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AMA

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VOL.21, NO.4, AUTUMN 1990

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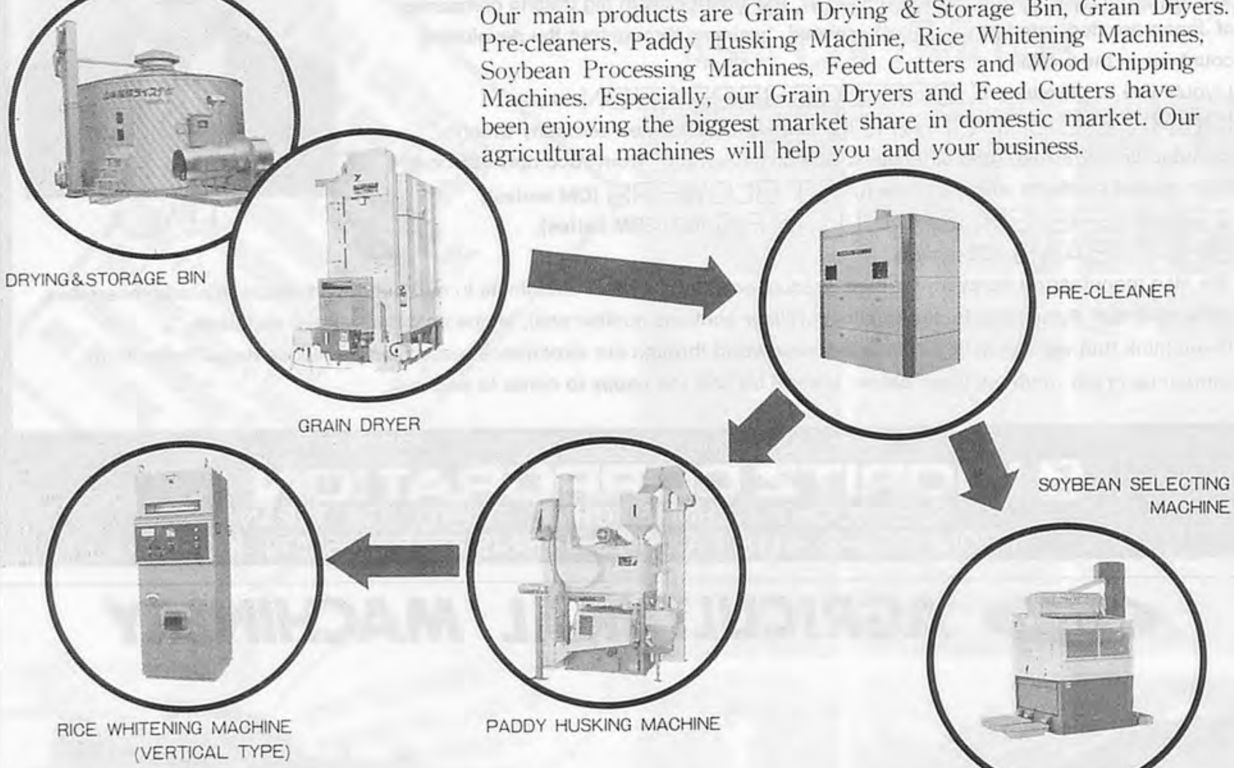

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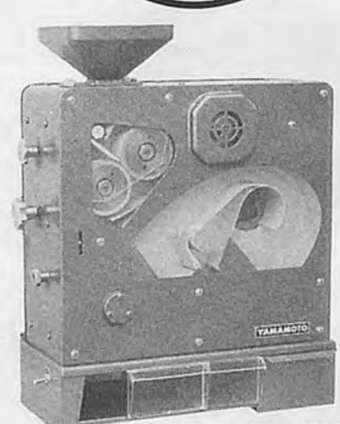

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EDITORIAL

The New Round Needs New Outlook

The New Round of consultations among delegates from advanced countries is underway in an effort to develop a new framework in international trade of agricultural products. The United States had maintained a position of 100-percent removal of protection for farm product exports in 10 years. This position, however, has been watered down to 70 percent even as negotiations and heated arguments continue among the delegates in the New Round.

It seems obvious that the arguments advanced by delegates from developed countries hardly reflect the interest of farmers—whether they be from developed or developing countries. In comparison, the arguments are evidently loaded in favor of the consumers as a whole although it is not easy to draw the line between farmers and consumers considering that farmers themselves consume imported farm commodities. Consider also the fact that even in the United States, farmers are a political minority in contrast with the political majority who are not only non-farmers but also work and live in urban centers.

The new outlook that the New Round needs is a simple matter of giving equal consideration to the plight of farmers world-wide. When this is the case, it will dawn upon the delegates that Mother Earth has a productive power that is repeatedly generated by the action and reaction of the ecological system. What this implies is that under current policies affecting agriculture in many, if not all, of the developed countries, it has become more and more difficult to maintain the reproductive capacity of agriculture on a long-run basis because more and more, farmers are not getting the right incentive of receiving better prices for their products.

Should the position of the United States prevail in the New Round, one is apprehensive that the ecological imbalance in many countries will be accelerated. Even as each country has its own peculiar geographical conditions and historical backgrounds, it is imperative that farm products should be traded at prices that inspire confidence among farmers. Therefore, the New Round of talks should take into account the regeneration of productive agriculture which is actually that of reconciling mankind and the ecological system. This also calls for consumers to carry part of the cost of maintaining the ecological system.

The prevailing low trend of farm product prices is spawning so much distress among farmers world-wide, particularly in developing countries where the ratio of farmers to the total population is high. The end result sees the youth moving away from the farms to the urban areas—leaving ageing farmers behind that jeopardizes farming operations even when farm machineries are available.

The New Round will indeed do well to focus attention also on the need to raise prices of farm products in the international trade.

The AMA and its readers eagerly want this new outlook to influence the current New Round.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
October, 1990

CONTENTS

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol. 21, No. 4, Autumn 1990

*   *   *

Development of Auger Digger as Attachment to Power Tiller

by

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Abstract

An auger unit that can be operated by a power tiller of 8-10 hp was developed to dig holes for planting tree-seedlings in agro-and social forestry programmes. The unit is capable of digging 35-40 holes/h. The size of the hole is 22.5 cm diameter and 45 cm in depth. The cost of the attachment is Rs. 2 500. The performance and cost of the power tiller-operated auger digger unit is compared with those of manual digging and tractor-operated auger digger.

Introduction

Of the total geographical land area of 328 million ha in India, 30 million ha are in the form of waste lands, degraded soils and marginal lands. In these lands, farming is not economically feasible and, therefore, alternative land uses have to be thought of. Agro-forestry systems involving a combination of woody perennials and annual cultivated forage plants with the animal component for long-term fertility restoration are presently advocated for such lands. In fact, agro-forestry is gaining momentum in the context of global energy crisis.

Power tillers are visualized as potential source of power for orchards and agro-forestry due to their compact size and manoeuvrability in narrow and cropped fields. With the development of matching equipment for food crops and orchards, their application in agro-forestry has immense potential. Tree planting has so far been done manually. With an increase in the tempo of tree plantation work, the need for a mechanized or semi-mechanized tree planting unit has been felt for some time now. A digger unit will also increase the extent of usage and versatility of power tillers.

Materials and Methods

The digger unit that was developed (**Figs. 1 and 2**) in this study is a standard equipment which can be front-mounted on any power tiller. The unit consists of a spiral auger actuated by a rack and pinion arrangement. By this arrangement the auger can be moved up and down with the help of a simple rotating hand wheel. The drive for the circular motion of the auger is effected through belt pulley and bevel gear transmission from the engine directly without affecting the transmission for movement of the power tiller. The entire assembly is mounted on a rectangular frame with necessary bearings and fixtures. The hand wheel provided at the side of the unit can be effectively used for depth control.

The main specifications of the digger are enumerated below:

Auger diameter – 22.5 cm
Auger pitch – 10.0 cm
Auger speed – 430 rpm
Maximum rack ply – 45 cm
Belt pulley transmission ratio – 1 : 2.5
Bevel gear transmission ratio – 1 : 1
Source of power – 8-10 hp power tiller
Overall dimensions of the attachment – 1677 mm height 636 mm width
Cost of power tiller – Rs. 34 000
Cost of the attachment – Rs. 2 500

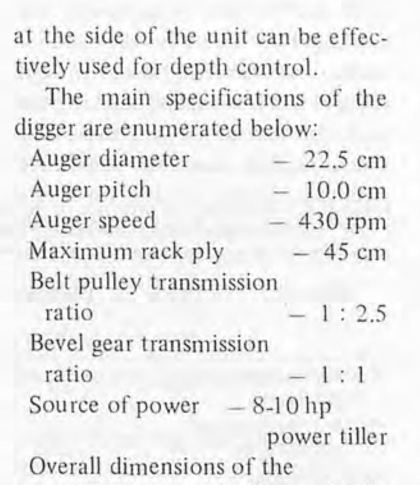

Fig. 1 Post hole digger.

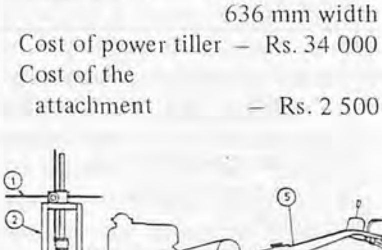

Fig. 2 Controlling the depth by hand-wheel.

Results and Discussion

The performance of the unit for digging pits as compared with the tractor auger digger and manual digging is presented in **Table 1**. The cost analysis is given in **Table 2**.

The cost of digging pits and the time consumed by power tiller digger is minimum as compared to the manual digging and tractor-operated digger. When the saving in cost and time is compared, it is observed that the power tiller auger digger unit excels. The savings are 6.00 and 91.45%, respectively, for making 100 holes. In the case of tractor attachment, even though there is 90.70% saving in time the cost is found to be more by 178.67%. The economic feasibility of the unit as compared with tractor and manual digging was analyzed (**Fig. 3**). It may be inferred that the pay back period for the power tiller auger unit is 3 years or 3200 pits whereas the tractor auger unit take 22 years for 22 500 pits for cost realization.

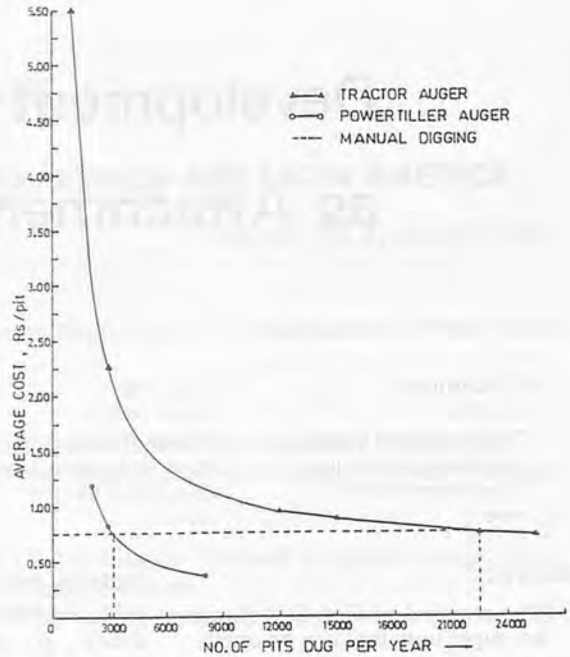

Fig. 3 Comparative cost economics of tractor and power tiller augers with manual digging.

Table 1 Comparative Performance of Pit Digging by Tractor Auger Digger, Power Tiller Auger Digger and Manual Digging

Method	Depth (cm)	Diameter (cm)	Time taken for 100 pits (h)	Cost of digging 100 pits (Rs)	Cost saving (%)	Cost saving (%)
Tractor-operated auger digger	45	30	3.10	209.00	−179	91
Power tiller-operated auger digger	45	22.5	2.85	70.40	6	91
Manual digging by pick axe and spade	43	45 (top) × 33.33 23 (bottom)	33.33	75.00	–	–

Table 2 Work-Sheet for Cost Analysis

Particulars	Power tiller	Tractor	Manual
Cost of auger attachment (Rs.)	2 500–00	8 000–00	– –
Cost of the basic unit (Rs.)	24 000–00	100 000–00	– –
Total cost (Rs.)	36 500–00	108 000–00	– –
Fixed cost of operation (Rs/yr):			
a) Depreciation	607–50	1 620–00	– –
b) Interest (14%)	520–50	1 386–00	– –
c) Shelter, insurance and housing (2%)	85–00	200–00	– –
d) Repair and maintenance (10%)	675–00	1 800–00	– –
Total	1 888–00	5 006–00	
Variable cost (Rs/yr):			
a) Fuel cost	357–50	1 200–00	
b) Oil cost	43–50	162–00	
c) Operator's charge	175–00	375–00	
Total	576–00	1 737–00	
Total cost of operation (Rs/yr)	2 464–00	6 743–00	
Total cost of operation (Rs/h)	24–64	67–43	2.25
Capacity of the unit (pits/h)	35–40	30–35	–3–
Cost of operation/pit	0.61–0.70	1.92–2.25	0.75

The cost analysis is made on the assumption that the digger works for 100 h a year.

Conclusion

The digger unit developed is simple to operate. It digs holes of 22.5 cm diameter up to a depth of 45 cm for tree planting. About 35-40 holes can be dug in one hour. It can be easily transported to different locations. A special advantage of the unit is that completely cylindrical pits are dug as against tapered holes dug along the length in manual digging. Since it is attached to a power tiller, it can reach spots where tractor entry and manoeuvrability are difficult. It is also possible to achieve reduced cost of operation and saving in time. At the same time, the unit also increases the versatility and the annual utility hours of a power tiller. ■■

Dual-mode All-crop Thresher for Egyptian Conditions

by
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Abstract

Tenderized wheat straw is widely used for animal fodder in Egypt and many other developing countries. Special beater type threshers are used in these countries for simultaneous threshing of wheat and tenderizing of straw. These threshers, however, cannot be used for threshing crops with tough straw or cobs such as paddy, sunflower, sorghum, etc., which are grown in rotation with wheat. These crops can be threshed with Axial Flow type threshers but such machines cannot tenderize wheat straw. Thus farmers in such developing countries do not have access to a single machine which can be used to thresh all the crops that they grow. Consequently the fodder-making crops are the only crops that are mechanically threshed. Paddy and some other crops continue to be threshed with manual methods or by treading under animals or tractors.

