y dx / \int_{x_0}^{x_n} y dx \qquad (2)$$

These evaluations will be performed for length and diameter in the cases of hulled peanut and the kernel.

Correlation Between Dimensions

The main objective of searching for a correlation between diameter and length values is to describe the peanut both with and without hull in a much more simple manner by reducing the number of parameters involved. For convenience, the correlation will be assumed to be a linear one. In order to find out to what degree this assumption may hold, the correlation coefficient R as calculated underneath will be referred to (Spiegel, 1975):

$$R^2 = \sum_{i=1}^{N_i} (y_i' - \bar{y})^{-2} / \sum_{i=1}^{N_i} (y_i - \bar{y})^{-2} \qquad (3)$$

$$\text{where } \bar{y} = a + b \sum_{i=1}^{N} x_i/N \quad (4)$$

y_i, y_i' are the recorded and calculated frequencies corresponding to the measured dimension x_i, respectively; N is the total number of samples in the set; a, b are the coefficients of the sought linear correlation, a and b are determined on the basis of the procedure summarized previously.

The dimensional interrelationships that are looked for are those between length and diameter of hulled peanut, that between kernel diameter and kernel length, the one between the diameters of hulled peanut and its kernel. By means of these relationships, once a single parameter, diameter of the hulled peanut is measured, it will be possible to predict the length of the hulled peanut, the diameter and length of the kernel without any resort to breakage or further measurement.

Dimensional Classification

Classifying peanuts according to size is important for many reasons. First of all, it is one of the necessary input data for the design of, for instance, grading machinery. Secondly, it provides a variable with which other properties may be investigated. Furthermore, it may also be a quality index, which will be a factor in the formation of its price in the marketplace.

The basis on which classification is to be founded is set up by calculating the average dimension ($\bar{x}$) and the associated standard deviation (σ_x) through the following expressions.

$$\bar{x} = \sum_{i=1}^{n} x_i/N \quad (5)$$

$$\sigma_x = [\sum_{i=1}^{n} (x_i - x)^{-2} / N]^{1/2} \quad (6)$$

Then, small-, medium- and large-size peanuts are so defined that their specific x dimension satisfies the following inequalities, respectively:

$$\text{small-size group: } x < \bar{x} - \sigma_x \quad (7)$$

$$\text{medium-size lot: } \bar{x} - \sigma_x < x < \bar{x} + \sigma_x \quad (8)$$

$$\text{Large-size group: } x > \bar{x} + \sigma_x \quad (9)$$

Using the probability function computed by relation (2), the percentage of each category in a given set can be easily determined.

Fitness of Geometric Model

As mentioned earlier, there are quantities both from the side of machinery and from the properties of peanut itself that are highly dependent upon the geometric shape. Therefore, any discrepancy to be observed between theoretical and experimental approaches or any deviation from the expected results will involve error due to approximation of the shape by a simple model. Hence, it is necessary at this stage to know how fit is the chosen geometric model on a quantitative basis. A close look at the kernel and hull will reveal that the latter is critical in terms of compatibility with the model. Thus hulled peanuts will be reviewed in this respect.

A practical method of testing fitness can be acquired by taking into account the volumes. The number (N) of peanuts contained in sets of classified and mixed samples is recorded and corresponding theoretical model volume (V_m) is evaluated:

$$V_m = [d/3 + (L-d)/2]\pi d^2 N/2 \quad (10)$$

Here in (10), correlation between length (b) and diameter (d) of the hulled peanut as obtained previously is to be used. Then the real volume of peanuts in the sets is measured by subtracting the volume of a suitable filling material from that of the total occupied space. Error in the model is then defined as the difference between the computed and measured volumes divided by the theoretical volume.

Shell Thickness and Void

Sets of coded peanuts are formed of each type. Two largest outer diameters and thickness of the hull, and diameter of the kernel are measured and recorded for each sample in the set. Then mean value and standard deviation of shell thickness and thus voids between hull and kernel are calculated. Since void varies along the long axis of a peanut, the minimum of the two values that occur on two largest hull diameters is considered as the critical one.

This information is important, for example, in the development of shelling machines. A rational approach to such machinery requires, among others, a knowledge of the behaviour of the peanut under loading. If damage to the seedling ability of the kernel is to be avoided, then magnitudes of load and deformation will be restricted to the values determined by shell thickness and especially voids.

Furthermore, it is indicative of the composition of the peanut which is made up of the hull and the kernel. Then it will signify the percent quantity of meat in a given peanut type.

Results and Discussion

Diameter and length of each hulled peanut in a set containing randomly selected 500 items are measured and recorded. Out of the readings from each set of Anamur, Antalya, Silifke and Osmaniye types, several formulations have been derived.

First, density functions have been obtained for diameter and length, as depicted in Figs. 1 and 2, respectively. Then using these, cumulative probabilities have been calculated and plotted against diameter, Fig. 3 and against length, Fig. 4. Based on the average and standard deviation of the samples in the sets, hulled peanuts of each four types have been classified with respect to their diameter and length, as small-, medium- and large-size shown in Table 1. Lastly, linear correlations between the diameter and the length of the hulled peanut have been established in each type, with their corresponding coefficients, as given in Table 2.

Randomly collected 100 peanuts of each type are coded to form four groups from which measurements of outside hull diameter and length, inside kernel diameter, and length as well as thickness of the shell have been taken. These data have been used in several ways to come up with certain results. One of these is that size distributions of kernel have been approximated, as drawn in Figs. 5 and 6. One further outcome emenating therefrom is the probability of encountering kernels with dimensions less than a given value. Figs. 7 and 8 exhibit such information for diameter and length, respectively. Upon calculating the mean and standard deviation values in each group, size classification of kernels has done in the form of small-, medium- and large-size categories according to their diameter and length (Table 3).

Another use of the data is to be found in correlating linearly the kernel diameter to its length. This is done for each peanut type and the results are gathered in Table 4.

By means of the coded data, the search for a linear correlation between the outside hull diameter and inside kernel diameter, in the

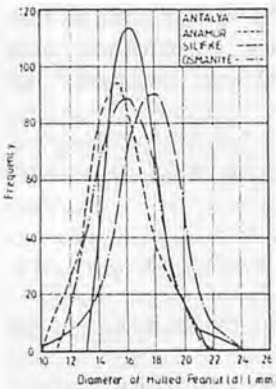

Fig. 1 Diameter frequency of hulled peanut.

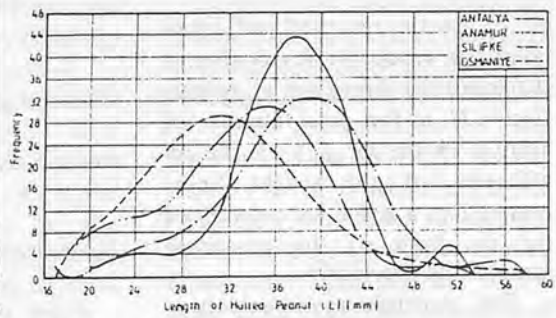

Fig. 2 Length frequency of hulled peanut.

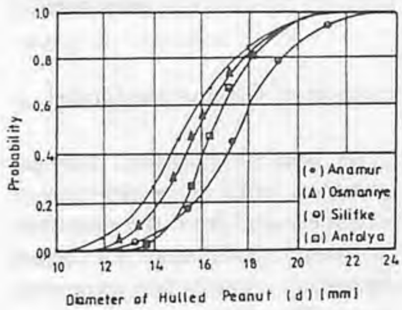

Fig. 3 Cumulative probability of hulled peanut diameter.

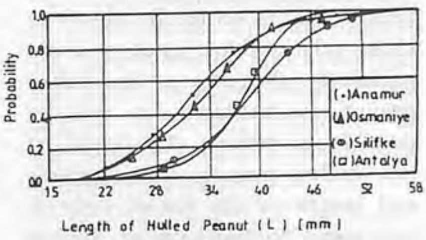

Fig. 4 Cumulative probability of hulled peanut length.

Table 1 Size Classification in Hulled Peanuts

Peanut Type	Dimension	Small-size (mm)	Medium-size (mm)	Large-size (mm)
Anamur	Diameter (d)	d < 13.2	13.2 ≤ d ≤ 17.7	d > 17.7
	Length (L)	L < 24.9	24.9 ≤ L ≤ 38.7	L > 38.7
Antalya	Diameter (d)	d < 14.8	14.8 ≤ d ≤ 18.4	d > 18.4
	Length (L)	L < 31.8	31.8 ≤ L ≤ 42.5	L > 42.5
Osmaniye	Diameter (d)	d < 13.8	13.8 ≤ d ≤ 18.1	d > 18.1
	Length (L)	L < 25.6	25.6 ≤ L ≤ 39.1	L > 39.1
Silifke	Diameter (d)	d < 15.0	15.0 ≤ d ≤ 19.7	d > 19.7
	Length (L)	L < 31.0	31.0 ≤ L ≤ 44.7	L > 44.7

Table 2 Length-Diameter Correlation in Hulled Peanuts

Peanut Type	Length (L)-Diameter (d) Correlation (cm)	Interval (cm)	Coefficient of Correlation (R)
Anamur	L = 1.7554d + 0.4699	1.0 ≤ d ≤ 2.2	0.57
Antalya	L = 1.4905d + 1.2477	1.2 ≤ d ≤ 2.4	0.50
Osmaniye	L = 1.3892d + 0.3022	1.0 ≤ d ≤ 2.3	0.58
Silifke	L = 1.6480d + 0.9098	1.0 ≤ d ≤ 2.5	0.58

least squares sense, has led to results given in Table 5.

Out of the recordings for shell thicknesses, the mean value and the standard deviation have been computed for each type of peanut and the results are shown in Table 6.

One further information extracted from the coded data is the average number of kernels per hulled peanut sample, as calculated in Table 7. One of its implications is that 80% of the hulled peanuts have two kernels inside them. This explains why two largest cross-sections along the long axis have to be taken into consideration in

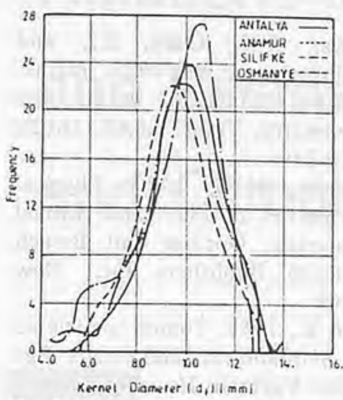

Fig. 5 Diameter frequency of kernel.

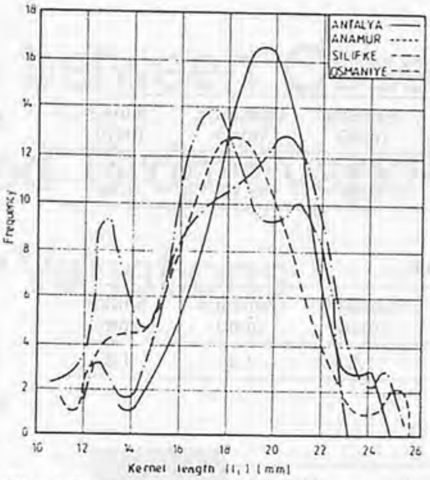

Fig. 6 Length frequency of kernel.

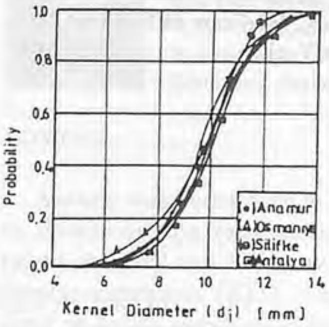

Fig. 7 Cumulative probability of kernel diameter.

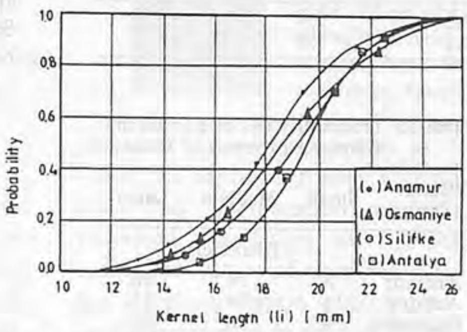

Fig. 8 Cumulative probability of kernel length.

Table 3 Size Classification of Kernels

Peanut Type	Dimension	Small-Size (mm)	Medium-Size (mm)	Large-Size (mm)
Anamur	Diameter (d)	$d < 7.5$	$7.5 \leq d \leq 11.1$	$d > 11.1$
	Length (L)	$L < 16.0$	$16.0 \leq L \leq 21.0$	$L > 21.0$
Antalya	Diameter (d)	$d < 8.0$	$8.0 \leq d \leq 11.6$	$d > 11.6$
	Length (L)	$L < 17.9$	$17.9 \leq L \leq 21.9$	$L > 21.9$
Osmaniye	Diameter (d)	$d < 7.5$	$7.5 \leq d \leq 11.2$	$d > 11.2$
	Length (L)	$L < 15.1$	$15.1 \leq L \leq 21.7$	$L > 21.7$
Silifke	Diameter (d)	$d < 8.1$	$8.1 \leq d \leq 11.2$	$d > 11.2$
	Length (L)	$L < 16.8$	$16.8 \leq L \leq 22.0$	$L > 22.0$

Table 4 Length-Diameter Correlation in Kernels

Peanut Type	Length (L)-Diameter (d) Correlation (mm)	Interval (mm)	Coefficient of Correlation (R)
Anamur	$L = 0.8732d + 9.8704$	$5.5 \leq d \leq 13.5$	0.51
Antalya	$L = 0.7673d + 11.5620$	$4.0 \leq d \leq 14.0$	0.48
Osmaniye	$L = 0.8937d + 9.4071$	$4.5 \leq d \leq 13.0$	0.53
Silifke	$L = 9.1505d + 7.6113$	$4.5 \leq d \leq 12.5$	0.64

Table 5 Correlation Between Hull and Kernel Diameters

Peanut Type	Hull Diameter (d_d)-Kernel Diameter (d_i) Correlation (mm)	Interval d_i (mm)	Coefficient of Correlation
Anamur	$d_d = 0.9125d_i + 6.8807$	$5.5 \leq d_i \leq 13.5$	0.62
Antalya	$d_d = 0.5150d_i + 11.9028$	$4.0 \leq d_i \leq 14.0$	0.48
Osmaniye	$d_d = 0.6988d_i + 10.0408$	$4.5 \leq d_i \leq 13.0$	0.66
Silifke	$d_d = 0.7219d_i + 10.3595$	$4.5 \leq d_i \leq 12.5$	0.52

order to determine the critical void space. After subtracting twice the value of the shell thickness and the kernel diameter from the relevant outside hull diameter, void space for each cross-section and for all the coded peanuts is estimated, which then produces the average and the standard deviation-values collected in Table 8.