This paper describes a dual mode thresher that has been developed in Egypt under the USAID supported National Agricultural Research Project (NARP) which can be operated both as a beater or an axial flow type machine. This machine can thresh all the popular cereal crops that are grown in the developing countries and can also make fodder from straw. The dual mode machine has generated much interest among farmers, and three manufacturers have now started commercial production in Egypt.

*Machinery development activities reported in this paper are being conducted at the Design Section of the Agricultural Mechanization Research Institute (AMRI), ARC, Giza, Egypt under the technical supervision of the author.

Introduction

Widespread acceptance of mechanical threshers for wheat and continued threshing of paddy with traditional methods is an interesting phenomenon common to Egypt and many other developing countries where wheat and paddy are grown in rotation. In such countries fodder from wheat straw, popularly known as "Tibn" in Egypt and "Bhoosa" in India and Pakistan, is widely used for animal feed.

Because of the fodder-making requirements, special beater type threshers, which shred and tenderize straw to make fodder, are widely used in these countries. The beater type machine, however, cannot be used for threshing crops which have fibrous straw or tough cobs, such as paddy, sunflower, etc. Such crops can be threshed with axial flow type threshers, but these machines cannot make fodder while threshing wheat. Consequently farmers in these countries do not have access to a single machine which can be used for threshing all the crops that they grow.

Types of Threshers in Developing Countries

All threshing machines have a threshing drum, which consists of a long cylindrical-shaped member to which a series of pegs, knives or rasp bars are attached on its surface. The threshing drum is mounted on two bearings and rotates in a perforated trough-like member, called the "concave." During threshing, crop is fed between the threshing drum and the concave, where it is subjected to a high degree of impact and frictional forces which detach grain from panicles. There are essentially two types of threshers popular in the developing countries, a) the Beater type and b) the Axial Flow type. The movement of crop material in the two types of threshers follows slightly different paths (**Fig. 1**).

In the Beater type machines, the threshing cylinder rotates in an enclosed chamber, with the lower part of the chamber forming the

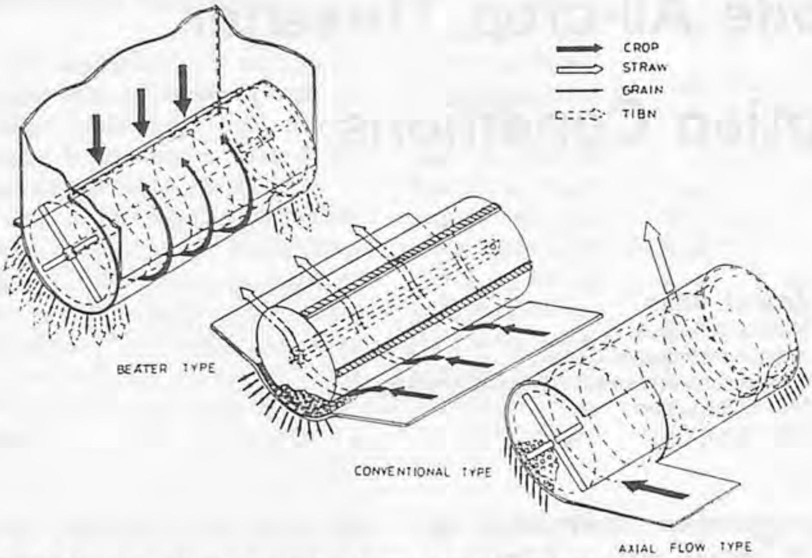

Fig. 1 Movement of crop material in beater. Conventional and axial-flow type threshers. AK 1989.

Fig. 2 Locally-produced Turkish beater type threshers popularly used for wheat threshing and fodder making in Egypt.

concave. This part has small perforations. There are no separate outlets in the machine for ejecting straw. In these machines, straw is shreded and tenderized by the beating action of the threshing knives until it is small enough to pass with grain through the small perforations in the concave. The beater type machines thus function like a combination thresher and hammer mill.

These threshers were specially developed for making fodder from straw which could be easily shredded and tenderized such as of wheat and barley. These machines are widely used in Egypt, India, Pakistan, Turkey, Iran, etc., where fodder from wheat straw is used for feeding animals. These threshers however cannot be used for threshing paddy, sunflower, sorghum, etc., i.e., for crops which have tough straw or cobs.

In the Axial Flow machines, crop moves spirally between the threshing drum and a circular concave for several complete turns. Crop is thus threshed for a longer duration by the repeated impact of the threshing pegs. In these machines, almost all of the grain is separated from the straw through the concave perforations. Straw is finally ejected through a large straw outlet at one end of the concave. Since all grain is separated from straw at the concave, bulky grain/straw separating and cleaning mechanisms are not needed, resulting in rather simple and compact designs. These machines can thresh almost all crops but cannot be used for making fodder from straw. The axial flow machines are mostly popular in the wet tropical countries such as the Philippines, Thailand, Indonesia, Sri Lanka, etc., where paddy is the primary crop.

All-crop Threshers for Developing Countries

Farmers in the developing countries need a single thresher which can be operated like a beater type machine for making straw fodder while threshing wheat and also work like an axial-flow machine for threshing other crops such as paddy, sunflower, sorghum, etc. In the past many attempts have been made to incorporate fodder-making features in conventional and axial flow type threshers by installing different types of straw chopping devices. These attempts have not produced satisfactory quality fodder as straw and more specifically the nodes were not sufficently tenderized by the chopping action. Fodder-making normally involves subjecting the straw to a very high degree of impact and friction for complete shattering and tenderizing of stems and nodes.

Some years ago, a convertible dual-mode threshing concept for both beater and axial flow operations was experimentally tried by the NARP agricultural mechanization specialist in the development of the IRRI-PAK multicrop thresher in Pakistan. It was felt that a similar concept could be utilized in developing on all-crop thresher for Egyptian conditions. A survey of farmers in the Nile Delta in 1988 indicated that conversion of the popular Turkish type wheat threshers (**Fig. 2**) to dual-mode operations could be a good solution for meeting the different threshing and fodder-making needs of Egyptian farmers. Such an approach would utilize the existing threshers that are already available with farmers and would facilitate rapid commercialization of the improved machine. The Turkish type wheat threshers which have beater threshing drums and built-in screen-air cleaners have gained much popularity during the last five years in Egypt. These machines are now locally manufactured by many companies and are widely used for threshing wheat and some other fodder-making crops. Rice, the second most important cereal food crop, however continues to be threshed by treading with animals or tractors.

Dual Mode Conversion of the Turkish Beater Type Wheat Threshers

The following specific modifications were carried out in the Turkish wheat thresher to incorporate the convertible dual-mode threshing features **(Fig. 3)**.

1. Installation of a set of louvers inside the threshing drum cover **(Fig. 4)** such that these could be set at 90 degrees to the drum axis for threshing wheat in the beater mode or at 75 degrees to the drum axis for threshing paddy and sunflower in the axial flow mode.
2. Installation of a hinged cover to partially block the full width beater type feed opening for feeding at one end of the threshing drum while threshing in the axial flow mode.
3. Fabricating an outlet with a door in the drum cover at the opposite end to the axial flow feed opening for ejecting straw. The straw outlet door is to be closed for threshing in the beater mode.
4. Installation of four straw thrower paddles on the knives of the threshing drum which were in alignment with the straw thrower outlet.

With the above modifications, all the original features of the beater type Turkish thresher were fully retained and yet the machine could be quickly converted from beater to axial flow mode by the following actions:

1. Setting the axial flow louvers at a 75 degree angle to the threshing drum axis.
2. Opening the straw thrower outlet door.
3. Restricting the full width feed opening to one end of the threshing drum by closing the partial feed cover.

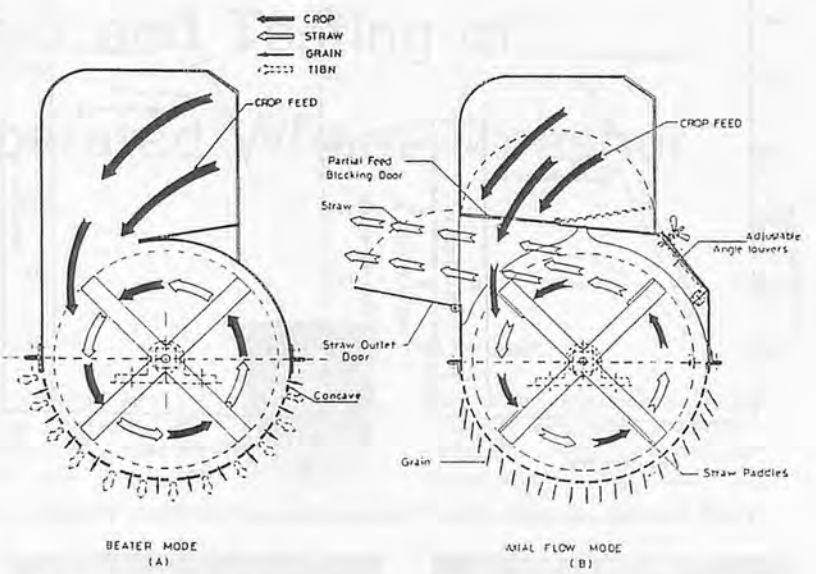

Fig. 3 Schematic view of the threshing drum-concave of the a) The Turkish beater type wheat threshers and b) The modified dual-mode all crop thresher, AK 1989.

Fig. 4 Adjustable angle louvers in the threshing drum cover of the modified dual-mode all-crop thresher. Louvers are shown in the axial-flow mode for threshing paddy.

Tests and Commercial Production

Two units of the modified dual mode all-crop thresher were tested on wheat and paddy during the 1989 harvesting seasons. A threshing output of 390 kg/h of wheat and 634 kg/h of paddy was obtained during these test runs with the machines. A maximum threshing output of 900 kg/h of paddy was recovered with one machine after the operators has learned to feed the machine at a steady high rate. Maximum grain losses of 1.5 and 1.2% were obtained for wheat and paddy respectively. Cleaning efficiencies ranged from 97.6 to 99.9% **(Fig. 5)**.

Farmers and manufacturers who have observed the machine in operation **(Fig. 6)** were most impressed with its performance. Much excitement has been generated by the successful conversion of the Turkish wheat threshers by the AMRI-NARP Program as many manufacturers have been trying for a number of years to adapt these threshers for paddy without much success. Three manufacturers have now started commercial production of the modified Turkish thresher in Egypt **(Fig. 7)**. The collaborating manufacturers, Messers Gabr & Co., Tanta Motors Co., and Mabrouk Brothers Co., have already sold over 100 of the new all-crop machines during the months of January-May 1990, even though the paddy harvest season is still five to six months away. Many farmers are now bringing their old Turkish threshers to these manufacturers for dual-mode conversions.

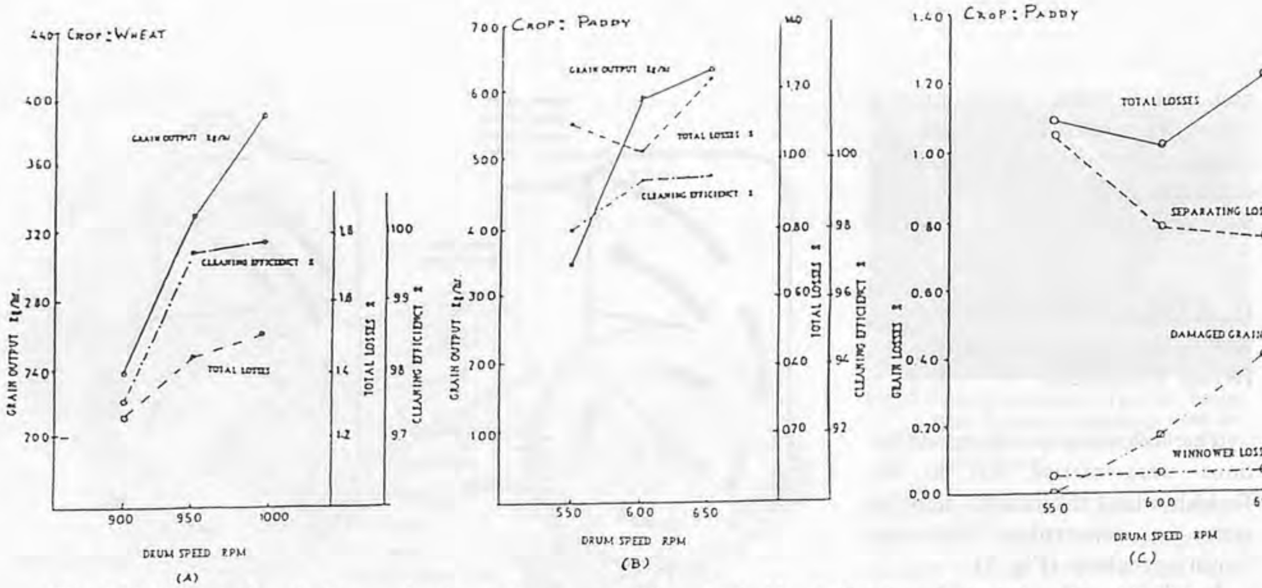

Fig. 5 Modified dual-mode all-crop thresher performance a) Wheat, b) Paddy, c) Threshing losses with paddy. AK 1989.

Fig. 6 Modified dual-mode all-crop thresher being used by farmers for threshing paddy in the Nile Delta. AK 1989.

Fig. 7 Modified dual-mode all-crop threshers being commercially produced by one of the cooperating AMRI manufacturers in Tanta, Egypt. AK 1990.

The dual mode all-crop threshers offer an excellent potential for expansion of the thresher markets and for generating year-around demand for threshers in Egypt. Farmers in India, Pakistan, Turkey, Bangladesh, etc., where wheat and paddy are grown in rotation and wheat straw is used for animal fodder, could also benefit greatly from use of such dual mode machines. ■■

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Development and Testing of a Power-operated Wheat Thresher

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Abstract

A power-operated wheat thresher was designed, developed and tested with a view to increasing the threshing efficiency and to reduce the cost of threshing in comparison with traditional methods of threshing wheat crop. It was observed that maximum threshing efficiency of 95.3% can be achieved by threshing the wheat crop at 9.25% moisture content at a peripheral speed of 1 027 m/min (500 rpm) when the concave clearance is 1.3 cm. It was also found that net unit threshing cost per quintal of wheat is Rs. 13.63 when threshed by this thresher as compared to Rs. 14.94 when threshed by traditional methods.

Introduction

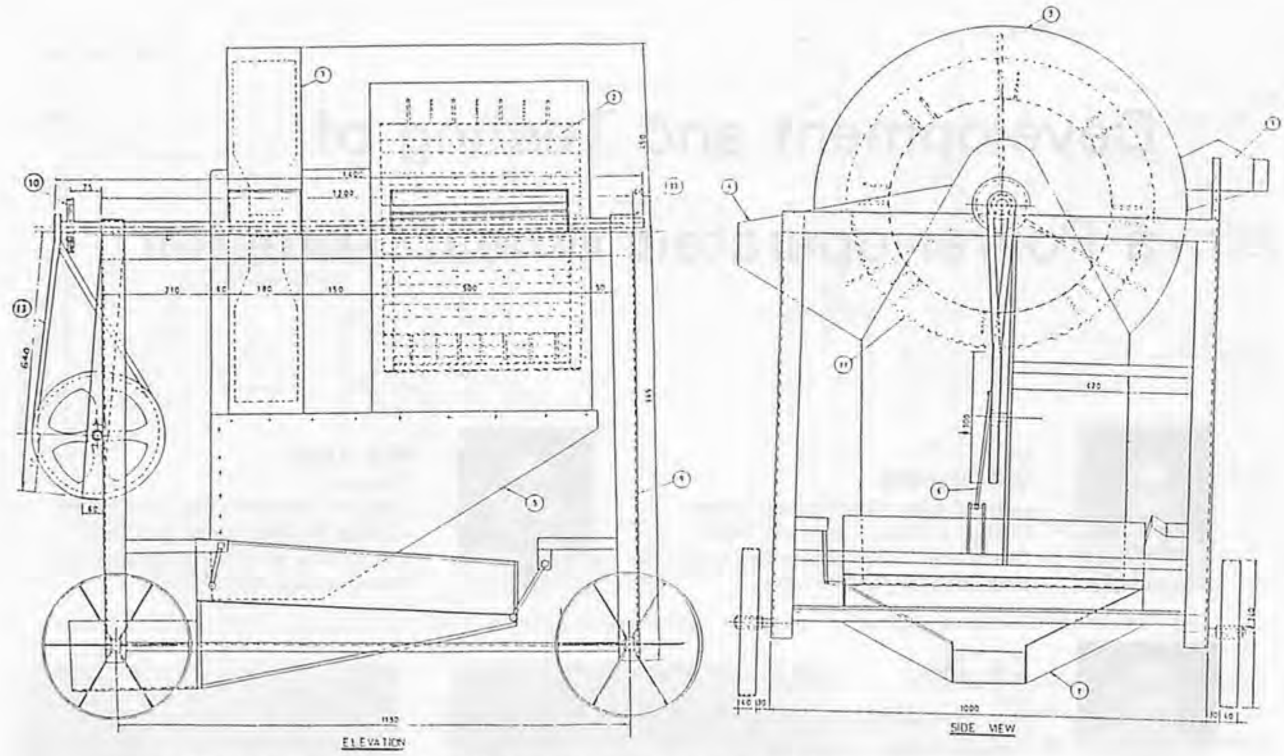
Wheat is the second largest crop grown in India after paddy. Not only the area but also the production of wheat per unit area has increased in the northern part of the country, particularly in the States of Punjab, Haryana and Uttar Pradesh. As a result, the stationary threshers of different makes have now replaced the traditional methods of threshing of wheat by trampling the crop.

During the last few years due to change of food habit of the people it was found that the wheat is being grown in sizable areas in the eastern states of India. The state of Orissa is situated between 17°50' and 22°30' N latitude and the medians of 81°21' to 87°38' E longitude and has got 6.56 million ha of cultivated area. The wheat cultivation in this state has increased from 0.09 million ha in 1962-63 to 0.79 million ha in 1983-84 producing 0.04 million tons and 1.50 million tons, respectively (**Table 1**). Though about 12% of the cultivated area is planted to wheat contributing about 2.19% of the total food grain production of the state, the threshing operation remains a major bottleneck in post-harvest phase of wheat production system in the eastern states of India, in general, and the state of Orissa, in particular, due to non-availability of suitable thresher. Therefore, it was felt to develop a suitable wheat thresher to cater to the need of the farmers. Regarding the prime mover, the power tiller was chosen to have the operation both in the yard as well as in the field, as the

Table 1 Area, Production and Yield of Wheat in Orissa, India.

Year	Area Million ha	Production Million t
1962-63	0.09	0.04
1963-64	0.15	0.08
1964-65	0.14	0.07
1965-66	0.13	0.10
1966-67	0.16	0.14
1967-68	0.15	0.15
1968-69	0.15	0.16
1969-70	0.14	0.17
1970-71	0.13	0.18
1971-72	0.21	0.39
1972-73	0.51	0.85
1973-74	0.52	0.83
1974-75	0.55	0.86
1975-76	0.63	1.07
1976-77	0.55	0.98
1977-78	0.68	1.37
1978-79	0.62	1.10
1979-80	0.51	0.82
1980-81	0.67	1.22
1981-82	0.66	1.25
1982-83	0.64	1.30
1983-84	0.79	1.50

Source: Agricultural Statistics of Orissa, Directorate of Agriculture and Food Production, Government of Orissa, Bhubaneswar – 28th June, 1987.



1. FEEDING CHUTE, 2. THESING CYLINDER, 3. BLOWER, 4. CHAF OUTLET, 5. HOPPER, 6. CONNECTING ROD, 7. OSCILLATING SEIVE, 8. TRANSPORT WHEEL, 9. FRAME, 10. V-PULLY, 11. CONCAVE, 12. BEARING, 13. V-BELT

Fig. 1 Design details of the thresher

power tiller is gaining popularity among the small and medium farmers of the state for the last few years.

Threshing principle depends on many bio-physical characteristics of grain in the earhead. A number of research work conducted to evolve the machine, method and material to have the operation easy, labour saving and effective with less loss and damage to the grain. Sharma et al (2) in 1984 designed, developed and tested an axial flow wheat-cum-paddy thresher. The spacing of the pegs in the section where wheat was threshed was 6.25 cm and the projection being 7 cm. They reported that the maximum output of wheat was 387 kg/h with threshing efficiency of 100%. The cleaning efficiency was 91.3 to 97.5%. Total grain losses was about 1%. Though the labour requirements were the same as that for conventional wheat thresher, the total cost of threshing by this thresher was Rs. 12.28 as compared to Rs. 13.07 with a conventional wheat thresher. Joshi and Singh (1) developed a multi-crop thresher named as Pantnagar IRRI multi-crop thresher with the total number of pegs of 120 fixed on 38 cm diameter rings and peg height being 15 cm on 4 cm x 0.5 cm flats. It was reported that the capacity, clearing efficiency, visible damage and sieve loss increased with an increase in cylinder speed at grain moisture content of 10.54, 12.10 and 14.30%. The capacity was 4.22 quintals per h at a designed speed of 800 rpm.

Design and Development

The thresher consists of (1) threshing unit (2) conveying, separating and cleaning units. The threshing unit comprises of the threshing cylinder and an adjustable concave with a little clearance between them. The cylinder is of 45 cm length and 50 cm diameter having the pegs 7.7 cm high on the cylinder arranged in a staggered manner at an interval of 6.5 cm. There are 16 slats and the cylinder has 56 pegs. The pegs are of dimension 1.25 cm dia and 7.7 cm height. After threshing the grain is conveyed to the sieve by an inclined surface where the chaff is separated.

The separating and cleaning unit consists of a set of sieves and blower. An aspirator type of blower is used to separate the chaff from the grain by blowing off the chaff from the grain collected at the platform. Three blades of 41 cm in length and 14 cm width are fixed to a bush at 120° angle with each other. The blower inlet diameter is 30 cm and outlet is of size 17.7 cm x 17.7 cm.

Two sieves of dimensions 90 cm x 80 cm and with different openings are kept in an angle iron frame. The upper sieve has a 6-mm opening with slightly slanted in opposite direction to lower the sieve in order to throw out the bigger chaffs that can not be blown off by the blower. The function of the lower sieve is to filter the foreign materials such as sand particles and dust. This is kept slanted towards the grain outlet with 1.5-

mm opening.

The set of sieve was connected to a V-pulley by 12 mm diam. connecting rod with the help of a pin which was connected to the frame of the sieves by two flats. The drive to the pully was obtained by V-belt and V-pulley of 6 cm diameter from the cylinder shaft. A reduction ratio of 1:5 was maintained for the sieve's oscillation.

An inclined surface just below the concave at an angle of 65° to the vertical was fabricated to move the chaff along with the threshed and unthreshed grain bundles to the upper sieve near the blower. A hopper of dimension 6 cm x 61 cm made of 1.5 mm M.S. sheet was fixed to the four side covers by nuts and bolts.

All the units are mounted on a single shaft of length 140 cm and entire thresher was covered by sheet metal to make the unit air tight to the possible extent so that the blower can operate efficiently. For easy transportation the unit is mounted on 4 metallic wheels of size 17 cm diameter and 4 cm width.

Testing Methods and Material

The thresher was operated by a Mitsubishi power tiller. Five ranges of peripheral velocity were used such as 904.02 m/min (440 rpm), 945.11 m/min (460 rpm), 986.20 m/min (480 rpm), 1 027 m/min (500 rpm) and 1 130 m/min (550 rpm) during the test run. These speeds were obtained by adjusting the throttle.

The wheat variety 'Sagarika' was taken for test which has grain-to-straw ratio of 0.588. Three levels of moisture content were obtained, i.e., 9.25, 12.00 and 14.50% (d.b.). The crop was dried by hanging over the rope in air. Three levels of concave clearance, i.e., 1.3 cm, 1.5 cm and 1.9 cm were taken. The total treatment combinations were 45. For each observation the mean of three replications were taken.

The moisture content of the grain was determined by air oven method at 70°C for 24 hours taking the sample of 5 gm. The moisture content was measured by dry weight basis. Also, for quick determination, the moisture content was found with the help of a universal moisture meter at the time of test.

For each test run a known weight of crop was fed at a time. The threshing time for each test run was recorded by a stop watch. The grains were collected at all outlets, such as at the main outlet, "bhusha" outlet, sieve overflow and feeding chute and weighed separately. During the test run the rpm of the cylinder was also checked. The above procedure was repeated thrice for all the combinations of cylinder speed, moisture content and concave clearence.

To study the economic use of the thresher the annual use was assumed to be 200 h. The labour charge was assumed to be Rs. 10 per day. For calculation of unit cost of operation it was assumed that the power tiller will be used for other agricultural operations by the farmers except the threshing days. Therefore, the annual use of the power tiller was assumed to be 1 000 h.

The initial cost of the thresher was calculated on the basis of total material used in fabrication and the fabrication cost of 25% of the material cost. The salvage value was assumed to be 10%. The interest rate of 14.5% and housing, repair and maintenance charges of 1% was assumed.

Results and Discussion

During the test it was observed that the threshing efficiency varied from 87.1 to 95.3% though the variations in most of the cases were very small. Maximum threshing efficiency of 95.3% was obtained at peripheral speed of 1 027 m/min (500 rpm) at the moisture content of 9.25% and concave clearance of 1.3 cm. The minimum threshing efficiency of 87.1% was observed at a peripheral speed of 904.02 m/min (440 rpm) at moisture content of 14.5% and concave clearance of 1.9 cm. It was observed that in most of the machine condi-

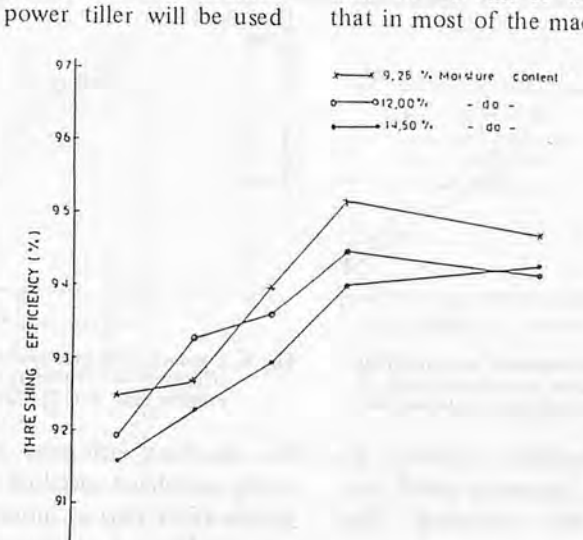


Fig. 2 Peripheral speed and threshing efficiency at 1.3 cm concave clearance.

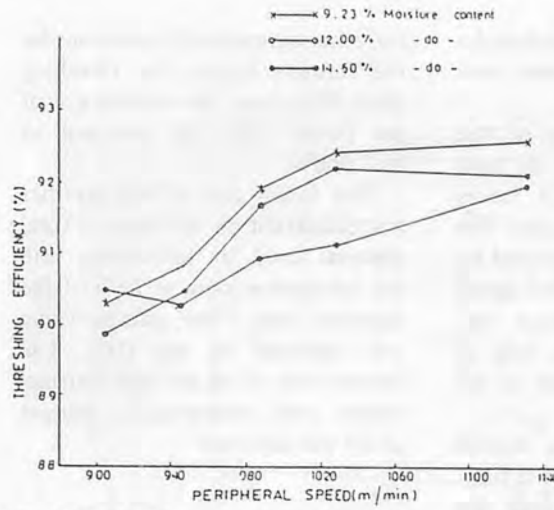


Fig. 3 Peripheral speed and threshing efficiency at 1.5 cm concave clearance.