Now that size classifications of hulled peanut and the kernel together with certain dimensional correlations have been set up, it is in order to find out what percent of a given random set includes small-, medium- or large-size peanuts. In the case of hulled peanuts, this can be deduced through Fig. 3 and Table 1, as done in Table 9. For kernels a similar deduction can be made from Fig. 7 and Table 3, leading to results in Table 10.

Finally, the relative magnitudes of error resulting from approximating the peanut shape by a regular geometric model are presented in Table 11. As can be seen from the Table, the quantitative suitability of the model ranges from 56% in the Silifke type, through 73% in the Antalya type to 77% in the Anamur and Osmaniye types.

Conclusions

Before any attempt can be made towards designing agricultural machinery, the related agricultural product should be thoroughly identified. Within this context, dimensional properties of several types of peanut grown in Turkey have been determined here in this paper. The results obtained will yeild design criteria for peanut processing machinery directly and indirectly, as well, since many other physical, mechanical and aerodynamic properties will be affected by these data.

Table 6 Peanut Shell Thicknesses

Peanut Type	Anamur (mm)	Antalya (mm)	Osmaniye (mm)	Silifke (mm)
Average Shell Thickness	0.85	0.89	0.75	1.06
Standard Deviation	0.30	0.36	0.30	0.36

Table 7 Average Number of Kernels Per Peanut

Peanut Type	Anamur (mm)	Antalya (mm)	Osmaniye (mm)	Silifke (mm)
Average Number of Kernels	1.7	1.8	1.8	1.8

Table 8 Critical Void in Hulled Peanuts

Peanut Type	Anamur (mm)	Antalya (mm)	Osmaniye (mm)	Silifke (mm)
Average Value	4.5	5.3	5.9	5.8
Standard Deviation	1.8	2.1	1.6	1.9

Table 9 Probability (%) of Hulled Peanuts in Diameter Intervals of Table 1

Peanut Type	Small	Medium	Large
	– Diameter –		
Anamur	16	68	16
Antalya	14	70	16
Osmaniye	14	70	16
Silifke	14	72	14

Table 10 Probability (%) of Kernels in Diameter Invervals of Table 3

Peanut Type	Small	Medium	Large
	– Diameter –		
Anamur	8	76	16
Antalya	11	74	15
Osmaniye	14	68	18
Silifke	14	72	14

Table 11 Extent of Deviation of Peanut Shape From Model

Peanut Type	Error (%)			
	Small-size	Medium-size	Large-size	Mixed
Anamur	51	33	10	23
Antalya	58	33	9	27
Osmaniye	66	31	13	23
Silifke	64	39	29	44

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Relationship between Observed and Estimated Crop Evapo-transpirations and Climate Variations


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Abstract

A study was undertaken in 1985 to determine the relationship between observed and estimated crop evapotranspiration (ETo), on one hand, and with variations in climate, on the other. The study was undertaken in five locations and 11 sets of data in Thailand. The observed ETo was obtained by the ratio of measured crop evapotranspiration (ETo) and crop coefficient (Kc) published by FAO. Five methods for estimation for ETo were used, namely; Modified Blaney Criddle, Modified Radiation, Modified Penman, Pan Evaporation and Jensen-Haise methods. The Mofified Penman method made the best performance as it possessed a real correlation with observed ETo in 10 cases. The Jensen-Haise method was unable to estimate a safe prediction during the wet season at its ETo was observed only for 2 cases. The Modified Radiation method possessed a real correlation in 5 cases; the Mofified Blaney Criddle and Pan Evaporation methods possessed correlation in 4 cases each. The values of observed ETo had a real correlation with climatological parameters in all cases except in one case at Chiang Mai (1983). Solar radiation, relative humidity, temperature and wind velocity influence observed ETo significantly in 1, 1, 2 and 3 cases, respectively.

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Introduction

Prediction of evapotranspiration quantities is a prerequisite to a complete understanding of the entire hydrological system. Many aspects of the evapotranspiration process have been studied in detail with emphasis on the development of evapotranspiration formulae based on climatic observations. How climatological variables such as temperature, humidity, wind velocity, vapour pressure and solar radiation influence evapotranspiration has been studied by several scientists, engineers and agronomists who contributed a large number of prediction formulae that can relate to reference crop evapotranspiration with some readily available climatic data. According to Doorenbos and Pruitt (1977) reference crop evapotranspiration is defined as "the rate of evapotranspiration from an extensive surface of 8 to 15 cm tall green grass cover of uniform height, actively growing, completely shading the ground and not short of water". These formulae have been developed and used from time to time and have been critically reviewed by various workers as cited by michael (1977). Broadly, these approaches fall in two classes: (1) purely empirical attempts to correlate evapotranspiration with one or more climatic factors, and (2) the application of a more theoretical approach. Such formulae have often been used under agro-climatic conditions different from those for which they were originally developed. It is, therefore, necessary to test the adaptability of these formulae by correlating with actual measurement of evapotranspiration under a new set of conditions. This study was undertaken with the same objective to see how well the ETo estimated and climatic variables are correlated with observed ETo for various locations in Thailand.

The methods most commonly used in estimating evapotranspiration are Blaney-Criddle, Radiation (Makkink), Penman, Pan evaporation, Jensen-Haise, Thornthwaits and Christiansen. The first four methods have been modified by Doorenbos and Pruitt (1977) and correlated against measured ETo at Yanganibi (Zaire), Port Au Prince (Halti), Davis (California), Wageningen (Netherlands), Montfant (France), Tai Amara (Lebanon), Coschocton (Ohio), Copenhagen (Denmark) and Brawley (California). These four methods, namely, the Modified Penman, Modified Radiation, Modified Blaney Criddle and Pan Evaporation appear to be in good agreement for a wide range of climates except possibly at higher altitudes and where the correction factor C in the Penman equation is relatively large (Tal Amora). Yu-Min (1982) correlated pan evaporation and reference crop evapotranspiration calculated from various methods for Thailand. The compared methods were Modified Radiation method, Modified Penman method and Jensen-Haise method. The Penman method provided the best correlation whereas the Jensen-Haise method did not show a good correlation with Pan evaporation.

Methodology

Data Collection

The weekly crop evapotranspiration data were collected from the Royal Irrigation Department and Kassersart University in Bangkok, Thailand. The daily pan evaporation, temperature, relative humidity, bright sunshine hours, solar radiation data were also collected from Royal Irrigation Department and Kasersart University. Wind velocity data, measured eight times a day, were collected from the Bangkok Meteorological Department.

Estimation of Reference Crop Evapotranspiration

Five methods used in the study for predicting reference crop evapotranspiration were based on climatological data. The five methods are the Jensen-Haise, Modified Blaney Criddle, Modified Radiation, Modified Penman, and Pan Evaporation. The Jensen-Haise method simplified by Schulz (1976) and the other four relationships recommended by Doorenbos and Pruitt (1977) were used for estimation of ETo.

Lysimeter Derived Reference Crop Evapotranspiration (ETo)

As the measured ETo data was not available in Thailand for this study, observed crop evapotranspiration data obtained from experiments conducted in that country was used. The measurements for crop evapotranspiration was taken by using lysimeter (non weighing type). The reference crop evapotranspiration (ETo) is related with crop evapotranspiration (ETc) by the relationship;

$$ETo = ETc / Kc$$

Where Kc is the crop coefficient, which varies with crop, its stage of growth, growing season and prevailing weather conditions.

By using observed ETc and proper Kc values, ETo can be obtained. A useful review of ETo and Kc for many crops from many parts of the world was published by Doorenbos and Pruit (1977). Since the same reference crop was used for the development of Kc values, the presented crop coefficients apply to each of the five methods. Since no Kc values have been developed by using the same reference in Thailand, the Kc values published by Doorenbos and Pruitt (1977) were used for this study. The ETo obtained by the ratio of ETc and Kc was assumed as observed ETo.

The crops which are considered for this study, their sites and growing seasons are given in **Table 1** and the length of different stages and corresponding values of Kc are collected in **Table 2**. Generally, the growing season of paddy and upland crops can be divided into three and four stages, respectively. The

Table 1 Sites, Crops and Their Growing Season

Site	Crop	Growing season
Chiang Mai	Rice Rice Soybeam	Rainy season 1979 (Jul-Nov) Rainy season 1980 (Aug-Nov) Rainy season 1983 (Aug-Nov)
Suphanburi	Rice Rice	Rainy season 1979 (Jul-Nov) Rainy season 1980 (Aug-Dec)
Petchaburi	Rice Rice	Rainy season 1979 (Aug-Nov) Rainy season 1980 (Aug-Dec)
Nakhon Ratchasima	Rice Sweatcorn	Rainy season 1980 (Aug-Nov) Rainy season 1981 (Aug-Nov)
Nakhon Pathom	Rice Cotton	Rainy season 1980 (Jul-Nov) Rainy season 1982 (Aug-Dec)

Table 2 Crop Coefficients (kc) and No. of Days of Each Growth State (ND) for Paddy, Sweetcorn, Soybean and Cotton (Doorenbos and Pruitt, 1977).

Crop	ND1	kc1	ND2	kc2	ND3	kc3	ND4	kc4
Paddy	*	1.10	*	1.05	28	0.95	–	–
Sweetcorn	20	0.91	30		34	1.10	10	1.00
Soybean	15	0.92	30		40	1.01	15	0.45
Cotton	30	0.92	50		60	1.08	48	0.65

* ND1 = (60 days nursery period); ND2 = (Total growing length after transplanting) – (ND1 + ND3)

crop coefficient for the respective growth stage is obtained by the method presented in Doorenbos and Pruitt (1977).

Regression Analysis

A linear regression analysis was conducted to see how well the observed ETo and estimated ETo are correlated. In order to know whether the ETo values observed follow a linear relationship with climatic variables influencing the evapotranspiration, a multiple linear regression analysis was conducted. The level of significance (T) of climatic variables to observed ETo was determined in order to understand which of the climatological parameters influence observed ETo significantly.

Results and Discussion

Five methods for estimating the mean daily ETo in mm/day on weekly basis were used, namely; Modified Blaney Criddle, Radiation, Modified Penman Pan Evaporation and Jensen-Haise methods. The observed ETo was correlated with estimated ETo and climatic variables.

Linear Regression Analysis of Observed and Estimated ETos

In order to determine how well these ETos are correlated, a linear regression analysis was conducted (**Table 3**). It was assumed that the values of correlation coefficients (R) which are significantly different from zero at 95% confidence limits indicate a true correlation. This was computed by applying the t-distribution at 95% confidence limits and that the values of correlation coefficients (R) equal to, or greater than the values of 0.58, 0.56, 0.54, 0.50 and 0.39 were significantly different from zero for the number of data points n equal to 12, 13, 14, 16 and 26, respectively. The R values that indicated a true correlation are marked with sign "#" in **Table 2**.

Moreover, the factors in the regression equation can be considered. A multiplying factor close to 1 and a constant factor close to 0 would indicate a very good agreement of ETo values (estimated and observed) for all levels of ETo. Whereas a multiplying factor close to 1 and a higher positive constant factor might indicate a constant leakage from the lysimeter creating apparently higher observed ETo values. It was assumed that a good agreement of ETo values for all levels of ETo existed, if the multiplying factor is within the range of

Table 3 Result of the Linear Regression Analysis of Observed ETo vs Estimated ETo

Station	Relationship [ETo(obs) vs ETo(est)]	Correlation coefficient (R)	Station	Relationship [ETo(obs) vs ETo(est)]	Correlation coefficient (R)
Chiang Mai (1979)	ETo(obs) = 1.191 *ETo(bla) + 0.089	0.50#	Petchaburi (1980)	ETo(obs) = 0.874 *ETo(bla) + 2.787	0.62#
	= 1.049 *ETo(rad) + 0.462	0.56#		= 0.573 *ETo(rad) + 2.697	0.16
	= 1.094 *ETo(pen)+ 0.468	0.56#		= 0.539 *ETo(pen)+ 2.821	0.18
	= 1.266 *ETo(pan)+ 0.103	0.46		= 0.624 *ETo(pan)+ 2.087	0.19
	= 0.777 *ETo(jen) + 2.642	0.27		= 0.511 *ETo(jen) + 2.565	0.19
Chiang Mai (1980)	ETo(obs) = 1.195 *ETo(bla) + 0.225	0.70#	Nakhon Ratchasima (1980)	ETo(obs) = 1.063 *ETo(bla) + 1.778	0.51
	= 1.172 *ETo(rad) + 0.239	0.63#		= 1.098 *ETo(rad) + 0.747	0.76#
	= 1.198 *ETo(pen)+ 0.907	0.80#		= 1.056 *ETo(pen)+ 0.990	0.68#
	= 1.288 *ETo(pan)+ 1.989	0.83#		= 0.602 *ETo(pan)+ 2.889	0.41
	= 0.682 *ETo(jen) + 2.971	0.32		= 0.585 *ETo(jen) + 2.065	0.45
Chiang Mai (1983)	ETo(obs) = 0.595 *ETo(bla) + 1.768	0.55#	Nakhon Ratchasima (1981)	ETo(obs) = 0.564 *ETo(bla) + 2.016	0.36
	= 0.551 *ETo(rad) + 1.728	0.47		= 0.534 *ETo(rad) + 1.673	0.83#
	= 0.618 *ETo(pen)+ 1.829	0.68#		= 0.944 *ETo(pen)+ 0.979	0.82#
	= 0.508 *ETo(pan)+ 2.797	0.11		= 0.740 *ETo(pan)+ 1.790	0.45
	= 0.649 *ETo(jen) + 1.765	0.46		= 0.710 *ETo(jen) + 1.056	0.82#
Suphanburi (1979)	ETo(obs) = 1.069 *ETo(bla) + 1.479	0.48	Nakhon Ratchasima (1980)	ETo(obs) = 0.515 *ETo(bla) + 2.482	0.13
	= 0.829 *ETo(rad) + 2.517	0.46		= 0.768 *ETo(rad) + 2.443	0.44
	= 0.786 *ETo(pen)+ 1.956	0.56#		= 0.720 *ETo(pen)+ 2.319	0.62#
	= 0.386 *ETo(pan)+ 2.662	0.12		= 0.609 *ETo(pan)+ 2.289	0.59#
	= 0.479 *ETo(jen) + 2.593	0.26		= 0.649 *ETo(jen) + 2.065	0.70#
Suphanburi (1980)	ETo(obs) = 0.612 *ETo(bla) + 2.293	0.51	Nakhon Pathom (1982)	ETo(obs) = 0.594 *ETo(bla) + 2.039	0.36
	= 0.835 *ETo(rad) + 2.359	0.41		= 0.693 *ETo(rad) + 1.715	0.36
	= 0.890 *ETo(pen)+ 1.532	0.57#		= 1.053 *ETo(pen)+ 0.863	0.67#
	= 0.547 *ETo(pan)+ 2.055	0.32		= 0.915 *ETo(pan)+ 0.884	0.75#
	= 0.554 *ETo(jen) + 2.270	0.14		= 0.679 *ETo(jen) + 1.707	0.47#
Petchaburi (1979)	ETo(obs) = 0.723 *ETo(bla) + 1.135	0.46			
	= 1.630 *ETo(rad) + 0.973	0.79#			
	= 1.128 *ETo(pen)+ 0.885	0.74#			
	= 1.093 *ETo(pan)+ 0.451	0.71#			
	= 1.550 *ETo(jen) + 0.085	0.29			

Note: # Indicates a real correlation.

0.8-1.20 and a constant factor within the range of −1 to +1.

The results of the linear regression analysis reveal that the Modified Penman method had real correlation in 10 cases, Mofified Radiation in 5 cases, and Jensen-Haise method in 2 cases. The Mofified Penman method is in good agreement with ETo for all levels in 6 cases; Modified Radiation method in 3 cases; Modified Blaney Criddle and Pan Evaporation method in 2 cases each; and Jensen-Haise method in none of the cases. At Suphanburi station in 1979-1980 none of the methods indicated a real correlation with observed ETo values except Modified Penman method which could be due to high mean relative humidity at Suphanburi which is 86.5% whereas at other stations it is within the range 77-79%.

It can be concluded from the discussion that estimated ETo Modified Penman method is well correlated with observed ETo than other methods due to the fact that it involved all climatic variables influence evapotranspiration. The Jensen-Haise method showed the poorest correlation which may be due to the reason that only temperature and solar radiation was considered in the estimating process of reference crop evapotranspiration. Since this method does not take into account the influence of relative humidity which is an important climatic factor, in estimating reference crop evapotranspiration, especially in a high humidity season, this method can not provide a safe prediction during the wet season.

Multiple Linear Regression Analysis

In order to see whether the ETo values observed follow a linear relationship with climatological parameters influencing the evapotranspiration, a multiple linear regression analysis was conducted. It was also assumed here that the values of correlation coefficients (multiple R) which are significantly different from zero at 95% confidence limits that the values of multiple R equal to, or greater than the values of 0.58, 0.56, 0.54, 0.50 and 0.39 indicating a real correlation for number of data points n equal to 12, 13, 14, 16 and 26, respectively. The values of multiple R indicating a real correlation are marked with sign "#" in **Table 4**.

It can also be observed from the results of the multiple linear regression analysis which climatological parameters are influencing observed ETo significantly. For this purpose the level of significance (T) of climatological parameters to observed ETo are presented in **Table 5**. The values of T equal to or greater than the values of t(α= 5%) of 2.23, 2.20, 2.18, 2.14 and 2.06 indicate a significant influence of climatic variables on observed ETo for the number of data points n equal to 12, 13, 14, 16 and 26, respectively. The results of the multiple linear regression analysis in **Table 4** are discussed below:

The values of observed ETo have a real correlation with climatological parameters in all cases except in a single case at Chiang Mai (1983). It can be observed from **Tables 3** and **4** that observed ETo shows a higher correlation with climatological parameters than with estimated ETo in eight cases. The results of the multiple linear regression analysis presented in **Table 4** indicate the correlation coefficients high enough to use the relationship for the prediction of reference crop evapotranspiration. **Table 5** shows that the wind velocity influenced

Table 4 Results of Multiple Linear Regression Analysis of ETo vs Climatological Parameters

Staion	Relationship [ETo (obs) vs climatological parameters]	Multiple R
Chiang Mai (1979)	ETo = −0,041(T) + 0.550(RS) − 0.045(RH) − 0.008(U) + 5.830	0.62#
Chiang Mai (1980)	ETo = 0.419(T) + 0.351(RS) − 0.188(RH) + 0.009(U) + 5.057	0.70#
Chiang Mai (1983)	ETo = −0.007(T) + 0.158(RS) − 0.045(RH) + 0.0007(U) + 6.290	0.51
Suphanburi (1979)	ETo = −0.485(T) + 0.509(RS) + 0.004(RH) − 0.005(U) + 15.193	0.82#
Suphanburi (1980)	ETo = −0.571(T) − 0.225(RS) − 0.270(RH) − 0.017(U) + 47.704	0.80#
Petchaburi (1979)	ETo = −0.528(T) + 0.116(RS) − 0.158(RH) + 0.027(U) + 28.452	0.90#
Petchaburi (1980)	ETo = 0.070(T) + 0.697(RS) + 0.278(RH) + 0.002(U) + 23.062	0.78#
Nakhon Ratchasima (1980)	ETo = 0.28(T) − 0.255(RS) − 0.279(RH) − 0.023(U) + 22.707	0.91#
Nakhon Ratchasima (1981)	ETo = 0.119(T) + 0.289(RS) − 0.047(RH) − 0.009(U) + 2.481	0.91#
Nakhon Pathom (1980)	FTo = −0.340(T) + 0.194(RS) − 0.254(RH) − 0.004(U) + 33.761	0.75#
Nakhon Pathom (1982)	ETo = 0.017(T) + 0.217(RS) + 0.714(RH) + 0.001(U) + 0.967	0.52#

Note: # Indicates a real correlation, where: T = Temperature in °C, RS = Solar radiation in mm/day, RH = Mean relative humidity in %, U = Wind velocity at 2 m height in km/day.

Table 5 Level of Significance (T) of Climatic Variables to Observed ETo, Number of Data Points, Values of t ($\alpha = 5\%$)

Station	T				n	(t)
	Temperature	Solar radiation	Relative humidity	Wind velocity		
Chiang Mai (1979)	−0.09	1.20	−0.39	−0.25	16	2.18
Chiang Mai (1980)	1.09	0.85	−0.66	0.30	13	2.20
Chiang Mai (1983)	−0.05	1.10	−0.77	0.08	14	2.18
Suphanburi (1979)	−2.14*	1.81	0.04	−0.59	14	2.18
Suphanburi (1980)	−3.04*	−0.78	−1.83	−2.73*	14	2.18
Petchaburi (1979)	−2.14	0.37	−1.49	3.18	14	2.18
Petchaburi (1980)	0.16	2.59*	2.19*	0.16	14	2.18
Nakhon Ratchasima (1980)	1.31	−0.86	−4.81	−2.92*	12	2.23
Nakhon Ratchasima (1981)	0.71	0.58	−0.28	−0.28	13	2.20
Nakhon Pathom (1980)	−0.52	0.37	−1.82	−0.98	13	2.20
Nakhon Pathom (1982)	0.44	1.60	0.64	0.35	26	2.60

Note: *Indicates climatic parameters with a significant influence on observed ETo.

observed ETo significantly in 3 cases, temperature in 2 cases, and solar radiation and relative humidity, only in one case.

Conclusions

1. The Modified Penman method showed true correlation in a maximum number of cases (10) and a good agreement with observed ETo for all levels in 6 cases, which proves its superior performance.
2. The Jensen-Haise method also showed a good correlation in 2 cases only but indicated its inability to estimate a safe prediction during the wet season. Whereas the Modified Radiation method exhibited a true correlation in 5 cases, the Modified Blaney Criddle and Pan Evaporation methods exhibited real correlations in 4 cases each.
3. The values of observed ETo have a real correlation with climatological parameters in all cases except in one case at Chiang Mai (1983). Solar radiation, relative humidity, temperature and wind velocity influence observed ETo significantly in 1, 1, 2 and 3 cases, respectively.

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Technology Transfer — An Experience at CIAE, Bhopal, India

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Abstract

The paper outlines the activities related to technology transfer at the Central Institute of Agricultural Engineering, Bhopal, India. The activities include product development for commercial production, supply of blue prints and prototypes, inplant guidance in upgrading of existing technology, marketing assistance, exhibitions, farmers' days, and manufacturers' day. Distribution of leaflets and other literature, screening of video and documentary films are regular features of popularization of agricultural machinery. The CIAE is only a small national R&D institution engaged in technology transfer directly. It, therefore, coordinates with other goverment and private agencies in the promotion and popularization of agricultural machinery.

Introdution

There has been a considerable increase in the adoption of improved farming practices by the farmer, including engineering inputs. The rate of adoption of tractors and tractor-drawn implements and irrigation equipment has been much more than any other engineering inputs. In particular, the adoption of bullock-drawn and manually operated implements and tools has been slow (**Figs. 1** to **4**). A monograph published by CIAE, Bhopal indicates that a large number of tools, implements and machinery develpoed by R&D institutions could not be commercially exploited. Along with many factors, one of the major limitations of the R&D institutions has been poor linkage with indusries in their large scale production and inadequate demonstration amongst farmers. Newly developed agricultural machinery requires concerted efforts to create awareness amongst the prospective users about their utility and economic advantages.

Mechanization Policy and Technology Transfer

The mechaninzation policy and agricultural machinery industries development are closely linked with each other. The Ministry of Agriculture of the Government of India adopted the selective mechanization policy with strategy and programmes to promote the production and availability of inputs for its proper implementation. The major emphasis has been to provide funds subsidy on hand tools, agricultural machinery and irrigation pumps to the farmers. The responsibility of supply of hardwares rests with State Agro-Industries Development Corporations established in all main provinces. They, however, have little experience in the production of agricultural machinery. These organizations are more of trader than manufacturer. For a meaningful selective mechanization policy, the following aspects need due consideration:

1. Promotiom of farm mechanization and review of its impact in increasing production and productivity and generation of employment.
2. Promotional measures in manufacture of improved machinery.
3. Monitoring and review of problems associated with popularization, credit, subsidy, training and repair and maintenance facilities.

One of the major constraints in the popularization of selective mechanization inputs is the identification of the technology. This is highly dynamic as it keeps on changing with the level of overall development of the country, as a whole, and industrialization and economic development, in particular. An appropriate implement accepted by a group of farmers in a particular region may have its limitation amongst another region under similar agro-ecological and economic conditions. The transfer of technology under such situation

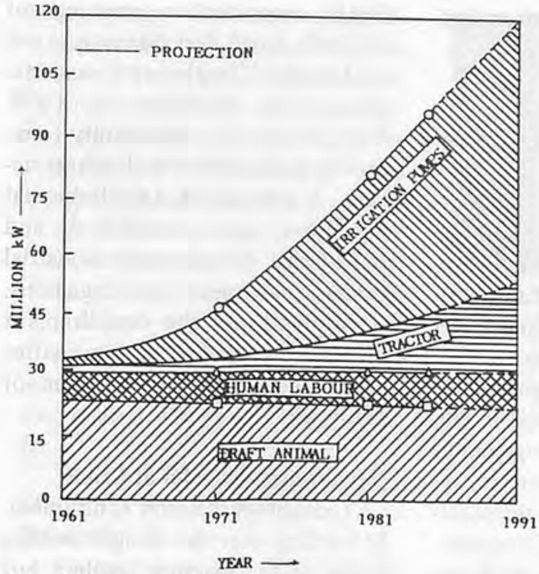

Fig. 1 Power on Indian farms.

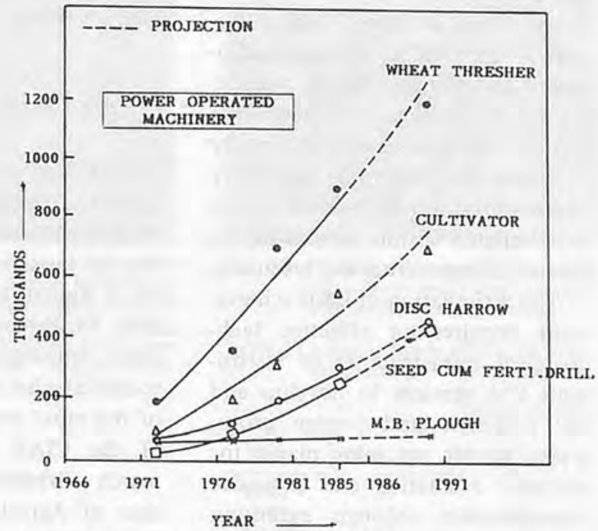

Fig. 2 Status and Projection of power and tractor-drawn machinery.

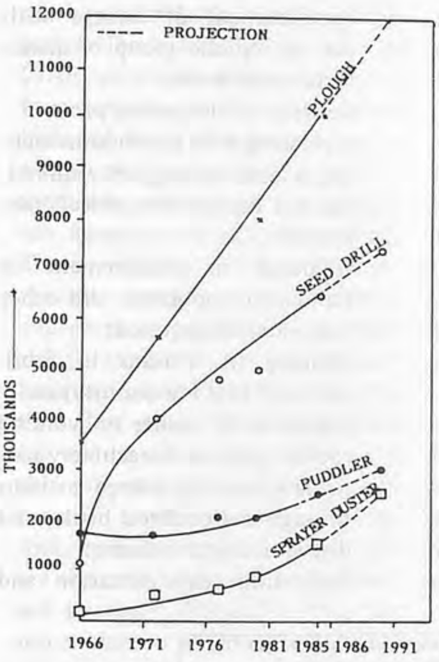

Fig. 3 Improved hand and animal-drawn implements.