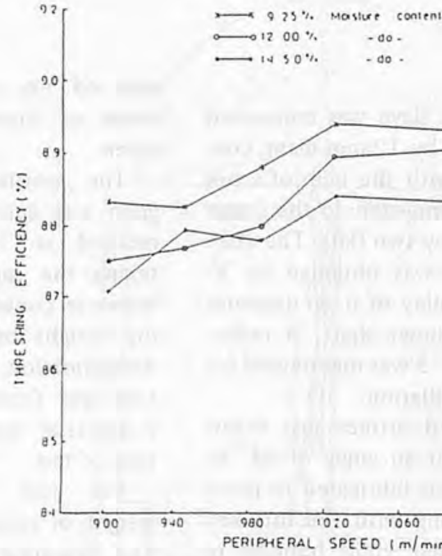


Fig. 4 Peripheral speed and threshing efficiency at 1.9 cm concave clearance.

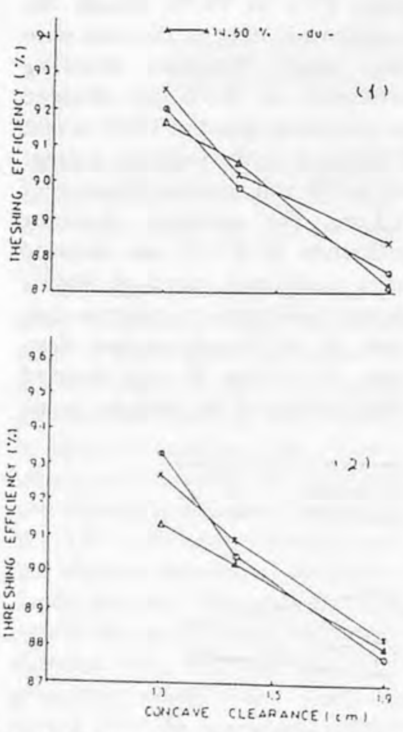


Fig. 5 Concave clearance and threshing efficiency at peripheral speed of 1) 904 m/min and 2) 945 m/min.

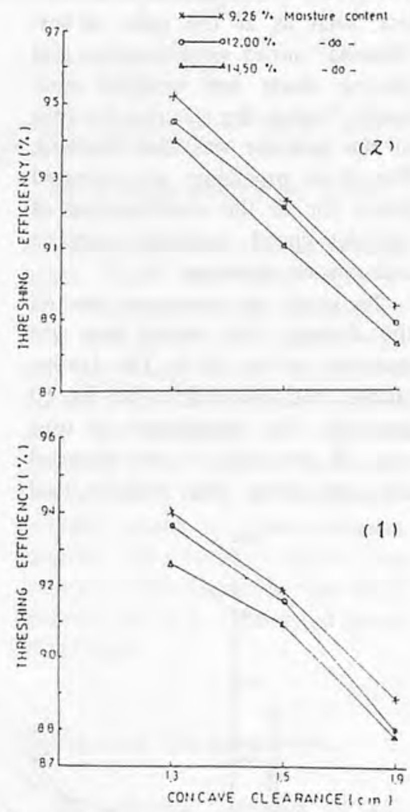


Fig. 6 Concave clearance and threshing efficiency at peripheral speed of 1)986m/min and 2)1027m/min.

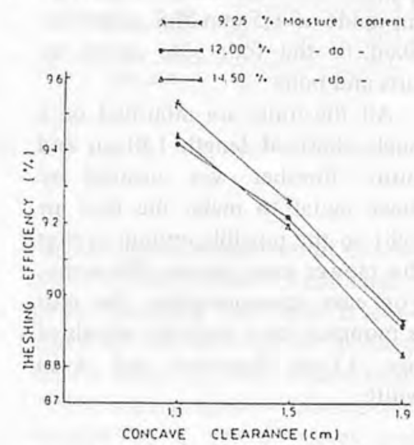


Fig. 7 Concave clearance and threshing efficiency at 1130 m/min of peripheral speed.

tions the threshing efficiency increased with increasing speed to a limit and then decreased. This decreasing nature may be due to high impact force exerted by the threshing cylinder on the crop which detaches the earhead along with the gain (Figs. 2, 3, 4). But the threshing efficiency increased at the peripheral speed of 1 103.03 m/min (550 rpm) at moisture content 14.5% and at concave clearance 1.5 cm which is very marginal. This shows that the speed 1 027 m/min is optimum. In most of the cases the threshing efficiency decreased with increase in level of moisture content at a particular speed and concave clearance. This may be due to the fact that less impact force is required for the grain to get detached from the earherd at less moisture content.

The threshing efficiency decreased with an increase of concave clearance at all peripheral speeds and all moisture content levels (Figs. 5, 6, 7). It may be due to the fact that as the speed increased the feed rate also increased. Due to greater feed rate with a higher concave clearance the crop does not get the necessary impact to detach the grain from the earheads. Moreover the rubbing force which plays an important role in threshing decreases with higher concave clearance.

It was observed that the capacity increased with an increase in peripheral speed for all moisture content and concave clearance (**Figs. 8, 9, 10**). The capacity was maximum at a peripheral speed of 1 130.03 m/min (550 rpm) where the concave clearance and moisture content are 1.3 cm and 9.25%, respectively. The range of capacity was 90.63 kg/h to 155 kg/h when the peripheral speed varied from 904.02 m/min (440 rpm) to 1 130.03 m/min from the speed 986.2 m/min to 1 027 m/min than other speed ranges for all concave clearance and moisture content. Beyond the speed 1 027 m/min the capacity is non-linear with increase in speed showing that the range of speed 1 027 m/min to 1 130.03 m/min is the working speed of the thresher. The capacity also decreased with an increase of level of moisture content of the crop for the peripheral speed and concave clearance (**Figs. 11, 12, 13**).

As the increase of cylinder peripheral speed caused the increase of blower speed, thereby discharging higher amount of air, the clearing efficiency increased with increase in peripheral speed of the cylinder at all the moisture content levels and concave clearance. It was observed that the highest cleaning efficiency of 96.2% was obtained

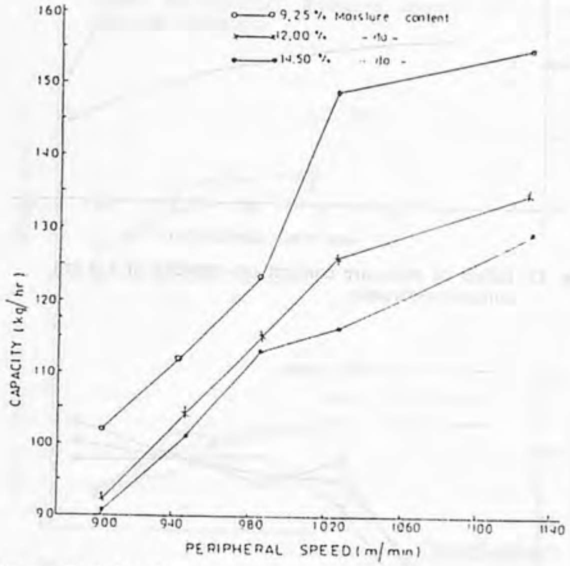


Fig. 8 Peripheral speed and capacity at 1.3 cm concave clearance.

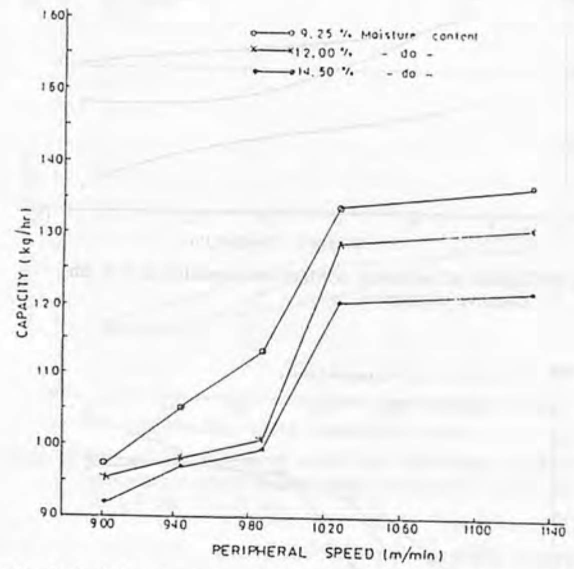


Fig. 9 Peripheral speed and capacity at 1.5 cm concave clearance.

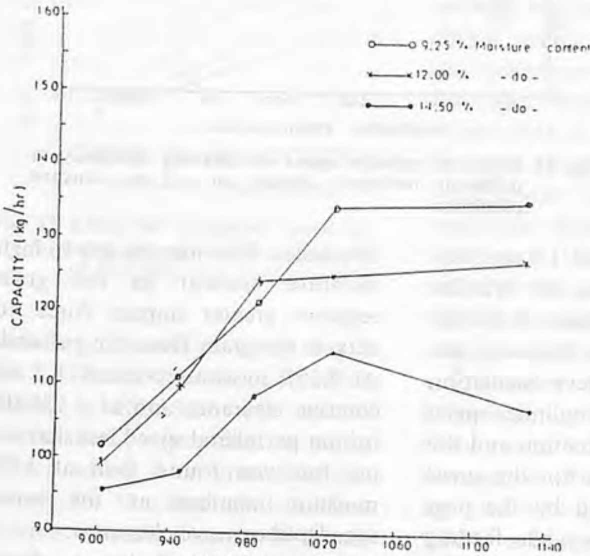


Fig. 10 Peripheral speed and capacity at 1.9 cm concave clearance.

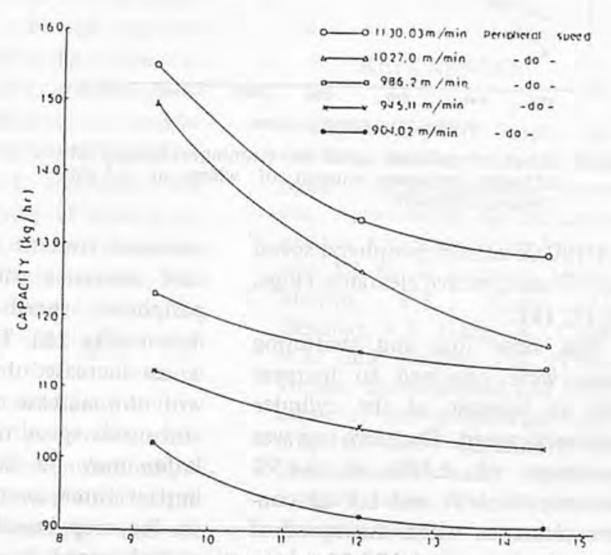


Fig. 11 Effect of moisture content on capacity at 1.3 cm concave clearance.

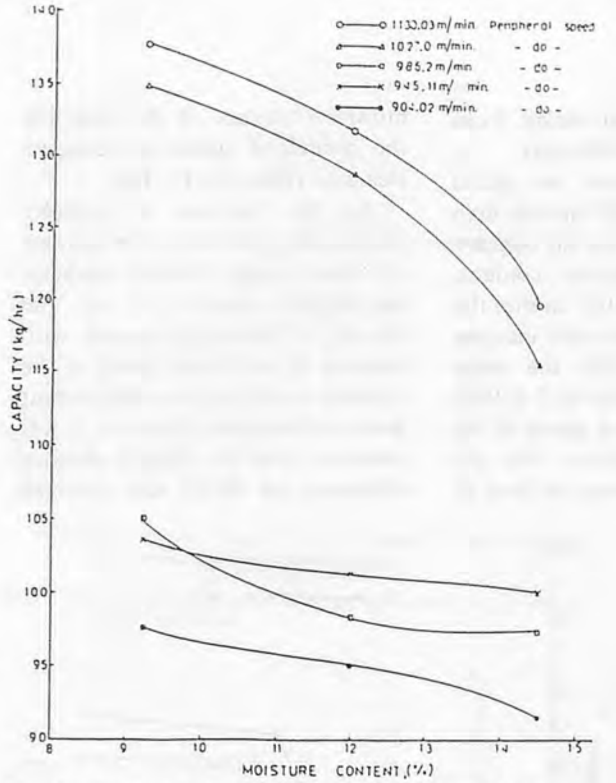


Fig. 12 Effect of moisture content on capacity at 1.5 cm concave clearance.

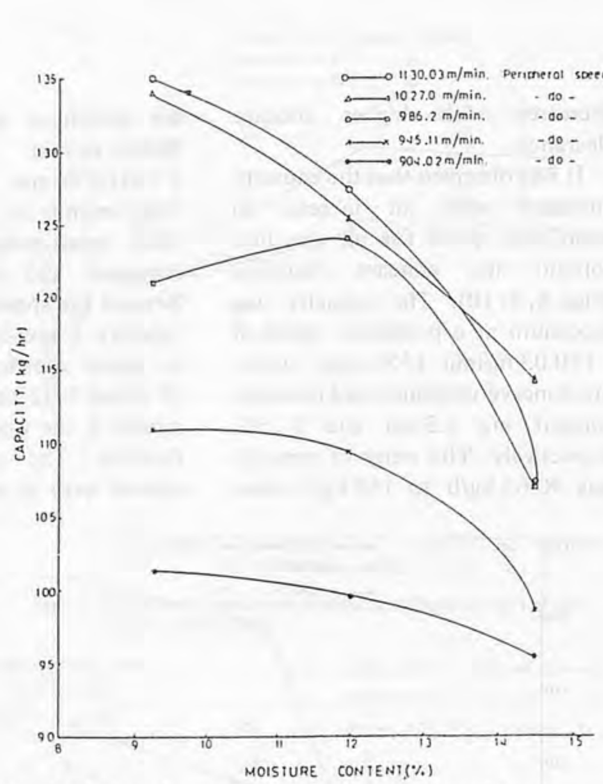


Fig. 13 Effect of moisture content on capacity at 1.9 cm concave clearance.