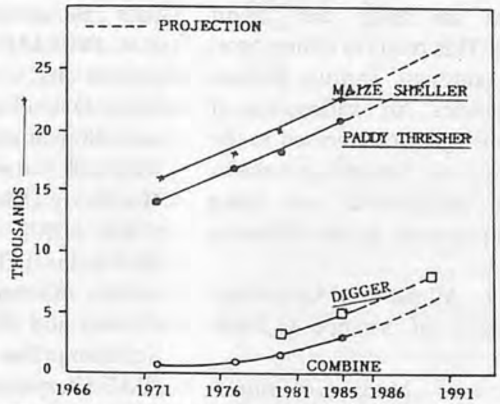

Fig. 4 Increase in special crop machinery.

poses implementation problems. Economic feasibility evaluation on farmers field should provide enough background information for a technology which has been introduced in another region of the country. For an accelerated adoption of the technology, the following steps need consideration:

1. Evaluation and upgrading of traditional technology. This will have immediate adoption by the industries as well as farmers.
2. Development of technology applying modern scientific and engineering knowledge through R&D.
3. Evaluation and adoption of imported technology.

Although technology transfer to manufacturers and farmers are two distinct activities needing different approaches, such activities mutually reinforce each other. The production of machinery by the manufacturers can be initiated only if the farmers motivate them to do so. If machines are promoted and actual demand is established through agricultural extension, the manufactures normally respond. Most often, due to lack of standards and nature of production in Small Scale Workshops, quality control is not adhered to. In effect, the farmers loose confidence in the machine.

The rural community is generally traditional and in the light of past experiences, often, skeptical of new innovations. The introduction may be possible through a select group of enterprising and receptive farmers and artisans. Demonstration in the field or through audio-visuals and training help in promoting the technology. The new innovations whether developed locally or based on imported machinery and material should be such that it is assimilated within the existing industrial infrastructure and resources.

The assimilation of R&D achievement requires an effective technological infrastructure of institutions and services to develop and test domestic and foreign prototypes, to set up pilot plants for intensive evaluation and extensive demonstration through extension and ORP network, to set up standards, and indeed to upgrade manpower at all levels and credit financing. This requires strong coordination amongst various promotional agencies. An examination of the various agencies involved in the promotion of technology shows that the programmes are being executed primarily by the following Ministries:

R & D – Ministry of Agriculture and Ministry of Science & Technology.

Promotion – Ministry of Industries and Ministry of Rural Development.

Extension – Ministry of Agriculture.

The various departments/institutions belonging to the above ministries work in isolation without proper coordination at the apex level which makes implementation and monitoring of the technology difficult and hence adoption slow. At the delivery end, there is a weak linkage among research institution, manufacturers, extension agencies and farmers. The Small Industries Development Corporations, District Industries Centres and Small Industries Service Institutes which are the functioneries of the Ministry of Industries have no or little effective machinery at and below district level to serve the small scale farm machinery manufacturers and village artisans.

C.I.A.E. and It's Infrastructure

The Central Institute of Agricultural Engineering located at Bhopal was established in 1976 under the jurisdiction of Indian Council of Agricultural Research (ICAR) (**Fig. 5**). Promotion of agricultural tools, implements and machinery sector at the national level is one of the most important programmes of the CIAE. In addition to research divisions, it has the Division of Agro-Industrial Extension, Trainers' Training Centre and Farm Science Centre whose major mandate is technology transfer. In this, the CIAE interacts with R&D instisutions, manufacturers and other technology transfer agencies, including international bodies like Regional Network for Agricultural Machinery (RNAM), USAID, NIAE (UK), IDRC (Canada) and IRRI (Philippines). The activities are executed through its Divisions, Centers and All India Coordinated Schemes. The RNAM and IRRI-CIAE Cooperative Industrial Extension programmes have been the major catalyst in the promotion and popularization of agricultural machinery. In order to have dialogue amongst research engineers, policy makers and manufacturers, the CIAE organized a meeting of All India Small Scale Manufacturers of Improved Implements and Machinery on December 12, 1979. This provided an opportunity to reorient its activities and infrastructure. A division of Agro-Industrial Extension was established and IRRI-CIAE Cooperative Industrial Extension Project was organized. A proposal for the establishment of 3 prototype production centres are under active consideration of the ICAR.

Technology Transfer at CIAE

Technology transfer is not merely handing over the designs or blue prints of the machine/product but includes

- Establishment of linkage with the appropriate group of manufacturers/artisans;
- Delivery of blue prints/prototype along with production technique and tooling, if required, jigs and fixtures for critical components;
- Guidance in procurement of standard components and other raw materials required;
- Training of artisans in fabrication of first few prototypes;
- Guidance in raising of working capital, plant and machinery particulary to the village artisans through nationalized banks and district industries centre;
- Evaluation, demonstration and

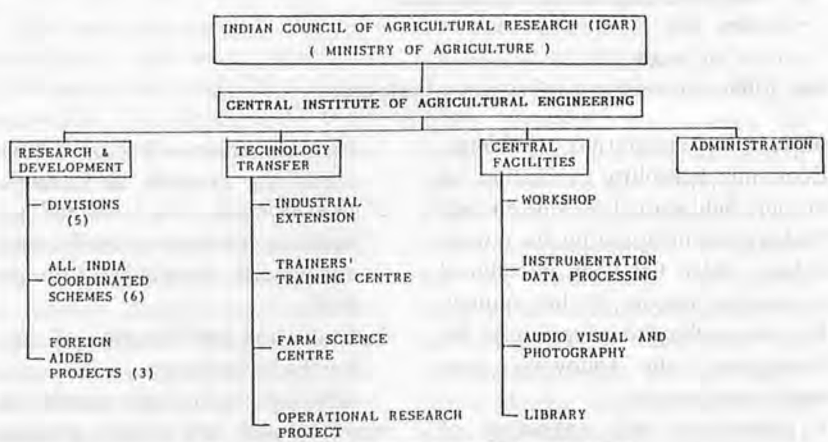

Fig. 5 Infrastructure at CIAE, Bhopal, India.

marketing of fabricated prototypes until the market is established. These programmes may be coordinated by involving other promotional agencies such as agricultural universities, Department of Agriculture and rural development agencies; and
- Coordination with other manufacturer in the delivery of technology.

Keeping the above factors in mind, the CIAE plans its activities related with technology transfer.

Status of Farm Machinery Industries

To gain a proper understanding of problems of the small scale farm machinery industries and establish linkage for technology transfer, the CIAE prepared status report on farm machinery industries which included level of industries, types and quantity of implement manufactured, procurement of design, raw material and major constraints. These reports were prepared through meetings, questionnaires and personal interviews. The study reveals that 52% of the industries have capital less than US$40 000 and 90% less than US$75 000. This has a strong limitation in the adoption of modern production techniques, lathe machines, shaper, drill, grinder, and welding sets are the major machine tools possessed by them. Presently, there are more than 17 000 manufacturers of agricultural machinery. A majority of the manufacturers do not have trained technicians/ engineer who could interpret the manufacturing drawings. The designs are thus copied from the existing commercial machines. There were about 35% industries who received technical assistance from the R&D instritutions. But this assistance was not adequate as technical guidance in development of prototypes were seldom rendered.

Fig. 6A Product development of a manual weeder to facilitate fabrication (Left: Frame fabricated from 40 × 4 flat with V-shaped cutting blade, Right: Multiple hole frame fabricated from 4 mm sheet with crescent-shaped blade).

Product Development

The designs of improved farm machinery to small scale industries are made available through R&D organizations. The experience has shown that these designs although may be functionally perfect, are deficient from production and aesthetic appeal angles. The CIAE thus identifies selected prototypes through extensive field evaluation of potential prototypes and modifies them for commercial exploitation (**Fig. 6**). A list of such farm machinery is given in **Appendix**.

The CIAE also prepares manufacturing drawings of agricultural machinery which were already being manufactured for the benefit of other manufactures. These drawings are supplied to the manufacturers at nominal charges. **Table 1** lists the supply of drawings to the manufacturers.

Guidance in Commercialization of Prototypes

The local manufacturers in Bhopal are regularly visited by scientists of the Institute to render assistance in the improvement of quality of farm machinery through adoption of proper material or production techniques. They are also provided with jigs and fixtures for fabrication of critical compo-

Fig. 6B Product development of a semi-axial flow multi-crop thresher with spiral aspirator blower.

Table 1 Annual Supply of Manufacturing Drawings

(Unit: number)

Year	Drawings	Manufacturers
1980	135	5
1981	412	12
1982	597	15
1983	436	25
1984	496	26
1985	533	27
1986	458	29
Total	3 067	139

Appendix Preproduction Development of Prototype at CIAE

1. Bakhar blade
2. 3-tyne grubber weeder
3. Dryland peg type weeder
4. Wheel hoe weeder
5. 3-Row seed-cum-fertilizer drill
6. 6-Row IRRI type rice transplanter
7. Tractor-drawn vertical conveyor reaper
8. Soybean thresher
9. Multicrop thresher
10. Tubular maize sheller
11. Groundnut decorticator

Fig. 7 A soybean thresher developed with the collaboration of a local manufacturer.

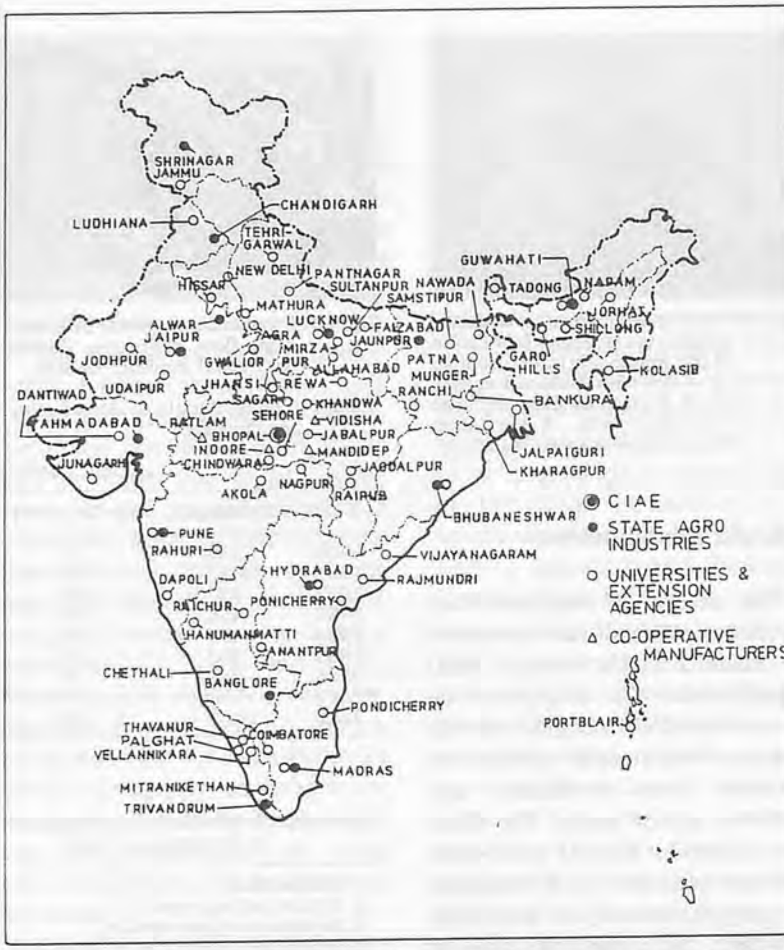

Fig. 8 Manufacturing promotion and supply of prototype for popularization by CIAE.

Fig. 9 In-plant guidance of manufacturers for quality improvement.

nents. The CIAE has been able to develop 17 cooperative manufacturers located in Bhopal (9), Vidisha (1), Mandideep (1), Indore (2), Ratlam (1), Ahmedabad (1), Pune (1) and Alwar (1) who make prototypes for CIAE. These prototypes are fabricated as per the specifications of CIAE for distribution to other manufacturers and extension agencies. The CIAE engineers help the manufacturers in the fabrication of few prototypes. Such help includes selection and procurement of material, development of jigs and fixture, guidance in fabrication, testing and evaluation and initial marketing. The CIAE undertakes product development project with the collaboration of manufacturers and these are executed in their premises. This accelerates the adoption of the technology (**Fig. 7**).

In addition to the cooperative manufacturers, the CIAE also supplies designs and prototypes to State Agro-Industrial Development Corporations of M.P., U.P., West Bengal, Gujarat, Maharashtra, Orissa, A.P., Tamil Nadu, Haryana, Jammu & Kashmir, Assam, Rajasthan and Bihar. Some of these corporations have started the production of machinery (**Fig. 8**).

Training of Manufacturers and Artisans

There are better avenues available in other consumer goods-oriented industries and thus qualified people find it more lucrative to work in such units. The farm machinery industries usually employ semi-skilled technicians. There are no adequate facilities available for training of these technicians. The quality of farm machines depends upon the skill achieved through experience. In addition to plant guidance, the CIAE organizes training programmes in the manufacturing technology of agricultural machinery and product development for manufacturing (**Fig. 9**) These includes visit to the industries where modern production techniques are adopted. The manufacturers are invited during testing of agricultural machinery which encourages them to build their own testing facilities. Regular trainings are conducted for the benefit of village artisans through the Farm Science Centre. These artisans are helped in the establishment of workshop in rural areas through District Industries Centres and Commercial Banks. The working capital to the manufacturers is provided by the banks against the supply order placed with cooperative manufacturers.

Marketing and Supply of Agricultural Machinery

One of the major constraints in the introduction of new agricultural machinery amongst the farmers is the lack of interest of manufacturers to undertake commercial production due to limited demand. The CIAE has taken the lead in the supply of prototypes to extension agencies. These prototypes are fabricated by cooperative manufacturers under guidance and quality control supervision of its engineers. About 2000 – 3000 prototypes are supplied every year. Table 2 lists the annual supply of prototypes to agricultural universities, farm science centres, agro-industries corporations, State Department of Agriculture, manufactured by about 60 manufactures and 10 State Agro-Industries Development Corporations. A number of States have adopted them under centrally sponsored popularization schemes of the central government. Implements like improved *bakhar* blade, *patela* harrow, seed-cum-fertilizer drill, weeders, reaper-harvesters, multicrop thresher, tubular maize sheller, sickle, groundnut decorticator, cleaner and grader are in great demand (Fig. 10).

Table 2 Annual Supply of Prototypes by CIAE, Bhopal

Name of implement	1981	1982	1983	1984	1985	1986	1987
Bakhar blade	–	2	109	86	151	31	10
CIAE toolframe	–	–	–	–	2	2	–
Patela harrow	1	1	1	2	1	11	15
Manual dibbler	3	–	2	8	7	8	–
Rice transplanter	–	5	10	12	7	9	2
3-tyne grubber	26	14	173	204	144	37	379
Wheel hoe weeder	5	4	249	312	243	79	131
Serrated sickle	–	10	395	1 319	128	82	898
Pegtype weeder	14	11	113	118	152	47	40
Tubular maize sheller	52	193	537	476	806	541	352
Groundnut decorticator	–	5	2	23	35	41	82
Rotary dibbler	–	–	–	3	5	5	2
3-row CIAE seed-cum-fertilizer drill	–	–	–	10	18	49	26
Bakhar	–	–	–	–	3	100	–
Mahakal seed drill	–	–	–	7	1	10	2
Pedal-operated cleaner	–	–	–	–	–	2	2
Multicrop thresher	–	–	–	–	2	–	–
Sack holder	–	–	–	–	–	–	9
Hand-operated cleaner	–	–	–	–	–	–	8
Total	102	245	1 591	2 580	1 703	1 056	1 958

Fig. 10 Distribution of prototype to selected farmers' under 'lab to land' program.

Fig. 11 Organization of workshop on development and modernization of agricultural machinery.

Meetings, Manufacturers' Days and Field Days and Exhibitions

The CIAE organizes regular meetings and manufacturers' days to have dialogue (Fig. 11). Free exchange of views are expressed in such occasions. Representatives from banks and other manufacturing promotional organizations as SISI, DIC, BIS and NABARD also participate. This provides a forum to have free discussion to sort out financial and technical problems. On many occasions farmers are also invited to these meetings. The manufactures are requested to display the products. The CIAE organizes international workshop on standardization of agricultural machinery, extension and popularization of agricultural machinery and product designs. Manufacturers are invited to attend such workshop.

The CIAE participates in national and international trade fairs and exhibitions. Exhibitions are organized by CIAE also at Bhopal.

T.V. and Documentary Films and Radio

The television and video films have become one of the most powerful mass communication media in the transfer of technology. The CIAE collaborates with the Directorate of Extension, Government of India and NRDC of India in the preparation of video films. These are telecast from Delhi, Lucknow and Nagpur. The CIAE also prepares its own video films on improved machinery. Such films have created awareness amongst farmers as well as manufacturers. The CIAE receives regular requests as a result of screening of such films.

Bulletin, Directories, Leaflets and Other Publications

The CIAE compiles information on technology developed in the country by various research organizations. This provides valuable information to the manufacturers.

The CIAE also publishes a directory on agricultural machineries manufactured in different parts of the country. Leaflets are available on new equipment developed. These help the manufacturers in market development.

The proceedings of summer institutes and training courses on design and manufacturing technology are available. These are helpful not only to research engineers but also to the manufacturers.

Coordination

The CIAE alone cannot develop the technology nor transfer it to users. It thus coordinates with other agencies in product development through coordinated schemes in prototype production through State Agro-Industries Corporation, NRDC, SISI, NID and popularization of agricultural machinery through Department of Agriculture and Cooperatives, Government of India and State Department of Agriculture. This is one of the major achievements of CIAE. It has created impact on the above organization. This is evident from the fact that a large number of senior officers from Agro-Industries Corporations, Director of Agriculture, Officials from SISI, NRDC, CAPART regularly visit the Institute and wish to have collaborative progammes. CIAE alone cannot serve the nation and, therefore, joins and with other organization engaged in the promotion of industries and popularization of agricultural machinery.

Conclusion

The R&D organizations in the country have established contact with local manufacturers in the promotion of products developed by them. But they have not been able to establish organic linkage with them in delivery of technology. This has been mainly due to absence of infrastructure in manufacturing promotions. The production technology of agricultural machinery is yet to find its place in their programmes.

The CIAE is the first institution in the country which has realized the importance of this activity and, therefore, created a Division of Agro-Industrial Extension. The transfer of technology of engineering input is different from other inputs like seeds and fertilizer. Mere demonstration does not help. Accordingly, the CIAE orientes its manufacturing promotional programmes.

The major achievement of CIAE has been the creation of an impact in the minds of manufacturers, farmers and extension agencies and other R&D organizations by providing technology of improved machinery. This is evident from the adoption of technology by manufactures and various states in their popularization programmes. But the CIAE alone cannot serve the nation and, therefore, coordinates with other similar organizations in manufacturing, promotion and popularization.

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Technical Considerations in Agro-based Project Planning and Evaluation:

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Abstract

The various aspects of agro-based project planning include choice of project and its viability, the need for the enterpreneur to have some knowledge of the project, project raw material and finished product handling, machine/equipment.

The paper establishes the hallmark of agro-based project planning as the technical issues involved in the above mentioned aspects since even the purely business considerations of the project depend on them. It maintains that project viability or non-viability should be the outcome of appropriate project planning and should not be confused with or evaluated from purely physical inducators of the profitability or non-profitability of the project as appears to be the trend in this country. The paper also presents real/hypothetical case studies to stress the importance of project viability and enterpreneur's knowledge of the project as well as raw material availability and machine/equipment sizing in the overall planning of an agro-based project.

In addition, specific recommendations on raw material availability, machine sizing and matching as well as project maintenance and management are presented.

Introduction

Proper planning or an agro-based project not only facilitates on-schedule development of the project but also guarantees the attainment of projected production levels. Such a proper project planning forms the basis of a bankable feasibility study of the contemplated enterprise.

Even when an agro-based project is one of the enterprises of the farm estate, its planning is usually the major specific planning to be carried out in the farm estate development plan. While the broad long term planning strategies as well as the economic feasibility considerations of the project are taken into account in the farm estate development planning, a much more in-depth planning of the project is usually required once the general farm estate development plans have been established.

Thus the identification of a particular agro-based project and the availability of the necessary investible funds to back it up should not be the only and/or major determining factor on which to base the decision of its establishment. It would appear that many people in this country who have the financial resources and/or real/claimed knowledge of agro-based projects have gone headlong into such projects without the benefit of a through planning. Such projects are not only bound to face problems but have been known to collapse and fold up eventually.

The sub-headings under which this paper discusses the technical consideration in agro-based project planning and evaluation may appear much more embracing than expected. This is necessary since it is not possible to discuss project planning without reflecting practically all aspects of the planning which generally relate to each other. Moreover, there is the need to identify planning options (where they exist) for any given aspect of the project planning and express the authors' views and recommendations.

Choice of Project and Its Viability

As agro-based project may initially be selected on the basis of the result of market survey, peoples' preference, taste and need with respect to the finished product are sometimes based on Government intentions and policy direction. Any or all of the above should enable the entrepreneur to determine in principle which agro-based projects have the chance of succeeding profitably. None of the above indicators, however, can make an anticipated project eventually successful without appropriate development and operational plans.

Unfortunately, in this country, the choice of projects, in general, are usually based on our concept of their viability as analysed only from such indicators mentioned above. Project viability, in our general understanding, refers to whether the project will be economically beneficial; will the project produce what it is intended to produce and will such products be readily sold to customers at reasonable profit? In order words, will the product be in demand? To many an entrepreneur, the answers to the above questions serve as the only viability test for the contemplated project rather than merely the indicators of its viability/profitability which they really are. A conclusive viability rating of a contemplated agro-based project cannot be readily established without a thorough and in-depth planning of the project.

In a "garri" producing project, for example, the project planning handles and evaluates issues such as: the sources of the raw material—cassava tubers; the production capacities that would accommodate the available raw materials; sources and capacities of machines/equipment; materials handling facilities; final product quality and the distribution network as well as maintenance and management arrangements. Hence the viability or non-viability of a project is only evident after a thorough planning and evaluation of the project has been carried out. We cannot, therefore, use general indicators from market surveys, the projected preferences and tastes of the consumers of the finished products, etc as the only or main determinant of the viability of the project.

Prospective entrepreneurs should not, and prospective consultants should not allow them (entrepreneurs) to regard general indicators of the chances of a particular project as the only measures of its viability in lieu of appropriate planning and evaluation. It is only through a thorough project planning that one can conclusively establish project viability or ensure its viability.

Need for Entrepreneur's Knowledge of Project

One may argue that the essentials for attaining and running a well-planned project include available funds to support all phases of the project on schedule and a good management team to oversee the project. We accede to the above argument provided the entrepreneur (investor) is an on-the-spot member of the good management team. This would imply that the entrepreneur has some definite knowledge on the details of the project. A definite knowledge of the details of the project makes the project planning easier and clearer to the entrepreneur who would be providing the funds at all stages of the project development.

In our example of the garri processing industry, cassava tuber is the required raw material. If this raw material has to be grown by the project, the entrepreneur has to be knowledgable in what it takes to grow cassava. Moreover, the cassava tubers may require to pass through several processes (peeling, grating, pressing, frying, etc) before the final product (garri) emerges. A definite knowledge on such processes is vital if the entrepreneur is to appreciate the need for several machines and machine components appropriately sized and matched for the production line. The final product (garri) must be marketed to the consumers in good state which requires good storage facilities and efficient packaging and distribution options. Once again, a fair knowledge, at least, on the above by the entrpreneur is definitely required and is probably a crucial aspect of the project planning strategy.

Project stage-by-stage development, inputs, outputs, yields/turnovers and/or gains must be understood by the entrepreneur in order to avoid rash decisions, impatience and over-expectations.

An entrepreneur does not have to enroll in an institution for this purpose since he can acquire all he needs from his consultants/experts provided he is interested enough in acquiring such knowledge. Armed with such knowlage, both the project planning and project implementation not only become easier for the consultants and the project management but also better appreciated by the enterpreneur. It is, therefore, strongly advocated that prospective entrepreneurs in agro-based projects/enterprises be encouraged to acquire some knowledge of their anticipated projects as an important project planning strategy. (See **Appendix A** – The essentials of a case study dealing with project viability and the entrepreneur's knowledge of his contemplated project).

Raw Material Availability and Potential

Probably, the most important aspect of planning an agro-based project/industry is the raw materials requirement to feed the project or industry. The raw materials are the inputs to the machines/equipment in the production line and hence detailed information on their availability is very crucial for the sizing of the machines/equipment. Some of the questions that immediately come to mind in this regard include: Are the raw materials available?;

Will they be purchased from local producers or produced/grown by the project?; What quantity will be available and how regular will this be?

One project planning option for raw materials provision may be the decision to purchase from local producers. In this regard the relevant questions will include the quantity that can be purchased and when this is available. The project plans in terms of continuous steady production will feature prominently in assessing the desirability of depending entirely on local supply of the required raw materials. This, in turn, introduces the issue of accessibility to the producers of the raw materials for the purpose of taking delivery of their products and the need for storage facilities to maintain the project on a steady production of the finished product.

Another project planning option for raw materials provision is the production of the raw materials by the project. This option calls for a much more detailed planning and programming of the entire project. In the case of the garri producing industry, a comprehensive cassava production sub-plan has to be formulated. The total area to be cultivated as well as the anticipated production output per unit area have to be ascertained. The crop production programme should be phased to coincide with the projected production output of the finished product. It is assumed here that preliminary investigations on available land, production techniques and other requirements have been carried out and appropriate decisions taken on each.

The third planning option for providing the raw materials requirement of the project is part supply from local sources and part production by the project. In this case the necessary considerations for each part source are the same as has been discussed above. Within this option may be included custom production of raw materials which is an arrangement whereby the project contracts local producers/farmers to produce for supply to the project on predetermined terms and conditions. The project may give assistance in cash and kind to enable the farmers to produce enough. Such assistance and guaranteed sale of products often encourage peasant farmers in their farm businesses thus helping solve the problem of raw materials supply to the project. But even this requires proper planning.

The important aspect about raw materials availability for an agro-based project/industry is that their total available quantity or potentially available quantity dictates the required machines/equipment's sizes and capacities. We cannot, therefore, attempt to tailor raw materials availability to already purchased machines/equipment as appears to be the case in this country where machines/equipment with capacities/sizes not related in anyway to potential raw materials availability have, in the past, been procured for projects. Such situations have usually resulted in gross under-utilization of the machines/equipment coupled with heavy maintenance costs.

While there is no doubt that tremendous opportunities exist for the production of various food crops and raw materials in this country, there is also no doubt that we are yet to avail of or reap such opportunities fully, considering our present economic status, the level of extension services and modern farming techniques available to the farmer and the rural infrastructural facilities available to enhance his farm business. Hence, it is almost impossible to project and rely on raw materials supply solely from local farmers for an agro-based project/industry expected to meet its planned output profitably. It is, therefore, our opinion that adopting the raw materials availability option of part supply from the project production is the most ideal in our present situation. The part-project production effort will account for a given percentage of the total requirement in line with available investible capital for a well planned and programmed raw materials production sub-project and after a most realistic estimate of the probable supply from the local farmers has been determined.

Another aspect of the raw materials availability planning is materials handling. The raw materials have to be conveyed from the fields (local farmers' and/or project farms) to the project site and since harvest time may be once or twice a year, the bulk of the raw materials have to be stored. The above calls for the provision of appropriate vehicles and storage facilities. In some cases the raw materials may be required to undergo processes not necessarily incorporated within the main production line. In such cases the requisite structures and facilities must be recognized duriing the planning stage and adequately provided for. It is accepted that the quality of the finished product of an agro-based project/industry depends, to a great extent, on the condition of the raw material prior to entry into the processing line. Clear appreciation and recognition of the required raw materials handling facilities and the adequate provision for same will place a project on the line to success in this regard.

Machine/Equipment Sizing and Matching

The machine/equipment size and capacity resulting from the determined production capacity of the project can be reflected in terms of daily production level as well as the number of shifts per day. For example, a daily production level of x unit capacity can be handled by one machine/equipment of total capacity of x units in a day of given number of working hours. The same production level can also be attained by two machines/equipment each of 1/2x unit capacity with either both machines operating for the same number of hours as before in a one shift-per-day work schedule or each machine operating for the same number of hours as before during one shift of a total two shift-per-day work schedule. Hence, the options presented above include either buying the large capacity machine or two of the smaller ones. Moreover, the phased planning strategy that has been recommended would imply that today's daily production level of x unit capacity will change to double or several times that capacity in the future. Thus, if we require a machine of x unit capacity today, we would require a much larger capacity in the future. From the above, a crucial planning question on machine/equipment sizing arises: Should we go for one giant machine/equipment that will accommodate the limit of potential raw materials availability even though we are aware that such machine will be grossly underutilized or should we procure smaller capacity machines/equipment and be prepared to procure more of such machines as the needs arise at probably an overall greater expense?