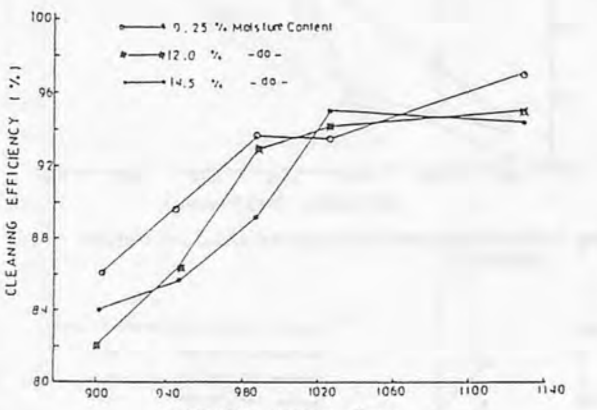


Fig. 14 Effect of cylinder speed on cleaning efficiency at different moisture content of wheat at 1.3 cm concave clearance.

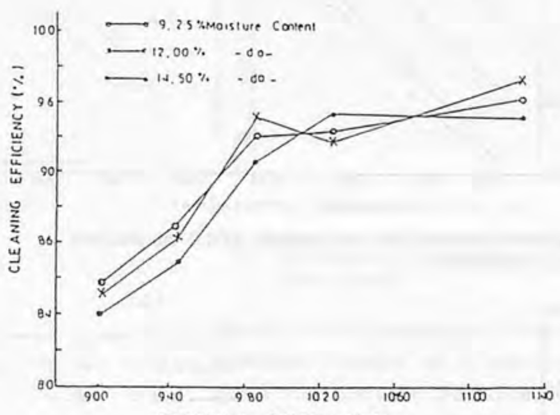


Fig. 15 Effect of cylinder speed on cleaning efficiency at different moisture content at 1.5 cm concave clearance.

at 1 130.03 m/min peripheral speed and 1.3 cm concave clearance (**Figs. 14, 15, 16**).

The sieve loss and shattering losses were observed to increase with an increase of the cylinder peripheral speed. The sieve loss was maximum of 2.48% at 14.5% moisture content and 1.3 cm concave clearance when the speed of the cylinder was 1 130.03 m/min (**Fig. 17**) and the maximum shattering loss was of 2.45% at 9.25% moisture content and 1.5 cm concave clearance when the cylinder peripheral speed was 1 130.03 m/min (**Fig. 18**). The former is due to an increase of sieve oscillation with the increase of cylinder speed and needs speed reduction and the latter may be due to the great impact force exerted by the pegs on the crop bundles while feeding at high speed. It was also observed that shattering loss was high at low moisture content for all concave clearances. This may be due to high moisture content as the grain requires greater impact force to detach the grain from the earhead. At 9.25% moisture content, 1.3 cm concave clearance and at 1 130.03 m/min peripheral speed less shattering loss was found than at 12% moisture content at the same speed and concave clearance.

The analysis of the economic use of the developed thresher reveals that the cost of the thresher,

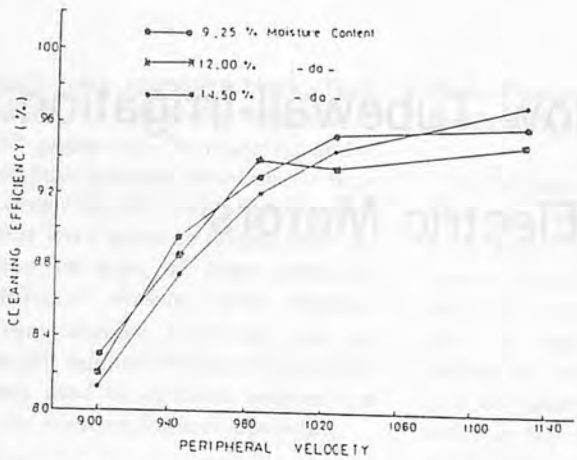


Fig. 16 Effect of cylinder speed on cleaning efficiency of wheat at different moisture content at 1.9 cm concave clearance.

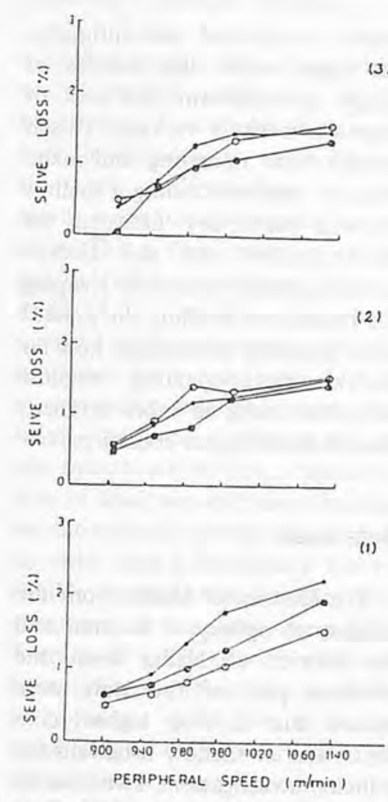


Fig. 17 Effect of peripheral speed on sieve loss at concave clearance of 1) 1.3cm; 2) 1.5cm; 3) 1.9cm

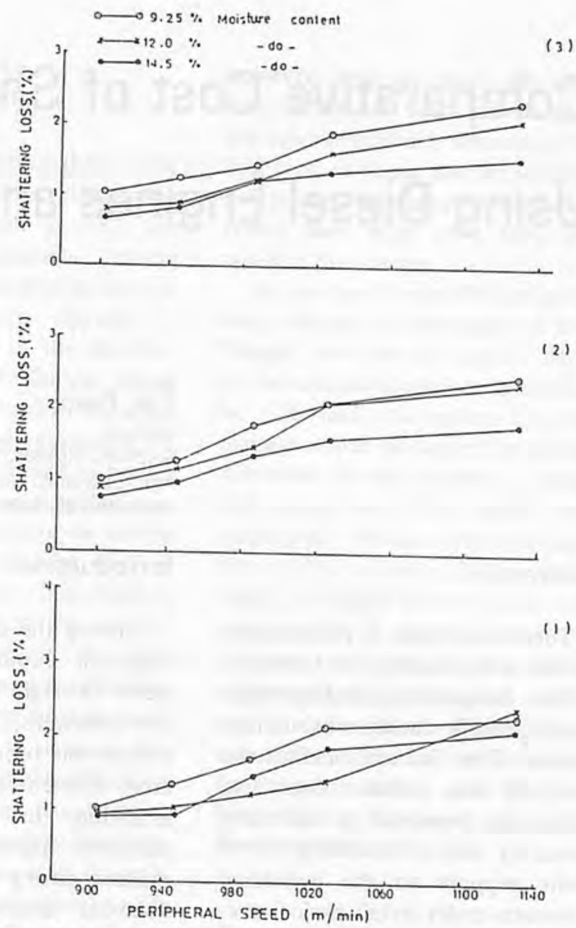


Fig. 18 Effect of peripheral speed on shattering at three moisture content at concave clearance of 1) 1.3 cm; 2) 1.5 cm; 3) 1.9 cm

including the cost of fabrication, is Rs. 3 023 and the cost of threshing wheat is Rs. 13.63 per quintal taking the power tiller as prime mover which is a suitable power source for the small and medium farmers whereas the cost of threshing by conventional methods was calculated at Rs. 14.94 per quintal of wheat threshed.

Conclusion

Wheat crop with high moisture content requires high cylinder peripheral speed to have high capacity and maximum threshing efficiency. Also, the threshing efficiency increases with a decrease in concave clearance. The peripheral speed of 1 027 m/min was optimum for maximum threshing efficiency of 95.3% at 1.3 cm concave clearance and at 9.25% moisture content. The highest cleaning efficiency of 96.2% was observed at the speed of 1 130 m/min. For better cleaning efficiency, some modification has to be made in the power transmission system. The maximum shattering loss of 2.45% was observed at 9.25% moisture content and at 1 130.03 m/min of peripheral speed.

The net unit threshing cost of wheat using the developed thresher was Rs. 13.63 per quintal, whereas it was Rs. 14.94 per quintal when threshed by conventional methods.

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Comparative Cost of Shallow Tubewell Irrigation Using Diesel Engines and Electric Motors

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Abstract

There has been a phenomenal growth in the number of tubewells in West Bengal for providing irrigation especially during rabi/summer seasons. The financial institutions have, of late, come forward to realize the potential groundwater source by way of extending liberal credit support to the individual borrowers under certain basic framework of schematic lendings.

From a household survey of 120 borrowers of tubewell loan, it has been observed that the shallow tubewells operated by electric motor appear to be superior to the shallow tubewells operated by oil engines. The electric motor hauled units tend to irrigate: i) proportionately higher areas; ii) involve relatively lesser cost — both operation and maintenance and finally; and iii) provide relatively cheaper irrigation per unit of land, compared to other lifting device, e.g., oil engine. The net impact of the cheaper irrigation through electric motor-run tubewell is expected to influence the repayment performance of this group of borrowers. Thus, as a matter of policy it is advisable to accord more weight on this type of lifting device for maximazation of incremental farm income and hence improvement in potential repayment performance.

Introduction

Among the different sources of irrigation exploitation of ground water through installation of shallow tubewells, the use of electric motors has been recognized as the most efficient and stable mode of irrigation. In West Bengal this particular aspect was increasingly realized during the 1970s. Various financial institutions have come forward to extend liberal credit to the target group of people who are mostly small and marginal farmers. As per the information available there would be more than 150,000 shallow tubewells in West Bengal, the majority of which have been sunk in the districts of 24-Parganas, Murshidabad, Hooghly, Burdwan and Malda. The Expert Committee on Agricultural Productivity in India envisages that during the 7th Five-year Plan, there would be an addition of 200,000 shallow tubewells in the state. In other words, the stock of shallow tubewells is expected to be rather impressive by the end of the current Five-year Plan.

The shallow tubewells can either be operated by diesel engines or by electric motors. If a shallow tubewell can be managed efficiently the cost of irrigation, which is the most important component of cost of cultivation, will fall relatively as compared to a shallow tubewell which is operated sub-optimally. But again when the sources of energy are different the cost of irrigation is likely to vary. This is because both operating and maintenance costs of running a shallow tubewell may vary between the diesel-operated and the electric motor-operated tube-wells. Keeping this hypothesis in mind, the present paper attempts to ascertain how far electric motor-operated shallow tubewells could be more efficient than its diesel engine counterpart.

Data Base

The District of Malda from the northern periphery of the state and the district of Nadia from the southern part of the state were chosen due to their highest concentration of shallow tubewells for primary investigation. Two blocks, namely: Harishchandrapur from Malda district and Nakashipara from Nadia district were identified for in-depth investigation. The list of beneficiaries were obtained from the controlling banks of these two blocks and then the same were categorized with respect to the type of beneficiaries such as composite beneficiaries (pump set and shallow tubewell), pumpset beneficiaries and only shallow tubewells beneficiaries. The total sample comprized of 120 beneficiaries — 60 each from respective block. Thus, in all, 71 composits beneficiaries, 42 pump sets beneficiaries and 7 shallow tubewell beneficiaries were chosen for the study. The respondents were asked to furnish information on type of crops grown in different seasons, area irrigated from shallow tubewells, sale of water, number of hours the machine was used in different seasons and cost incurred for such operation.

Profile of Shallow Tubewell Owners

A few useful but very obvious socio-economic parameters of the beneficiary households have also been investigated so as to have a thorough understanding of the minor irrigation programme in the state. This is very important in the context of a programme which is designed to benefit a particular segment of the community who are supposed to be the sole beneficiaries under this programme. Besides, the other related aspects like operational holding, fragmentation of land, etc will have a bearing on the efficacy of the programme. In order that a beneficiary will be eligible for bank finance with subsidy, one is supposed to possess 5 acres of lands out of which at least 2.5 acres should be available on a single patch. It is rather interesting to observe that although the programme was tailor made for small and marginal farmer, about 1/3 of the respondents belonged to other category of farmer with operational holding more than 5 acres of land. Thus it appears that although theoretically this groups of farmers are not eligible for institutional subsidies, they appear to have availed of such privilege which goes against the norm of financing for such scheme. This is indeed an identification problem.

Basic Features of Shallow Tubewells

It has been observed that of the total of 113 pump sets fitted with bore wells, as high as 88% are diesel-operated pumpsets, leaving only 12% to be operated by electricity. A very sharp contrast is noticed in respect of the distribution of diesel and electric pump sets over the districts. For instance, while 22% of the pumpsets of Malda district is observed to be run by electricity, the comparable figure for Nadia turned out to be barely 2%. Thus, it is observed that in Malda district there has been a deliberate attempt on the part of Government to electrify the shallow tubewells wherever possible. In the absence of any further qualitative information to support the reasons for such high electrification ratio, what one can conclude is that the Government may probably had taken a positive step towards electrifying the shallow tubewells of Malda. This information has been compiled separately both for diesel-operated shallow tubewells and electricity-operated shallow tubewells. Besides obtaining relevant information on costs of irrigating one's own lands in different seasons, the cost involved for sale of water has also been taken into account. Without taking into account the various costs incurred on selling of water, the analysis could have been partial since majority of the shallow tubewell owners are small and marginal farmers and have lands distributed on fragmented plot leading to sub-optimal availability of potential irrigation command. This is the reason why this group of farmers are increasingly dependent on other lands for the sale of water.

Although the diameter of the discharge pipe as per specification of the scheme should be 2.5 inches, in about 10% of the cases the same is reported to be 3 inches. This is, however, not a major deviation from what has been laid down in the scheme guideline because of the fact that at times the beneficiaries are guided by many other factors rather than what have been provided in the scheme.