We strongly recommend smaller capacity machines. This is in line with our earlier recommendation on phased project planning strategy since we are not presently able to guarantee the quantity of raw materials available form sources other than the project's source. The project's source can only be guaranteed if well planned and to be well planned, past experiences in our case require that it be phased. More important, however, is the issue of maintenance, repairs and spare parts which will be discussed in detail later. The breakdown of one giant machine brings to a halt the entire project. With several machines the breakdown of one may hardly be noticed since the other will be in operation while the broken down machine is being repaired. Where the smaller capacity machines are used alternately as in shift work schedule, the incidence of breakdowns resulting from continous use will reduce and make for longer lasting machines/equipment. The issue of overall investment on one giant machine, on one hand, and several smaller capacity machines, on the other, may not arise when we consider the effect of the breakdown of the giant unit and the accompanying total incapacitation of the entire project. Nothing can pull down a project soon after it goes into operation like disillusionment on the part of the entrepreneur/investor due to unexpected development. Nothing can be more unexpected than the packing-up, probably due to a minor problem, of an ultra modern and probably automatic, giant machine soon after commissioning.

Another advantage of smaller capacity machines over a giant unit is with respect to machine matching. Like machine sizing, machine matching is an important project planning strategy. Machine matching requires that machine/equipment components match each other Hence, one machine component can easily be used by another unit whose corresponding component is faulty. This project planning strategy ensures that not all machine/equipment units are out of production at the same time. Effective machine matching can only be achieved with two or more machine /equipment units. (See **Appendix B** – a hypothetical case study on raw material availability and machine sizing).

Maintenance, Management, Spares and Personnel

It would appear that the aspect of project planning for maintenance and management has suffered most in this country. Usually, the projected returns of a project as estimated from its feasibility study and the available investible capital are the only things required by the Government or private entrepreneurs to commission a project. Machines/equipment are consequently from anywhere in the world without due regard to the personnel and spares required to keep the machines operational. Sometimes the machines may be the only ones of their type in the country. A typical example is the Nigerian Sugar Company at Bacita, where the processing plant packed-up soon after the expatriate personnel who installed it left the country. In this particular case, not only the factory packed-up but also the sugar plantation–the raw material sub-project–which had to stop production since there was no operation plant to feed.

Project planning for maintenance and management should recommend machines/equipment manufactured in the country, where available or those, though would be imported from outside, are already commonly in use in the country. In all cases, including when a machine/equipment brand is to be imported for the first time, substantial maintenance and servicing spares should be costed and provided for in the total cost outlay for the machines/equipment. We recommend 12 - 18 months spares initially to be purchased along with the machines and the updating of such spares as they are depleted. The important consideration here is that apart from occasional breakdowns, machines/equipment have to be periodically serviced. Spare parts are, therefore, required at all times during the life of the plant. We strongly advocate that consulting firms and experts involved in the planning and implementation of agro-based projects insist on the above planning strategy.

Apart from spare parts, there is also the issue of appropriate personnel for managing the project as well as servicing/repairing the machines. Proper personnel is usually a major problem in projects, particularly those owned and run by private entrepreneurs. It is not uncommon in this country, for example, to have the relation of the entrepreneur as the manager (chief executive) of a project even though such a relation has no knowledge on the details of the project or its products. The state of affairs in such a project is better imagined than discussed.

Project planning for management and maintenance must plan, provide for, and insist on appropriate personnel both in the management and maintenance cadre, both of which should be hired competitively, salaried and apportioned specifically defined duties. We are of the opinion that certain issues related to personnel and management which either hitherto had received little or no consideration in project planning in this country or are now the accepted general mode of operation of projects in industrialized countries, would facilitate the attainment of the above planning strategy. These issues include:

i) The employment of local or expatriate professionals.
ii) The mix of local professionals and expatriate professionals at the senior technical/management cadre.
iii) Combination or partnership or co-operation with related enterprises in matters of both production and distribution. This could provide for risk sharing.
iv) The modern management of personnel which involves all workers, especially the senior and intermediate staff as part owners of the project/enterprise. Although technical information on this is available, the programme, to the best of the authors' information/experience, is not in use anywhere in Nigeria. In industrialized countries, however, the programme is fast becoming the rule rather than the exception.

We advocate the employment of expatriate professionals either where equivalent local professionals are not available or where they (expatriate) will serve side by side and be understudied by their local colleagues. We also strongly recommend the indepth study, evaluation and adoption of the issues of combination/partnership or co-operation with related enterprises in order to share risks as well as involving the employees as part owners of the project/enterprise.

Finished Products

We have noted that the machine is sized based on the total available raw material. Before the size/capacity is confirmed, it is necessary to examine thoroughly the finished product output level and plan and provide for appropriate material handing facilities as well as its (finished product) marketing and distribution system. Hence, while machine/equipment output must depend on the available raw materials, the efficiency and effectiveness of handling, distributing and marketing the finished product most confirm the desirability of the determined machine output. A well-defined and established marketing and distribution system for the finished product must be worked out early enough during the project planning to enable the results to be used in confirming the determined machine/equipment size and capacity.

Conclusion

The hallmark of agro-based planning has been established as the relevant technical considerations involved in its various aspects since even the business consideration heavily depends on them. Agro-based project viability is the final outcome of a thorough project planning and should not be confused with or taken as the indicators of the apparent profitability of the project as appears to be the trend in this country and probably elsewhere in the developing world. In the area of agri-business in Nigeria and most African countries, practically any agro-based project/industry can be viable provided it is planned in line with the suggestions discussed in this paper which we recommend as the proper project planning procedure.

Specifically, we recommend the determination and structuring of an agro-based project/industry entirely on the available or possibly available raw material. In our present situation, we recommend part supply of this raw material from local supply source and part supply by the project through a raw materials production sub-project. Based on everyday experience around us, we strongly advocate that the private enterpreneur who is usually the sole investor on a project should avail himself/herself of definite knowledge on the details of the contemplated project and its final products as an important project planning strategy. We isisist on machine/equipment sizing based on available raw materials and confirmed by a desirable output level of finished product that can be efficiently and effectively handled, distributed and marketed. On the issue of project planning for maintenance, we strongly object to any compromise on providing for at least 12 - 18 months spares along with the cost estimates of the required machines/equipment and the appropriate updating of same as they are depleted. We also insist on the planning and providing for competitive recruitment of qualified and trained staff for the management and maintenance of the project.

Appendix A

Essentials of a Case Study on Project Viability and Entrepreneur's Knowledge of the Project

Recently an enthusiastic prospective entrepreneur rushed to us to request that we advise him on the best type and source of dryers for parboiled rice. We readily gave him the simple information he sought. When we then asked him for what project he needed the dryers, we were informed that he planned to go into the business of custom drying of par-boiled rice for farmers just in the same way as there exists custom milling of rice. He assured us that he had been advised that there was a big business in the project. Rather surprised at his confidence, we asked him the following questions, among others:

1. Do you know what is involved in parboiling of rice?
2. Do you know the state of parboiled rice as it is discharged from the boiler?
3. How do you propose to obtain the rice to be parboiled from the farmers?
4. What size of consignment of rice do you expect from an individual farmer at a time?
5. Since drying must start immediately after parboiling, how do you propose to handle the different consignment of rice paddy from different farmers? How do you plan to schedule or control deliveries from farmers such that each consignment goes into the dryer as it is delivered?
6. What basic data have you on which to base the capacity of the dryers you wish to procure?

Sadly enough, our apparently confident entrepreneur had no answers to any of the questions. He definitely knew nothing about the processes involved. After we had calmly explained a few things to him, we convinced him of his unpreparedness for the project at that material time. Needless to add that he left us disenchanted.

Appendix B

A Hypothetical Case Study of Raw Material Availability and Machine/ Equipment Sizing

A prospective entrepreneur calls on you and confidently states that he is not only interested but is fully prepared and ready to commission a "garri" producing industry. He proudly explains that he is financially ready to go in for a 5 t/h plant and that his only problem is where to obtain the appropriate machines and associated equipment.

While the financial capability of this entrepreneur may not be questioned, the immediate reaction to the above story by the professional in this area of interest is that he (entrepreneur) does not in the least appreciate the implication of his plans.

Lets examine some of these implications. He desires a garri producing machine of 5 t/h capacity. In a 10-h working day, for example, his factory should be producing 50 t of garre. We note that 4 t of cassava tubers will yield 1 t of garri. In other words, our entrepreneur requires 50 x 4 or 200 t of cassava tubers input per day for his factory (assuming a one-shift work). At a conservative yield of 10 t /ha of cassava tubers, he (entrepreneur) requires 20 ha of cassava farm land to supply the daily requirement of his factory.

So far so good. Twenty hectares of cassava farm land input requirement per day for a garri factory could be theoretically possible.

But then, consider the harvesting of the tubers from this area. Once more let us assume a conservative harvesting rate of cassava tuber as 0.01 ha/h-man (our traditional method of harvesting). Thus 20 ha of cassava farm land would require 2000 h to be harvested by one man.

The point of emphasis here is the magnitude of the numbers arising from the simple evaluation made above. That every aspect raised above is theoretically possible but cannot be argued. After all 2000 persons deployed to the 20 ha cassava farm would have completed harvesting the tubers in 1 h; let alone introducing efficient mechanized harvesting. But making available 20 ha of cassava farm ready for harvest every day for the factory is entirely a different proposition which requires thorough planning to be achieved in our present condition.

That our apparently confident entrepreneur did not have any idea of the basic evaluation made above before deciding on the capacity of his contemplated factory is quite obvious. ■■

Agricultural Mechanization at a Crossroad in Nigeria

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Abstract

After 40 years of agricultural mechanization in Nigeria there seems not more than tales of woes to show for it simply because policy makers equated agricultural mechanization to tractorization. Both population density and land use intensity suggest the use of human labour and animal traction. However, similar tractors are widely used throughout the country as Government and private tractor hiring units (THU) under which tractor time is grossly under-utilized, as compared to residual THU. Animal traction, though gaining in popularity, is not pushed institutionally because of the fear of trypanosomiasis in the Southern rain forest zone. This needs not be so because of the obvious advantages of animal traction and also because N'dama cattle which is tsetse fly-resistant can provide the tractive force.

Introduction

By 1988, Nigeria has experienced 40 years of agricultural mechanization with woeful cries of failure and catastrophic experiences. The Colonial Development Corporation, a profit-oriented organization, initiated agricultural mechanization in the country with Mokwa Land Settlement Scheme which was planned for 800 settlers on a land area of 50 000 acres (C.D.C., 1949). The project was a failure and abandoned for the government of Northern Region because of "... continued losses, poor harvest ..., unsatisfactory work of unsatisfactory settlers and still unresolved technical problems." (C.D.C., 1953). Baldwin, (1957), attributed the failure of Mokwa project to lack of knowledge and experience with the ecological system. He stressed that money, machinery and technical skill were not substitutes to knowledge and experience of the ecosystem.

The Western Region Production Development Board launched tractor hiring units (THU) simultaneously with the Mokwa project. Although the objectives of the scheme were equally laudable, the scheme was similarly pronounced a failure.

The Federal Department of Agriculture and Land Resources (1982) has declared that over 90% of the soil which are mechanically cleared, have been badly damaged. They contended that at least 20% are, in fact, no more suitable for arable cropping and that another 10% or so, are on their way out due poor yield, increased or complicated problems of soil management, desert encroachment in the North, and downward movement of the Savannah in the South.

The question is, where does agricultural mechanization go from here? This is the question which this paper is addressed to. In order to answer this question such issues as policy makers' concept of mechanization, options in tractor management, and animal traction as an alternative to tractorization will be discussed.

Mechanization Defined

To Nigerian policy makers, agricultural mechanization means tractorization. This interpretation follows from the Green Revolution Program of the 2nd Republic 1979-83 (F.M.A. 1980) summarized by Idachaba, (1981) as follows:

1. Substitution of appropriate mechanical energy for human energy.
2. Replacement of Government THU by private THU.
3. Area clearing and sub-division among farmers.
4. Inclusion of land development schemes in the agricultural schemes of the Agricultural Development Projects (ADP).
5. Mechanization of small farms.
6. Credit scheme for equipment and machinery purchases.

7. Government subversion for private machinery services and repair facilities.
8. Group equipment ownership.
9. Ensuring the maintenance of minimum land management standards.

In pursuance of this concept of mechanization, the Federal Government imported 3 390 tractors into the country between 1980 and 1982 (FDA, 1983). Awoyemi, (1985), put the total expenditure on farm machinery procurement for the Green Revolution Program at 41 million Naira (4.6 Naira equal one US dollar). Furthermore, between 1977 and 1983 a total of 98 650 ha of land were cleared – bulldozed – by the Federal Government for farmers while Federal Government parastatals cleared over 200 000 ha. (Awoyemi Ibid).

Because of this narrow concept of mechanization, the Government could not address herself to the pressing energy needs of the farmers, for instance, in weeding. If mechanization were understood as the injection of other sources of energy which can be manipulated by man into agricultural production process or as defined by Arno (1986) as "... the completion of farm operations with minimum use of power, within the shortest time, at a low cost and increasing quality," or as seen by Anazodo (1986) "... the process of development and introduction of mechanized assistance of all forms and at any level of sophistication in agricultural production," the agricultural mechanization policy and program could have been different.

The policy and program could have been failure proof because they could have been based on Lantin's et al (1985) four mechanization foundation factors of

(i) research and development;
(ii) education, training and extension;
(iii) maintenance support service; and
(iv) marketing, financing and credit system.

Failure to adopt a broader perspective of mechanization has denied the country of mechanization advantage which have accrued to nations in similar ecological zones. As outlined by Anazodo (1986) such benefits as increased:

(i) productivity;
(ii) economic operation;
(iii) increased agro-business activity;
(iv) improved workingenvironment;
(v) dignity of farming;
(vi) reduced losses, drudgery; and
(vii) substitution of costs for adverse effects.