As per the Ground Water Investment Report, Government of West Bengal, the average aquifer depth in the sample blocks is reported to be 100 feet. As against this, the average depth of water for sinking tubewells for the district of Malda and Nadia are 87 feet and 81 feet, respectively. While a greater proportion (80%) of the shallow tubewells in Malda district have been sunk within a depth of less than 80 feet, only 8% of the shallow tubewells of Nadia fall within this category. Most of the shallow tubewells of Nadia are found to have been installed at a depth of 80-99 feet as compared to over 100 feet in Malda district.

Economic Efficiency Analysis

The factors that have been taken into account while computing the efficiency analysis between the diesel-operated shallow tubewells and electricity-operated shallow tubewells are broadly:

i) Number of hours run in different crop seasons;
ii) Operating cost;
iii) Maintenance cost; and
iv) Area irrigated over seasons by shallow tubewells.

If the entire crop year can be divided into three seasons viz., Kharif, Rabi and Summer and then aggregated, it is observed that on an average an electricity-operated shallow tubewell is working for 65 h per acre per season **(Table 1)**. Of course, the working rate is highest during summer season (112 h) due to the typical cropping pattern adopted by the farmers for cultivation of summer paddy. The diesel-operated shallow tubewells,

Table 1 Average Working Hours per Acre/Season by the Type of Pumpsets

Season	Diesel-operated pumpset			Electricity-operated pumpset		
	Malda	Nadia	Combined	Malda	Nadia	Combined
i) Kharif	16.5	18.3	17.6	19.9	21.7	21.0
ii) Rabi	20.8	32.9	29.1	28.7	38.9	30.0
iii) Summer	119.8	98.9	107.0	113.3	90.9	112.0
Total	64.6	45.7	53.4	66.0	37.6	64.6

however, are relatively underused with 53 h per acre per season. The seasonal behaviour in the use of diesel-operated shallow tubewell also follow the same pattern as has been observed for electricity-operated shallow tubewell. During kharif season shallow tubewells are used very sparingly depending on the necessity of the farmers. In other words, shallow tubewells are meant for providing protective irrigation during kharif season.

The average annual maintenance cost of diesel-operated pumpsets has been estimated at Rs. 769 and Rs. 646 for the districts of Malda and Nadia, respectively. On the other hand, electricity operated pumpsets are reported to be requiring Rs. 531 as annual maintenance cost in Malda district as against Rs. 769 for diesel-operated sets. This means that the electricity operated pumpsets are more economical over diesel-operated one when only average annual maintenance cost is taken into account. The economic efficiency of electricity-operated shallow tubewell over diesel-operated one can probably be better explained by taking into account the operational cost of running the shallow tubewells. With the rise in number of hours run the increases in operational cost becomes directly proportional. It is worthwhile to recall that the electric pumpsets have a tendency to be operative for longer periods of time, but the rise in operating cost is not proportional to the rise in working hours because of the fact that electricity tariff is charged on annual flat rate basis.

It is worthwhile to analyze the gross command area achieved by using different types of lifting devices (**Table 2**). The interesting pattern in the realized command is that the electricity-operated shallow tubewells irrigate proportionately higher area compared to diesel-operated tubewells. For instance, in Malda one diesel set seemed to be irrigating 7.09 acres of gross cropped area as against 9.59 acres of gross area of electric motor-operated tubewells. This holds good irrespective of geographical locations of the tubewells. Thus, it is observed that not only the maintenance and operating costs are lower for electric devices but they also tend to irrigate proportionately large areas compared to diesel-operated units.

Taking into account both maintenance and operation costs, the costs of irrigation per acre of land were Rs. 392 and Rs. 255 for diesel-operated units and electric motor-operated units, respectively. Further, not only the cost of irrigation is relatively economic in case of electric motor-operated units but it is also observed that expenditure on account of annual replacement cost is also lower for the electric motor-operated sets. This is very obvious since the number of breakdowns of the pumps has also been observed to be relatively less compared to the diesel-operated units.

Policy Implications

Table 2 Gross Command Area Achieved by Districts and Cost of Irrigation
(area in acre; cost in Rs. / acre)

Particulars	Malda	Nadia	Combined
Area			
Diesel	7.09	8.23	7.71
Electric	9.59	8.90	9.51
Total	7.63	8.25	7.94
Cost			
Diesel	465	339	392
Electric	260	180	255

The relative cost of irrigation using electric motor-operated shallow-tubewells being cheap, it would be obvious to observe that these groups of beneficiaries would score over other beneficiaries in realizing higher incremental income provided other parameters remain unchanged. Thus, the expected additional incomes is likely to affect the repayment performances of the borrowers. This is an important issue to be kept in mind, particularly for the lending institutions for disbursing loan on minor irrigation. In this regard, the necessary support needs to be extended by the concerned department of the State Government so as to enhance the coverage of rural electrification programme. The role of the rural electrification department thus becomes an important aspect of providing relatively cost effective irrigation to the weaker section of the society in particular and to the society as a whole.

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

Mulching, Temperature Control and Crop Production in Drip Irrigation


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Object

The purpose of mulching is usually to conserve soil moisture by reducing evaporation but it may also be used to modify soil temperature, for example, to enhance soil warming against frost hazards and in weed control. In desert areas where there is excessive daily soil surface warming and excessive night cooling, the use of proper mulch to limit these temperature hazards is necessary to alleviate the harsh environment in which the plants are to be grown.

Traditionally, insulating material such as hay, straw, leaf, moss, etc. have been used. More recently, artificial mulches have become common, including foam, plastic films (opaque, translucent or colored), paper, and aluminum foil.

The present study deals primarily with the effect of mulching on soil and air temperature profile. Data from white translucent, black colored plastics, groundnut husk (crushed to 1/4 of original size) and rice husk were compared to that from a control plot (no-mulched). Secondly it evaluated the effects of those mulches on yield, evapotranspiration, water use efficiency and growth given that the soil moisture was kept at a optimum level through adequate monitoring of the evapotranspiration process.

Material and Method

Two separate experiments will be reported in this paper: one dealing with the effect of the type of mulch used in soil temperature control and the other, with the evaluation of the effects of those mulches on yield, plant growth, evapotranspiration and water use efficiency.

Experiment 1

In this study the system used consisted of 3 boxes, with length 28 cm, width 28 cm and depth 35 cm. The sides of the boxes were wrapped with a styrene foam to prevent heat exchanges with the ambient atmosphere. The boxes were then filled with sand to a height of 30 cm. For 3 days the surfaces of the sand in 2 boxes were covered with white translucent and black colored plastics. Temperatures were recorded at 15 cm height, on the mulches and soil surfaces, and at 5, 15 and 25 cm depth. The sand in the remaining box was left bare (control plot) and temperatures were recorded the same way as in the mulched plots to allow for comparison. At the end of the 3 days the plastic mulches were removed and replaced by 2 different types of mulches consisting of groundnut and rice husks (1 cm depth). Air and soil

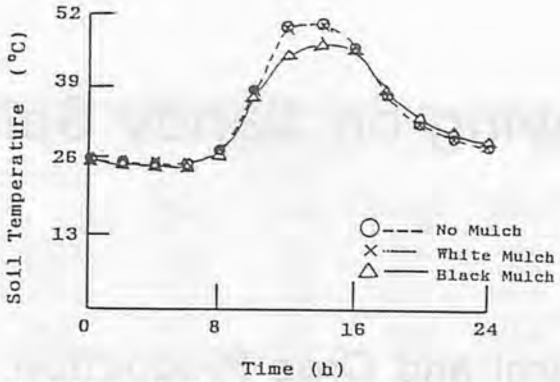

Fig. 1 Effect of mulch type on soil surface temperature.

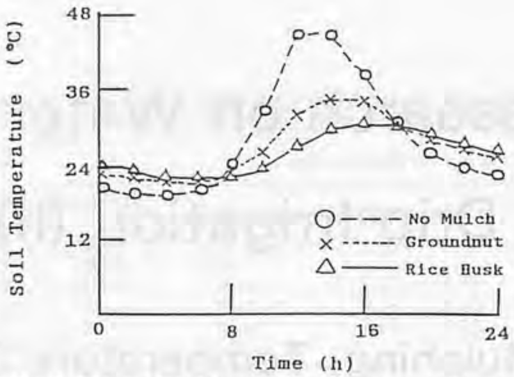

Fig. 2 Effect of mulch type on soil surface temperature.

profile temperatures were recorded similarly for 3 days in the mulched and control plots. At the end of the period, the hottest day was selected in both series of measurement and temperature profiles were compared to that in the control plot.

Experiment 2

The system used comprised of 40 plots which were individual boxes similar to those used in a previous study (3) and consisted of boxes with length 18 cm, width 13 cm and depth 8 cm. The boxes were filled with sand to a height of 7 cm and were perforated at bottom with 6 holes for drainage. A rectangular mesh to the size of the box were laid at the bottom to prevent sand from leaking. *Komatsuna** was planted in all boxes in 2 rows with 15 plants for each row. White translucent, black colored plastic, groundnut and rice husks consisted the mulch treatments partitioned in 8 boxes per treatment. The mulches were applied between the rows with 2 holes provided at 10 cm interval to supply the irrigation water. The 8 remaining boxes have no mulch applied (no-mulched) and were considered as control plots. Irrigation water was supplied through a graduated "micropipete" and accounted for the amount of water evapotranspired by the crop the previous day. In a hot day this amount was doubled to limit the risks of water stress. The amount of water evaporated was calculated by weighing 2 boxes selected in each treatment before and after irrigation and the mean value of evaporation from the 2 boxes represented the evapotranspiration amount for the given treatment. This way the evapotranspiration process was adequately monitored. Fertilizer was dissolved in the irrigation water and was equally applied once every other day in all plots. The treatments were started on July 13 when the seedlings reached about 6 cm height. Crop sampling was performed from 2 boxes every 7-day interval and included 4 periods during the growing period. Yield and growth (weight per plant) were deducted for each treatment. At the end of the 4 periods a number of plants, evapotranspiration /water used and growth were evaluated to determine the individual treatment on yield.

Results and Discussion

Experiment 1

Figs. 1 and 2 give examples of the changes on soil surface temperatures brought about by type of mulches used. Data from white translucent, black colored plastics and control (no-mulched) are shown in **Fig. 1** and that from groundnut, rice husks (1 cm depth) and control in **Fig. 2**. **Fig. 1** shows that in a hot summer day the maximum surface temperature in the white mulch plot was almost similar, and in the black mulch plot more than 3°C cooler than in the control. At night, the differences in soil surface temperature between those mulched plots and the control were very small, although the warmth in the mulched plots were retained. The overall response in the white mulch plot was pretty mulch identical to that in the no-mulched soil. On the other hand, the black mulch plot showed a daytime soil surface temperature generally cooler than in the control. **Fig. 2** shows that the maximum surface temperature in the groundnut and rice husks plots scored, respectively, a record 13°C and 18°C cooler than in the control. At night, the minimum soil surface temperature in those mulched plots were 3°C and 4°C, respectively, warmer than in the control. This suggests that the use of groundnut and rice husks mulches in dry or desert areas could be a good tool to alleviate the extreme temperatures experienced as well in daytime than at night.

The results of a similar experiment are portrayed to show the profiles of air and soil temperature associated with no-mulched sand soil and the 4 types of mulch at the maximum (PM. 12.00) and minimum (AM. 2.00) temperature. **Fig. 3** shows the cause of white and black plastics, respectively, at the time of maximum and minimum temperatures while **Fig. 4** portrays the groundnut and rice

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

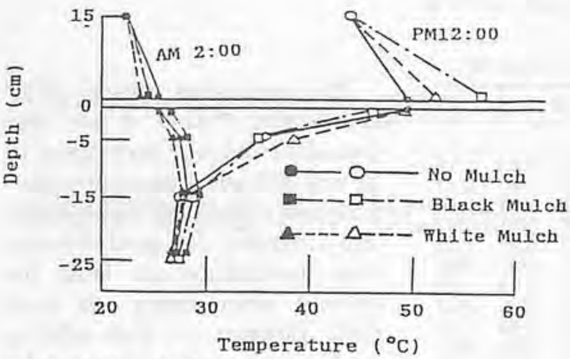

Fig. 3 Profiles of air and soil temperature.

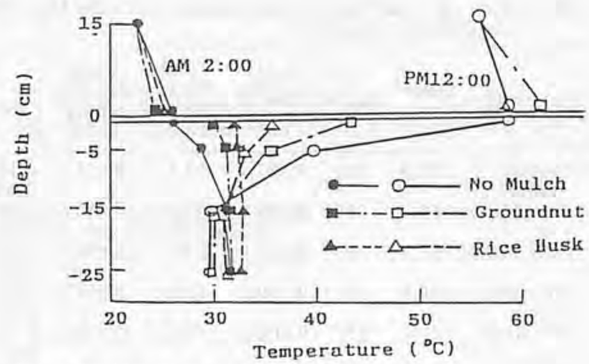

Fig. 4 Profiles of air and soil temperature.

husks mulch at those times. Fig 3 shows that the surface of the black plastic because of its lower albedo, a proportion of shortwave radiation reflected by that surface, absorbs more radiation that the bare soil and as a result its surface temperature rose to about 57°C, 7°C warmer that in the control. However, this heat could not easily be passed down into the soil because of the insulation provided by the air trapped beneath the sheet and the lower conductivity of the latter. Neither could that heat be dissipated as latent energy, heat released or absorbed per unit mass by a system in changing phase, because the plastic was dry and impervious to water; note also that the moisture status of the sand was very low and even null (over-dried sand). The only remaining channel for heat loss was upwards as sensible heat, energy exchange with the air. The soil profile temperatures under that mulch are slightly cooler than that in the no-mulched soil from surface to 5 cm depth and remained equivalent to those at 15 and 25 cm depth. At night, when the plastic would have prevented much of the longwave radiation loss from the soil surface, the temperature remained very slightly warmer at surface and stayed the same as that in the no-mulched soil from 5 to 25 cm depth. The surface temperature of the mulch was equivalent to that of the no-mulched soil. The mulch cover, therefore, regulates somewhat soil temperature and acts as a source of sensible heat for the atmosphere.