Agboola and Omueti (1982) listed such adverse effects as:

(i) intensive weathering of weatherable minerals and soil organic matter;
(ii) leaching of nutrients;
(iii) changes in soil structure and nutrients status due to the decline in soil organic matter;
(iv) reduced infiltration due to the blocking of both macro and micro-pores caused by the solubilization of clay particles resulting in flooding;
(v) nutrient imbalance in the soil.
(vi) over-liming of soil;
(vi) high soil acidity;
(viii) claypan formation and impeded drainage;
(ix) silting of adjoining rivers and Erosion; and
(x) erosion and low cropy yield.

Mechanization Sequence

The mechanization sequence of European nations, in historical perspective, according to the World Bank (1986), was from muscular energy to animal traction and thence to tractorization. Pingali et al (1985) have observed a positive correlation between this sequence and such variables as farming intensity, population density and the food supply system which is defined as progressive shortening of the fallow periods.

According to Nwoko (1988) the fallow system, population density and the farming intensity in Nigeria have defied the positive relationship which Pingali et al discovered in Africa South of Sahara. The main reason for this defiance is that mechanization in Nigeria was dictated by political decisions of the Governments in power.

Because of the diversity of ecological zones within Nigeria, the mechanization sequence of European countries does not need to be followed. At the same time, there is no justification for the current state of affairs in which similar types of tractors and implements are used from the Delta areas to the arid Savannah parts of the country with the only difference being the use of bulldozers in land clearing.

The use of bulldozers in land clearing is unregulated. Shortsighted pursuit of private benefits has promoted windrowing and knockdown methods which are cheaper than felling trees by chain saw by 67.3% and 34.4%, respectively, (Federal Department of Forestry, 1983) and which ruins the soil permanently for future cultivation.

Options in Tractor Management

Given that tractorization is imperative in some ecological zones under enforceable standards, the question is who should own and manage the tractors. Currently, there are two broad types of ownership: Government and parastatal and private ownership.

Government and parastatal owners operate tractor hiring units (THU) at subsidized costs to farmers who own 5 ha or more. Private ownership can be solely commercial rental THU, or residual THU (Nwoko and Durojaiye 1987), or, solely own use tractor ownership system. Residual THU which is normally practised by cooperative farming unions involves ownership of tractors for own use and renting only if it is profitable to do so after satisfying own demand.

As shown in **Table 1**, there is gross under-utilization of tractor time in both public and solely commercial THUs. Under-utilization is due to several reasons among which are the following:

(i) Tractors are used only during the rainy season.
(ii) The THUs do not own farms in which the tractors can be engaged when there is no demand for their services.
(iii) For those who demand the services of THUs the demands are for both "time synchronic and time-bound operations."
(iv) Because of the smallness of farm sizes, a lot of time is lost on inter-farm transportation.

In addition to tractor under-utilization, **Table 2** shows that public THUs operate at a loss ranging from 26 to 59% in that they do not cover their cost of operation. Furthermore, because their services are priced below those of commercial units, the subsidies of the former range from 106% to 340%. Subsidizing THUs is a way to socialize mechanization of agriculture. But since the operations of private THUs are profitable continued subsidy of THUs will decrease both the growth and profitability of private THUs.

It has been demonstrated by Nwoko and Durojaiye (1987) that it is neither possible to maximize profit by operating THU solely nor by owning and utilizing the services of tractors solely in the owner's farm. The latter is constrained by the size of the farm and the availability of labour while the former is limited by:

(i) competitive impossibility and informal price regulations; and
(ii) "time-synchronic and time bound" nature of farm operations.

It would appear, therefore, that a clear favoured option which will be to:

(i) reduce under-utilization of tractors; and
(ii) eliminate Government subsidies.

in order to institutionalize residual THUs.

Animal Traction Alternative

Although animal traction or mixed farming was introduced at Daura in Northern Nigeria in 1922 (Alkali, 1964) its growth between 1929 and 1965 was very limited as shown in **Table 3** because of high failure rates. The causes of the high failure rates were:

(i) Farmers sale of cattle to pay high local taxes;
(ii) High cost of cattle;
(iii) Difficulty of plough maintenance; and
(iv) Smallness of farm holdings (Nwoko, 1978).

At the inception of World Bank-supported Agricultural Development Projects (ADP) – in 1976, a base-line survey in Gombe ADPs showed that 79.95 of the farmers neither possessed ox – ploughs nor work bulls; 1.2% had work bulls but no ploughs; while 1.7% had ox-ploughs but no work bulls (GADP, 1977). This implies that only 17.2% of the farmers in the Bombe ADP area possed both work bulls and ploughs. But Makumba (1985) reported that more than three-quarters of the farmers use ox to prepare land; much less than 10% of the farmers used tractors on well under 1% of the total measured area. The indication, therefore, is that ox-ploughs are nowadays very popular in the Northern savannah of Nigeria.

The general arguments is that the ox-plough cannot be used in the Southern rain forest zone of Nigeria because of typanosomiasis from tsetse fly infestation. This argument has been rebutted by Pingali et al (1985) who argued that the smallest breed of cattle, N'dama, can be of high tractive power depending on unit health and constitution. Besides, the rain

Table 1 Tractor Time Under-utilization

(Unit: %)

State	1980	1981	1982	1983
Ogun	62	–	–	–
Rivers	42	–	–	–
Imo	43	–	–	–
Oyo	–	63	–	–
Plateau	–	–	45	–
Kwara	–	–	32	–
Benue	–	–	–	50

Source: U.G.N. Abimbola and J.A. Dairo, "Characteristics and sources of Data on Agricultural Mechanization in Nigeria" In Record Keeping and Agro-Statistics Data Bank in Nigeria ARMTI Table 5.

Table 2 Loss From THU

Operation	Percent
Ploughing	26.14
Harrowing	37.47
Ridging	59.21
Rotavating	35.14

Source: Nwoko S.G., Op. cit. p. 25.

Table 3 Distribution of Mixed Farming in Northern Nigeria, 1929-1963

Year	Nos. Started	Failure rate (%)	Cumulative total
1929a)	9		7
1930	13	15	17
1931	31	8	44
1932	71	6	108
1933	84	10	173
1934	139	4	298
1935	384	4	621
1936	474	4	1 054
1937	445	4	1 433
1938	321	9	1 598
1939	231	15	1 559
1945b)	N.A.	N.A.	2 400
1956	N.A.	N.A.	1 500
1965	N.A.	N.A.	3 600

Sources:
a) Report of Nigerian Livestock Mission, London, His Majesty's Stationary Office 1950 Colonial No. 266 Table 4 P.52.
b) Data from 1945 were obtained from Lacerent, L.K. (1968) "The Use of Bullocks For Power On Farms in Northern Nigeria" Bulletin of Rural Economics and Sociology Vol. 3 N. 2 pp. 235-262.

forest zone produces year-round fodder so cattle feeding is cheaper than in the savannah land.

Although there are no yield differentials between tractorization and animal traction (World Bank 1986) the former has definite advantages over the latter. Such advantages include inexpensive soil fertilization with farm yard manure, efficient use of crop residue and relatively low capital investment. The low cost of ox-plough acquisition makes it easier for individual farmers to acquire their own units.

Summary and Conclusion

Since the nation's interest is in increasing farm output and since tractorization does not necessarily increase yield, farmers should be encouraged to adopt various ways of increasing output. From Arno's (1986) analysis, the best of such ways include the use of mineral fertilizer, irrigation and plant protection methods.

Because Nigerian policy makers have adopted a narrow concept of mechanization, tractorization was introduced to farmers at a time when other variables like population density and farming intensity called for a different type of farm energy source. Tractorization has degraded a lot of soil on which it was applied. For the public and private THUs, there is a severe economic loss arising from tractor time underutilization which can only be cured by a combination of own use and hiring services if tractorization is imperative.

But field study indicates that animal traction can be popularized among farmers because of its low capital investment requirements, farm yard manure supply and effective use of crop residue. It might, therefore, be more profitable financially and in the long run in terms of soil preservation to encourage more farmers to adopt animal traction.

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Design and Development of a Tractor-drawn Automatic Sugarcane Planter

by
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Abstract

A fully automatic tractor-drawn sugarcane planter was designed and developed at the Indian Institute of Sugarcane Research, Lucknow. All the operations involved in sugarcane planting, viz opening of furrow, dropping of setts with desired overlapping, placement of insecticide and fertilizer and covering of setts with a blanket of soil, are accomplished in a single pass. A two-row unit can easily be operated by a 35-hp tractor. During field trials, the planter gave an output of 2.5 ha/day of 8 work hours.

Introduction

Sugarcane planting is one of the labour intensive operations in sugarcane culture. Traditionally, sugarcane is planted manually with the help of bullocks and a 'desi' plough. On an average, it requires 17 man-days and 2 pair of bullocks for a day to plant 1 ha of field (1). A drop type tractor-drawn semi-automatic sugarcane planter was designed and developed at IISR, Lucknow. (2). Non-uniform dropping of setts, high labour requirement and fatigue to the operators, were major limiting factors and as such these planters could not find much favour with the growers. A roto-drum planter developed at PAU, Ludhiana, was a modification of the IISR design in the sense that setts were dropped into the pockets of a rotating drum rather than in the stationery chute. The problems remained the same with this design also. Srivastava and Menon (3) designed a tractor-drawn automatic planter which could not become a commercially viable unit because the metering system was not perfect. There was intermittent choking due to bent cane pieces and bridging effect in the seed hopper. This resulted in making gaps in the stand of the crop. Keeping these factors in view, the work was initiated on the design and development of a suitable cane metering system which can be used successfully with tractor-drawn sugarcane planter (drop type) as well as in the animal-drawn planter with slight modification in the design of the drive systems. Such type of planter has been designed and successfully field-tested.

Design Criteria

The basic design considerations are summarized below:

1. Integrally mounted on a 35-hp tractor.
2. Arrangement for all the operations from opening of furrows to covering of setts with a blanket of soil and its compaction. Rows could be made within a spacing of 750-900 mm.
3. Application of fertilizer and insecticide at recommended doze.
4. Uniform dropping of setts in the range of 400 setts per 100 m row length with 3-5 cm of overlapping between the setts. The metering system to be designed in the manner so as to accommodate even slightly bent cane pieces.
5. Capacity of the seed box and fertilizer box to be fixed so as to cover a distance of minimum 100 m per filling with a view to minimizing the number of the fillings.
6. Low labour requirement and an expected output about 3 ha/day so as to make it a economically viable unit.

Keeping these considerations in view, the design of the various components was developed. **Fig. 1** shows a side view of the equipment giving configuration of the various systems.

Technical Details

The IISR automatic sugarcane

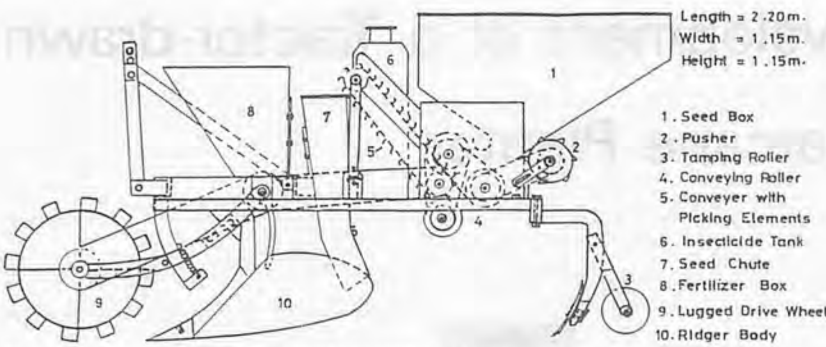
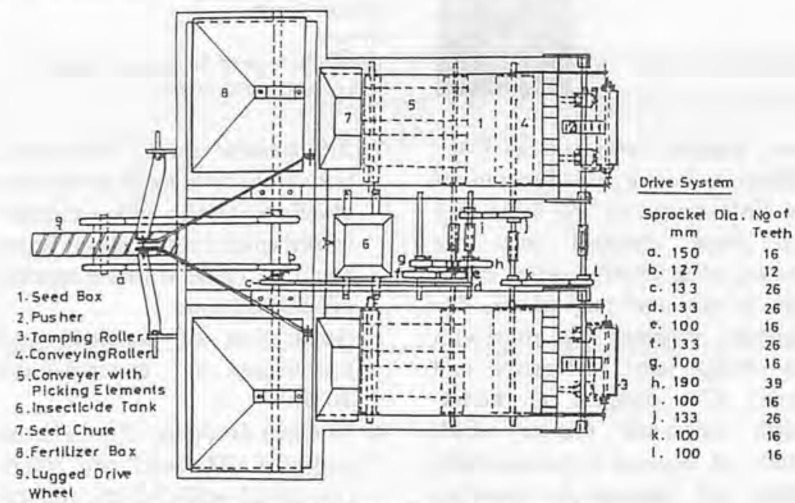


Fig. 1 IISR tractor-drawn automatic sugarcane planter, side view.



Sprocket	Dia. mm	No of Teeth
a.	150	16
b.	127	12
c.	133	26
d.	133	26
e.	100	16
f.	133	26
g.	100	16
h.	190	39
i.	100	16
j.	133	26
k.	100	16
l.	100	16

Fig. 2 IISR tractor-drawn automatic sugarcane planter, top view.

planter (Fig. 1) is designed as an attachment to the standard tool frame on which ridger bodies are bolted. The spacing between two ridgers is adjustable as per recommended row-to-row spacing. An auxiliary frame is bolted with the main frame on which, metering system for seed cane has been provided.

The metering system is salient feature of the automatic planter. It comprises of the following components: Seed box, Pusher wheel, Conveying rollers, Picking elements rivetted on a flat belt conveyer, seed chute, and drive system.

1. The seed box is made of 20-gauge mild steel sheet and the overall diamensions are 860 x 380 x 560 mm. The front and rear walls are straight up to a height of 250 and 150 mm, respectively, and then inclined at an angle of 60°. The two walls end into a small compartment on the conveying roller. The cane pieces slide on the conveying roller towards the picking elements. The rear wall has a vertical slot through which pusher wheel moves.

2. The pusher wheel is circular (150 mm diameter) and 6 units of backward inclined lugs (25°) were welded on its periphery. The pusher wheel moves through a slot in the rear of the seed box and pushes the cane pieces forward on the conveying roller.

3. The conveying roller is a mild steel 125 mm dia and 350 mm long meter pipe with rubber coating on it. The conveying roller takes the cane pieces into the temporary storage space, where these are picked up by the elements of the conveyer belt.

4. Twenty-three picking elements of L section (20 mm x 20 mm) made of mild steel, are rivetted on a flat belt conveyer system. The spacing of picking elements are kept so that even bent cane pieces can be accommodated.

5. Seed chute is made of mild steel and opens into furrow. Cane sett pieces pass through the chute and drop horizontally in the opened furrow with desired overlapping. lapping.

6. The drive system for various components of the planter is provided through a 400-mm diameter lugged wheel. Twelve 50 x 50 mm lugs are welded on the periphery. Two sprockets are provided to take the drive to a common shaft from where the drive is further transmitted to fertilizer-dispensing system and other components of the metering system of the planter. The drive system is shown separately (Fig. 2). The size of sprockets has been selected so as to drop specified numbers of setts per unit length with 3-5 cm of overlapping between the setts.

Fertilizer and Insecticide Dispensing System

The fertilizer dispensing system comprises of fertilizer box with side walls inclined at an angle of 25° to vertical. The wall inclination was selected considering the repose angle of urea, which is the most commonly used fertilizer. Two pieces of die-cast aluminium fluted rollers were used for metering of fertilizer in desired quantity. The drive is given through the ground wheel. The insecticide tank is provided on the main frame and is applied on the setts and in the furrow by gravity flow. At the end, setts are covered by a blanket of soil through four cultivator tynes with double point reversible shovels. A tamping roller at the end compacts the soil cover to conserve soil moisture.

Method of Operation

The planter is linked with the tractor and properly levelled. The seed box is filled with setts in an orderly manner and similarly the fertilizer box and insecticide tank are also filled. Planting operation is started. As the tractor moves, the furrow is opened, setts are pushed towards the conveying elements with the help of the pusher wheel and conveying roller. Eight to 10 cane pieces always remain in the temporary storage space from where these are picked up by the picking elements one by one continuously and missings are avoided. The picked up setts move upward on the conveyer belt and are dropped into the furrow through the seed chute. Fertilizer and insecticide are also applied in regulated quantity simultaneously before the setts are covered with a blanket of soil and at the end, soil cover is compacted with a tamping roller. All the operations involved in cane planting are carried out in a single pass. On an average, one filling is sufficient for planting 156-160 m row. Stock of seed material, fertilizer and insecticide is kept ready for immediate replenishment. **Fig. 3** shows the equipment in operation.

Fig. 3 IISR automatic planter in operation.

Table 1 Cost Comparison of Cane Planting with Conventional System and Automatic Tractor-Drawn Planter

Items	Conventional system	Tractor-drawn automatic planter
Labour requirement	17 man days	2 man days
Bullock pair hours	16	–
Tractor hours	–	3
Labour cost @ Rs.12/day	204	24
Bullock pair hour cost @ Rs.5/h	80	–
Cost of tractor hour @ Rs.50/h	–	150
Total cost of planting 1 ha	284	Rs.174
Output per day	1 ha	2.59 ha

Test Results

A. Machine parameters

1. Technical specifications
   Length : 2.20 m
   Width : 1.15 m
   Height : 1.15 m
   Weight : 3.5 quintals
2. Capacity of seed box:
   500 setts
3. Capacity of fertilizer containers : 50 kg.
4. Capacity of insecticide tank :
   20 litres
5. Row to row spacing :
   adjustable within 750-900 mm

B. Crop parameters

1. Variety COLK, 7810
2. Sett length : 300-350 mm
3. Av. diameter of sett .
   25-30 mm

C. Operational parameters

1. Depth of planting :
   200-250 mm
2. Setts dropped per 155 m :
   450-500 mm
3. Overlapping between setts :
   25-30 mm
4. Soil cover over the setts .
   100-120 mm
5. Soil moisture : 12% (wet basis)
6. Time taken to plant 155 meter distance (two rows simultaneously) : 3 min
7. Time taken for replenishing seed/fertilizer & turning etc./ turn (2 rows) : 2 min
8. Total number of rows planted per ha : 74
9. Time taken per row planting :
   1-5 min
10. Av. time taken in filling of seed box fertilizer box and turning etc. per row basis . 1 min
11. Av. time taken for planting 2.05 min one row
12. Total time taken for planting 1 ha : 74 x 2.5 = 3.08 or say 3 h.
13. Average output of the planter per day of 8 h work:
    2.59 ha or say 2.5 ha.
    Labour requirement : 2 men

Cost

The cost of operation of the planter has been compared with the conventional system of cane planting with a 'desi' plough and a paid or bullocks. The results are summarized in the **Table 1**.

Conclusion

The IISR fully automatic tractor-drawn sugarcane planter is a useful time and labour saving device. On an average the output of 2.5-3 ha/day of 8 h work can be achieved with the help of two labourers. There is a net saving of Rs. 100 per ha of sugarcane planting in comparison with conventional system.

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NEWS

AMA Co-editor Merle L. Esmay Dies

Merle L. Esmay

ASAE Fellow Merle L. Esmay, long time co-editor of AMA (Agricultural Mechanization in Asia, Africa and Latin America), died April 12 in East Lansing, Michigan, USA. Esmay, 69, was professor emeritus at Michgan State University in East Lansing, where he taught agricultural engineering from 1956 until his retirement in 1986.

In 1982, Esmay was awarded the ASAE Kishida International Award for making "outstanding contributions toward food and fiber production, improved living, and education of people outside the United States."

In 1979, he and Roy E. Harrington were co-leaders of a group of 15 ASAE delegates who traveled to China on a 21-day technical exchange misson. Esmay played a key role in organizing the exchange, which was first proposed by the Chinese agricultural ministry at a time when the United States and China had no formal relations. With Esmay's patience and support, the trip finally became a reality over two years later. It was the first U.S./China technical exchange to take place following normalization of relations between the two countries. The ASAE publication Glimpses of China, a record of the exchange co-edited by Esmay and Harrington, is still used as a resource for groups planning visitors to China.

Gajendra Singh Receives 1990 Kishida International Award

Gajendra Singh, professor of agricultural engineering at the Asian Institute of Technology (AIT) in Bangkok, Thailand, has been awarded the 1990 Kishida International Award by the American Society of Agricultural Engineers (ASAE).

The award was presented during the Society's 1990 International Summer Meeting, June 24-27, at the Ohio Center, Columbus, Ohio.

The Kishida International Award presented annually to a member of ASAE for "outstanding contributions to food and fiber production, improved living, and education of people outside the U.S.A."

Established in 1978, the award is sponsored by Shin-Norinsha Co., Ltd. of Japan, publisher of Agricultural Mechanization in Asia magazine and other publications. It is named after Yoshikuni Kishida, founder of the publishing firm and widely acclaimed pioneer in agricultural mechanization in Japan and Asia. Singh is presented the Kishida International Award in recognition of his "outstanding agricultural and food engineering education and research leadership in Asia."

By helping to form the Division of Agricultural and Food Engineering at AIT, Singh laid the foundation for international-level, postgraduate studies in agricultural engineering in Southeast Asia. He served as division chair from 1977 to 1984 and, under his dynamic leadership, the division grew from a minor branch of systems engineering to its present status as the largest and most active division in the school.

EIMA—Intern'l Agric. Machinery Manufacturers Exhibition
Nov. 7-11, 1990, Bologna, Italy

The world of machinery and equipment for agriculture and gardening, livestock and poultry raising will be on show for their respective 1990 editions at EIMA and ZOOTECH, which will be held, for the former on the Bologna Fairgrounds and for the latter at Modena Exhibitions, from the 7th to the 11th of November 1990.

The results of the 1989 editions of both exhibitions express, on the figures alone, their success in terms of exhibitors present and visitors who attended: EIMA and ZOOTECH reached together a quota of 1 665 exhibiting firms (1 440 Eima and 215 Zootech), for a total of 15 000 pieces of machinery of every type on exhibit; visitors were over 80 000 and officially registered foreign operators were more than 8 500 from over 100 different countries.

The forecast for the '90 editions of EIMA and ZOOTECH, which can be seen from the significantly large numbers of applications already received, predicts a vast and qualified Italian and foreign participation of manufacturing firms for machinery and equipment designed for agriculture, gardening and livestock and poultry raising which should more than satisfy the interest and needs of operators and experts in the field.

For information contact:
EIMA.00161 Roma, Via Lazzaro Spallanzani, 22/a

BOOK REVIEW

Agricultural Enginnering Soil Mechanics
(Developments in Agricultural Engineering, 10)
(Netherlands)

by E. McKyes

This book provides an introduction to classical soil mechanics and foundation engineering texts, and applies these principles to agricultural engineering situations. Theoretical design formulae are given, plus tables and graphs of handbook numbers such as bearing capacity factors, wall pressure factors, soil cutting numbers and soil mechanical properties. Many example problems of design and analysis are solved in the text, and there are unsolved problems given for each chapter.

The text begins with descriptions of soil origins and classification systems, including agricultural classification schemes, and then introduces classical concepts of soil strength and strengthen measurement techniques in the laboratory and in the field. Soil mechanics is applied to the design of shallow foundations, and the design formulae as well as tables of bearing capacity factors for design use are provided. New research and design findings in the specialized area of tall and heavy farm silos are also given, in addition to deep pile foundation design for heavy structures on very soft soils. Water flow in soils is treated, together with stability of ditch bank slopes and small earth dams, design of retining walls and pressure in bins and silos, soil erosion and protection methods, soil cutting and tillage design methods, soil compaction analysis, the use of geotextiles and problems of soil freezing.

Size 24.5 x 17 cm, pp292, hard cover. Price: US$57.50/Dfl. 120.00.

Published by Elsevier Science Publishers, P.O. Box 211,1000 AE Amsterdam, The Netherlands.

Agricultural Engineering Proceedings of the 11th International Congress, Dublin, 4-8 September 1989
(Netherlands)

edited by V.A. Dodd and P.M. Grace

The book presents a broad coverage of basic and applied research projects dealing with the application of engineering principles to both food production and processing and illustrates the considerable contribution made by agricultural engineers in the development of one of man's oldest industries, agriculture. Approximately 450 papers from over 50 countries world wide, were presented at the congress and are included in these proceedings.

The papers have been classified into a series of four volumes as follows:

Volume 1. Land and water use. Land use of peatlands, including peat production, drainage and hydrology; traffic and transportation systems in agriculture including the design, construction and maintenance of rural and farm roads, on and off-farm transportation systems; environmental aspects of land use including the land spreading of animal manures and sewage waters, the processing of animal manures, drainage, irrigation, soil erosion and water management.

Volume 2. Agricultural buildings. Environmental control in buildings for animal production including heating, ventilation, dust and other contaminants, odour emissions and control; Current design practice for the layout of buildings for animal and crop production and storage; the design of farm buildings in relation to the landscape; the use of new materials and construction methods; low cost farm buildings including greenhouses; computerized controlled feeding and milking of livestock buildings and the consequences for the management and welfare of livestock.

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Volume 4. Power, processing and systems. Controlling energy operated processes in agriculture with emphasis on post harvest technology including grain drying; fundamental and applied aspects of processing agricultural products including rice, coffee, carrots and milk; recent developments in tractors and fuels. Management and decision making systems for agricultural machinery. Application of new techniques in education, research and development.

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

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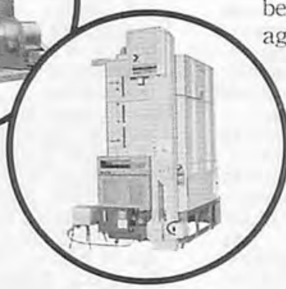
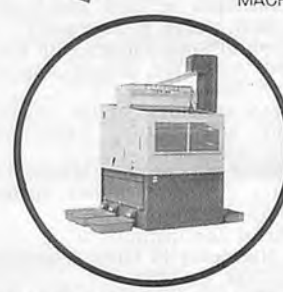


GRAIN DRYER

PRE-CLEANER

SOYBEAN SELECTING MACHINE



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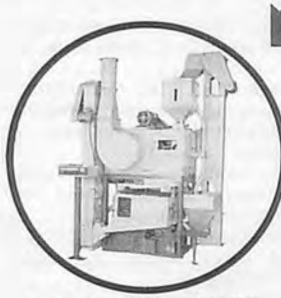

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- ★ Seed Processing Plant
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- ★ Feed Cutter (Cylinder Type & Wheel Type)
- ★ Wood Chipping Machine
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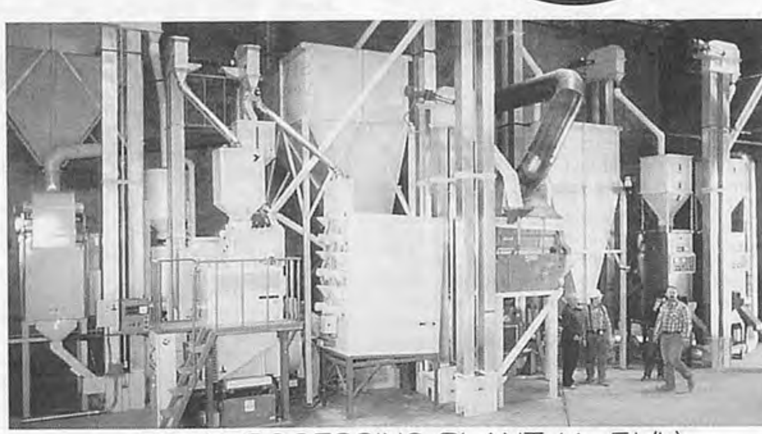

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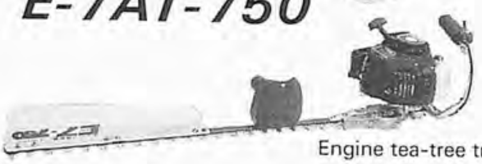
OCHIAI is the top-ranking tea-leaf picker manufacturer in Japan. OCHIAI's products are used in tea-producing areas worldwide.

Engine tea-tree trimmer

E-7AT-750



Engine tea-tree trimmer

E-7-750

Mini trimmer

E-7-600

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)				

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

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