The white mulch exhibits a radiation budget very similar to the no-mulched soil. Because of a higher albedo than the black mulch, its surface temperature (approximately 52°C) was 2°C warmer than that of the no-mulched soil. Because of a more efficient conductivity than the black mulch, the soil profile temperatures under the white mulch remained equivalent to that in the no-mulch soil. At night, the same phenomenon was observed, and the surface temperature of the mulch was equal to the no-mulched soil.

Groundnut and rice husks as hay are characterized by a very low conductivity. Because their albedos were similar to that of the no-mulched soil (same color), the surface temperature of the rice husk mulch was similar, and that of the groundnut mulch 3°C warmer than the control. However, the heat transmission through those mulch layers was so poor that the soil heat flux was the weakest, and the soil surface temperatures as noted previously remarkably low in those plots. As a result, the soil profile temperatures remained much cooler than that of the bare soil, specially from surface to 5 cm depth. At night, the opposite phenomenon was observed. Heat loss from the soil surface was much prevented and the temperatures in the soil profile stayed warmer than in the no-mulch plot. The following points to a great advantage of hay type mulch such as groundnut and rice husks over plastic mulch, specially white translucent plastic, in desert or arid areas when the aim is not only to save water but also to provide to the plants a good temperature environment. A black plastic mulch cover can be a good daytime soil temperature regulator with a possible disadvantage, however; if the plants extend above the mulch, their type might experience a more extreme climate.

Experiment 2

As shown in a previous paper, stress conditions can drastically reduce growth. This problem can be corrected by increasing the frequency of irrigation in hot stress days or be correctly monitoring the evaporative demands and gradually supplying or replacing the water losses to keep moisture in the soil at an optimum level. In this paper, through adequate monitoring of the water demands to limit subsequent stress conditions, we investigated the effects of the 4 types of mulch cited previously on yield, evapotranspiration and water use efficiency.

Table 1 shows data on total yield, evapotranspiration, water use efficiency and growth of *Komatsuna* on the 4 periods of measurement. The data show that the rice and groundnut plots give the best yield and the highest number of plants. The 2 types of plastic mulch give comparable yields and amount of water evaporated, with the black plastic mulch having the highest water use efficiency among all the

Table 1 Data on Total Yield, Evapotranspiration, Water Use Efficiency and Growth in the Different Treatments

Treatments	Yield[a) (g)	# Plants[a)	Total Water[a) (cc)	Total Water /Plant (cc/plant)	Water Use Efficiency[b) (g/cc)	Growth (g/plant) 1	2	3	4
Control (Bare)	150.9	221	9,807.2	44.4	0.0154	0.19 (56)	0.54 (55)	0.83 (54)	1.18 (56)
White Plastic	153.7	213	8,682.0	40.8	0.0177	0.24 (56)	0.48 (54)	0.96 (49)	1.25 (54)
Black Plastic	153.3	207	8,160.0	39.4	0.0188	0.23 (58)	0.53 (57)	0.99 (44)	1.38 (48)
Groundnut Husk	161.8	222	9,750.2	43.9	0.0166	0.22 (54)	0.55 (60)	0.89 (54)	1.27 (54)
Rice Husk	171.4	233	9,408.2	40.4	0.0182	0.23 (59)	0.59 (59)	0.90 (55)	1.23 (60)

a) Total for the 4 periods. b) Total harvested yield divided by total water used. ( ) # plants per period.

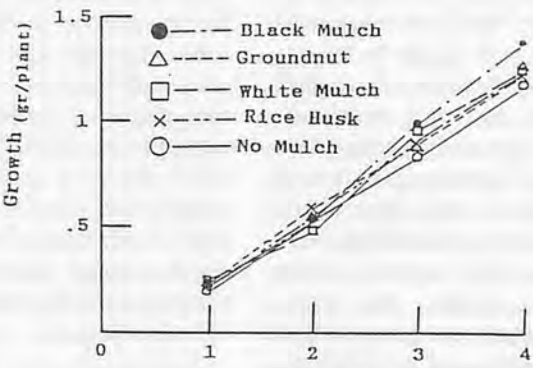

Fig. 5 Growth vs period.

treatments. The control plot gives the lowest yield which was somewhat comparable to that of the plastic mulches and as expected, the highest transpiration rate and thus the lowest water use efficiency. The groundnut mulch plot with a good yield also scored a good water use efficiency and a transpiration rate equivalent to that in the control plot.

This result was expected because even though the groundnut mulch yielded fairly cool soil surface temperature, its surface was warmer than that of the bare soil. This extra energy would be used in the sensible heat transfer with the atmosphere and as latent heat in the evapotranspiration process. Therefore, groundnut mulch did not suppress water losses to the air as effectively as the other covers. For rice husks mulch, because of the low heat flux, evaporation was considerably reduced in comparison with the control plot and water use efficiency analogue to that in the black plastic mulch. The following suggests that the use of groundnut and particularly rice husks as surface covers in arid regions could definitely cut cost because of their readily availability and guarantee high yeild and good water use efficiency. The caution that will be drawn here is that these mulch covers could provide a good environment for insect pests as they produce ideal soil surface temperature.

The adequate monitoring of the evaporation demands limit the hazards of hot stress day. As **Table 1** and **Fig. 5** show, there is no reduction in growth during the 4 different periods. Final growth was highest in the black mulch plot owing to the limited number of plants remaining in that plot. In fact, according to the statistical F test, all the growths were not significantly different at the 5% level. This is partly due to the good moisture conditions kept in all plots.

The conclusions coming out of experiments 1 and 2 are that groundnut and rice husks prove to be very efficient temperature regulator and cold, when coupled with drip irrigation, be good low-cost tools, particularly rice husk, for efficient water saving and good yield. However, as they offer a good environment to insects adequate pest control methods are to be performed.

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Development and Testing of Pedal-cum-Power Operated Air Screen Grain Cleaner

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Abstract

A medium capacity pedal-cum-power operated air screen grain cleaner costing Rs. 2 500 (without electric motor) was developed and tested for wheat, soybean and chickpea. Test results show the capacity of the cleaner to vary between 350-600 kg/h and 500-900 kg/h (input capacity of 14.7-26.5 g/kWh) for pedal and power operated, respectively. For pedal operated cleaner, the purity of separated grain was achieved maximum at 99.9% for chickpea with a screen effectiveness of 80.6% and minimum at 99.5% for wheat with a screen effectiveness of 71.3%. While for power-operated cleaner, the purity was achieved maximum at 99.9% for soybean and minimum at 99.6% for wheat. However, screen effectiveness varied between maximum at 81.7% for chickpea and minimum at 74.1% for wheat. Economic analysis has shown the cleaner to be highly bankable in terms of return-on-investment and annual benefits from the processor's point of view. Besides, a good number of man-days per year are generated per capita investment for employment.

Introduction

Harvested grain (threshed/shelled /dried) needs further processing for separation to get rid of various types of contaminants of undesirable matter, viz; inert material, common and noxious weed seeds, other crop/variety seed, deteriorated seed, damaged seed and/or off-size seed. Thus, the marketable grain should be cleaned and graded before it is used for consumption.

Cleaning and grading would result in reduced bulk of the material, high value products, safe and longer storage, increased life span of milling machinery, more out turn of better quality milled products and pure by-products. Kachru et al (1987) in their study have indicated that grain cleaned /graded would fetch a farmer/processor an extra income of Rs. 250-400/t.*

Food grain crops, threshed by manual or animal treading method is generally cleaned by dropping it to natural wind in India. This method is time consuming, inefficient and brings drudgery to the workers. Mechanically threshed grain is often cleaned by winnowers giving unsatisfactory results. Kachru et al (1987) in their survey inferred that the commercial type cleaners /graders available in the market were of large capacity and high cost. Most of them were imported and required skilled/semi-skilled manpower to operate them. The average capacity of these cleaners /graders was of the order of 1.0 to 5.0 t/h with a price range of Rs. 10 000 to Rs. 120 000. However, the grain cleaners either manually or power operated available in the market have been found to achieve some success but were expensive and incompatible size-wise. It was, therefore, felt necessary to develop an efficient, low cost and medium capacity manually/power-operated grain cleaner to be used at farmer's, trader's and processor's level.

The objectives of the study were to:

i) design and develop a low-cost and medium-capacity pedal-cum-power operated air screen grain cleaner;
ii) determine machine and operating parameters for effective separation of grains; and
iii) make economic analysis for finding the bankability of using the cleaner.

Materials and Methods

Development of Air Screen Grain Cleaner

A medium-capacity pedal-cum-power operated air screen cleaner was designed and developed for

*1 US$ = Rs. 15.

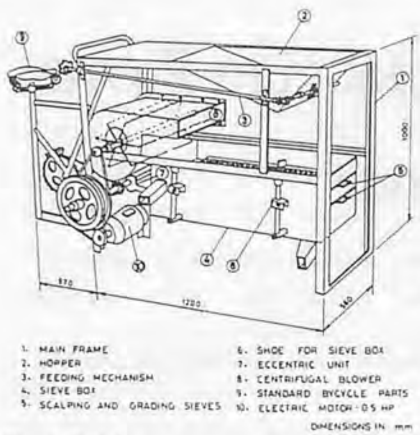

Fig. 1 Pedal-cum-power-operated air screen grain cleaner.

separation of foreign matter from agricultural grains. The machine (**Fig. 1**) is made up of mild steel and consists of a grain hopper, with feeding mechanism, sieve box on hanging shoes, blower unit, driving and eccentric unit. The machine could be operated either manually (pedal) or by an electric motor.

Separation takes place on the basis of difference in size and weight. The grains from hopper are dropped to top scalping sieve by gravity and controlled by a feeding mechanism (**Fig. 1**). With the help of a blower, air is blown across the falling grain whereby lighter materials are blown away.

Separation with two sieves is achieved by difference in size. Larger impurities are retained over the top screen and the undersize is separated by the bottom grading sieve. The cleaned and sound grains are retained over the bottom screen and delivered outside through a spout (**Fig. 1**). The machine specifications of the cleaner are given in **Table 1**.

The cleaner has a provision for interchangeability of screens for cleaning various types of granular products. The pitch of the screen box could be changed by adjusting the shoe height at both sides/ends of the screen box. The reciprocating motion of the sieve box was achieved by eccentric mechanism on the main shaft driven by sprocket-chain drive from pedal shaft. Air

Table 1 Machine Specifications of the Cleaner

Cleaner type	Overall dimensions mm	Total weight kg	Type of drive	Power requirement
Pedal-operated	1600 x 500 x 1000	100	Sprocket and chain, V-belt and pulley	Manual (pedal)
Power-operated	1600 x 500 x 1000	110*	V-belt and pulley	0.5 hp electric motor

* with electric motor.

draft at the falling grain plane was achieved by incorporating air blower (centrifugal fan) driven by V-belt pulley (**Fig. 1**).

The increase in annular cross section in the scroll around a blower wheel was assumed to be proportional to the developed length of the wheel periphery. The angle between the developed scroll surface and blower wheel periphery, known as diffuser angle, has been selected as 4°. Based on this value and wheel diameter, the shape and dimensions of the scroll were determined and the design of the unit completed. Pressure conversion was accomplished as the cross section of the air stream expands in the increasing annular space on the periphery of the blower wheel from cutoff to discharge. The cutoff eliminates almost all free circulation of air within the housing.

Physical Properties of the Grain

Mechanically threshed samples of freshly harvested wheat (variety: WS-147), soybean (JS-7244) and chickpea (C-235) stocks produced at the Institute's farm, were procured for separation purposes. The samples were analysed by Standard Methods (Hall 1957, Wratten et al. 1969, Mohsenin 1970) for identification and percentage of each foreign matter present in the sample and for the determination of physical properties, viz: size (length, width/diameter, thickness), specific gravity, moisture content and 1 000 grain weight.

Based on the basic information, thus collected, sieve sizes for 2-screen cleaner and air flow needed to achieve optimum separation for the threshed product were determined.

Testing and Economic Analysis for the Cleaner

The cleaner (pedal and power operated separately) was tested for one major variety of each of wheat, soybean and chickpea. Purity was determined as fraction of clean seed at clean seed outlet in per cent. Screen effectiveness (also called cleaning efficiency or cleaning index) was calculated by the following expression (IS: 5718-1980)

$$\eta = \frac{100 \times E(F-G)(E-F)(1-G)}{F(E-G)^2(1-F)}$$

where,

η = screen effectiveness, %

E = fraction of clean grain at clean grain outlet, decimal

F = fraction of clean grain in feed, decimal

G = fraction of clean grain at foreign matter outlets (combined), decimal

Air flow rate was measured with the help of an electronic vane anemometer (range: 0-25 m/s).

Economic analysis in terms of cost of operation, working capital, break-even-point, return-on-investment, net benefits and employment generation per unit of capital investment for both, pedal and power operated cleaner was done in order to determine the bankability of the cleaner (Kachru et al. 1986).

Results and Discussion

Physical Properties of Grain

Physical properties, viz; size (length, width/diameter, thickness), moisture content, 1 000 grain weight and specific gravity of wheat, soybean and chickpea are presented in Table 2.

Testing of the Cleaner

While testing the cleaner for the grains, it was observed that the long slender stems, light chaff and bigger/smaller pieces of hull were turning on end and passing through the top screen. This could be avoided if it would be flat and slide over. Thus, a sheet of ordinary cloth with polyethylene lining underneath was drapped over the top screen. By this, long pieces of stem could not turn up on end to go through the round/oblong holes of top screen but would slide down the screen underneath the smooth polyethylene/rough surface and screened over.

The machine and operating specifications of pedal-cum-power operated air screen cleaner used for grain separation are shown in Table 3. Test results and sieve sizes of the cleaner for the separation of the three selected grains are given in Table 4. The capacity for pedal-operated cleaner varied between 350 kg/h for wheat and 600 kg/h for soybean. The purity of the cleaned grain was achieved maximum at 99.9% for chickpea and minimum at 99.5% for wheat. While as, screen effectiveness for pedal operated cleaner was achieved maximum at 80.6% for chickpea and minimum at 71.3% for wheat. For power operated cleaner, the capacity varied between 500 kg/h for wheat and 900 kg/h for soybean with input capacity of 14.71/kWh and 26.5q/kWh, respectively.

The purity of cleaned grain was achieved maximum at 99.9% for soybean and minimum at 99.6% for wheat. Screen effectiveness was achieved maximum at 81.7% for chickpea and minimum at 74.1% for wheat.

Table 2 Some Physical Properties of Wheat, Soybean and Chickpea Samples

Parameter/property	Grain		
	Wheat	Soybean	Chickpea
Variety	WS-147	JS-7244	C-235
Constituents present in the threshed crop	bold/small wheat, broken, immature paddy and rice, dirt/dry mud particles, trash, stalks, husk weed seeds	bold, small and split soybeans, dry mud particles, clods, stalks, pods and dirt	bold, small and split gram, dry mud particles, stalks, pods and dirt
Size, mm			
length	6.81 ± 1.66	7.71 ± 1.02	7.46 ± 1.32
width/dia	3.09 ± 0.22	6.12 ± 0.64	5.47 ± 0.72
thickness	2.77 ± 0.24	4.80 ± 0.65	5.36 ± 0.69
Av. equivalent dia	3.88	6.09	6.03
mud particle dia	–	3.67 ± 1.51	3.25 ± 1.82
Moisture content, %(db)	6.66	11.26	6.97
1000 grain weight, g	48.88	123.85	142.42
Specific gravity			
grain	1.41	1.19	1.36
mud particles	3.17	2.76	2.89

Table 3 Machine and Opeating Parameters for Grain Cleaner

Parameter	Pedal operated	Power operated
Screen dimensions, mm		
Scalper	750 x 430	
Grader	750 x 430	
Screen pitch, degree		
Scalper	7	
Grader	7	
Hopper capacity, kg	40 (wheat)	
Length of stroke of sieve box, mm	20	
rpm at eccentric unit	160-180	280
rpm at blower unit	640-720	1120
Air velocity, m/s at:		
Blower outlet	7.31	8.03
Winnowing section	6.23	6.80

Table 4 Test Results of Pedal-cum-power Operated Cleaner for Separation of Grains

Parameter	Grain		
	Wheat (WS-147)*	Soybean (JS-7244)*	Chickpea (C-235)*
Pedal-operated			
Capacity, kg/h	350	600	500
Purity of the cleaned grain, %	99.5	99.8	99.9
Screen effectiveness, %	71.3	78.8	80.6
Sieve size, mm			
Scalper	5	8	8
Grader	2x20	3.2x20	3.2x20
Power-operated			
Capacity, kg/h	500	900	800
Input capacity, q/kWh	14.7	26.5	23.5
Purity of the cleaned grain, %	99.6	99.9	99.8
Screen effectiveness, %	74.1	81.0	81.7
Sieve size, mm			
Scalper	5	8	8
Grader	2x20	3.2x20	3.2x20

* Variety.

Economic Analysis

The economic parameters for both cleaners (pedal and power-operated) have been determined for four different operational conditions, namely; purely custom-based; 50% custom-based and 50% selling; purely selling and farmer's own use. The results for pedal and power operated air screen cleaner have been presented in **Table 5**.

The cost of operation for pedal operated cleaner was calculated as low as Rs. 1.40/q for soybean at 100% custom hire to a maximum as Rs. 3.00/q for wheat at 100% sale **(Table 5)**. The annual net profit to the user could be as high as Rs. 13 300 with a return-on-investment of 80%. Besides, an employment of 80 to 130 man-days/year/Rs. 10 000 capital investment can be generated using pedal operated cleaner.

With power-operated cleaner, the cost of operation varied between Rs. 0.95/q for soybean at 100% custom hire to Rs. 2.65/q for wheat at 100% sale **(Table 5)**. The annual net profit could be earned as high as Rs. 27 576 with return-on-investment of 108%. **Table 5** shows that the employment generation by using power operated cleaner varied between maximum of 355 to minimum of 47 man-days/year/Rs. 10 000 capital investment.

Table 5 Economic Analysis[a] for Pedal-cum-power Operated Air Screen Grain Cleaner[b]

Economic parameter	Operational condition: 100% custom hire	50% custom hire and 50% sale	100% sale	Self use
Working capital (weighted), Rs.				
Pedal	212	23 532	48 852	212
Power	266	27 146	74 026	266
Cost of operation, Rs/q[c]				
wheat				
Pedal	2.20	2.65	3.00	2.20
Power	1.75	2.20	2.65	1.75
Soybean				
Pedal	1.40	1.70	1.95	1.40
Power	0.95	1.20	1.50	0.95
Chickpea				
Pedal	1.55	1.85	2.15	1.55
Power	1.05	1.35	1.65	1.05
Break-even-point (weighted), q/y				
Pedal	487	343	302	161
Power	534	379	340	191
Annual net profit, Rs.				
Pedal	3 414	8 357	13 300	n.a.[d]
Power	6 546	17 061	27 576	n.a.
Return-on-investment, %				
Pedal	133	87	80	n.a.
Power	194	118	108	n.a.
Employment generated, man-days/y/Rs. 10 000 of capital investment				
Pedal	468	125	72	n.a.
Power	355	85	47	n.a.

(a) Assumptions for economic analysis
- Useful life of cleaner : 10 year
- Salvage value : 10%
- Interst rate : 15% per year
- Operation : 8 h/d
- Opeartion/y : wheat-25 d, soybean-25 d and chickpea-10 d

(b) Cost of equipment : Rs. 2 500 (1.00 US$ = Rs. 15.00)
Cost of equipment (with motor) : Rs. 3 300

(c) q : quintal (1.0 q = 100 kg)

(d) not applicable

Conclusions

1. A low-cost medium-capacity air screen grain cleaner was designed and developed which could be operated manually (pedal) or by electric power.
2. The testing of the developed cleaner with wheat, soybean and chickpea both in laboratory and at farmer's field have given satisfactory results for efficient cleaning and ease of handling, requiring little skill.
3. The pedal-cum-power operated cleaner is highly bankable in terms of return-on-investment and annual benefits from the processor's point of view. Besides, a good number of man-days/year are generated per unit capital investment for employment.

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Utilization of Wind Power and Wetted Pads to Evaporatively Cool Dairy Cow Sheds under Hot and Arid Climatic Conditions

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Abstract

Evaporative cooling obtained as a result of wind flow through three different types of wetted pads was investigated during the hot and arid summer conditions prevailing in Al-Hassa Oasis of Saudi Arabia. The wetted pads used in the study were: corrugated cellulose pad, two-layer plastic fabric commonly used in wind breaks and shades, and three-layer pad of the same fabric. All three types of pads were stretched along the windward side of an open dairy cow shed and were maintained wet during day time of the summer months. Wind speed, dry bulb and wet bulb temperatures were measured outside and inside the shed; just behind the wetted pads. Saturation efficiency was calculated for each pad.

Cellulose pad gave the best cooling, with dry bulb depression varying between 10 and 20°C and saturation efficiency between 67.5 and 66.7%. The three-layer plastic fabric pad was the second best followed by the two-layer plastic fabric pad which gave a wet bulb depression varying between 8 and 15°C and a saturation efficiency between 50 and 65.9%. Wind speed varied between 1.1 and 9.8 m/s with northerly direction frequency of occurrance amounting to about 85% during the experiment.

Introduction

The need for providing cool air to lactating dairy cows to alleviate thermal stress conditions has been well documented in literature (2, 5, 6, 8, 9, 11, 13, 16, 18, 27 and 28). Various types of evaporative cooling systems have been developed for dairy housing under hot and arid climatic conditions (1, 10, 12, 14, 19, 21, 22, 24 and 26). Fan-and-pad and water spray injection systems proved to be the most effective and most economically feasible under those conditions (12, 14, 17, 20, 23 and 25).

Fan-and-pad evaporative cooling systems require exhaust fans to force air through the wetted pads into the space to be cooled. This requirement entails fairly high initial and operational costs and may, in most cases, impose some restrictions on pen design and animal housing regime (25, 26). Water spray injection systems, on the other hand, are quite suitable for open, naturally ventilated pens but they are prone to some practical problems such as excessive wetting of cows during relatively calm days and excessive spray drifting during windy days (1). Moreover, spray nozzles often get blocked by dirt and/or accumulation of salts in the sprayed water. The use of wind to modify environmental conditions in dairy housing has been, so far, restricted to natural ventilation and, to a limited extent, spray injection evaporative cooling of open sheds during summer. It has been shown (3, 15) that for standard air density of 1.2 kg/m^3, the static pressure, P, over a plane wall perpendicular to wind flow could be expressed as:

$$P = 0.6\,V^2 \text{ Pa}$$

where, V = wind speed in m/s

This pressure varies from positive on the windward side of the building to negative on the leeward side.

The rate of air flow, Q, through an inlet, due to wind force, is given by the following empirical equation developed by ASHRAE (4).

$$Q = EAV$$

where,

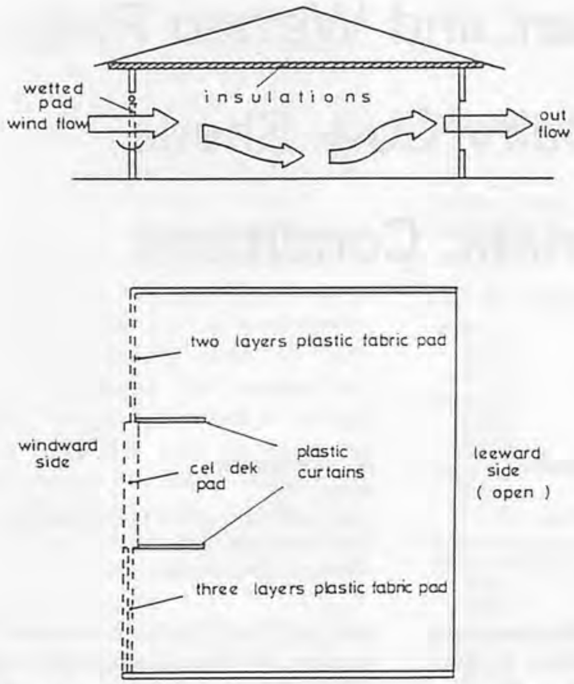

Fig. 1 Cross-section and plan view of the experimental shed.

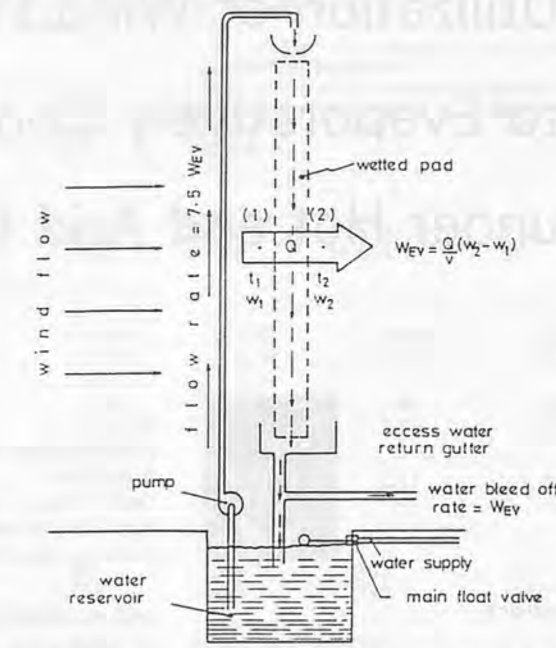

Fig. 2 Schematic representation of the water circulation system through the pads.

E = Effectiveness of opening = (0.5 – 0.6) for perpendicular wind, 0.25 – 0.35 for diagonal wind, at 45° with opening.

A = free area of opening, m^2
V = wind velocity, m/s

To get maximum air flow inlet openings should be perpendicular to wind flow as much as possible.

Materials and Methods

An open-side dairy shed, 7.2 x 10 m was used in the experimental work. The shed was oriented in such a way that one of the 7.2 m long sides was facing north. This side was sub-divided into three equal sections, and one type of wetted pad was stretched across each section. The wetted pads were: 100 mm thick corrugated cellulose (known commercially as cel dek), two-layer plastic fabric (used as 40% effective partial shade or wind break) and three-layer of the same plastic fabric as shown in **Fig. 1**. A 50 mm x 50 mm wire grid was used to support the plastic fabric pads and keep them vertical all the time. Plastic sheets, about 1.0 m long were stretched between neighbouring pads into the shed to prevent air mixing over a short distance behind the pads.

As shown in **Fig. 2** the three types of pads were wetted by water evenly distributed along the top edges. Excess water from pads was collected into a gutter running along the lower edges of the pads, and returned to a water reservoir for recirculation. The rate of water circulation through the wetted pads was maintained at 7.5 times the rate of evaporation from the pads as recommended in literature (3). To prevent salt build-up in the recirculated water, a water bleed off, at a rate equal to the average rate of water evaporation from the pads, was by-passed from the excess water return path and rejected so that it would be replaced by fresh water. In this way salt concentration in the recirculated water was maintained at a constant acceptable level.

Dry and wet bulb air temperatures were measured outside and inside the experimental shed, just behind the wetted pads. A simple psychrometer was used in these measurements. Air velocity was also measured by a propeller type anemometer outside and inside the shed. Measurements were taken twice a week, at 1300 during the day throughout the summer months – July to September, 1985.

Results and Discussion

Table 1 shows the experimental data, namely; dry bulb temperatures, wet bulb temperatures and air velocities, obtained during the summer months – July to September 1985. The dry bulb temperature prevailing outside and inside the experimental shed, just behind the wetted pads, are shown graphically in **Fig. 3**.

The relative cooling efficiency of the three wetted pads was measured by the saturation efficiency (η) calculated for each type of pad by the following equation:

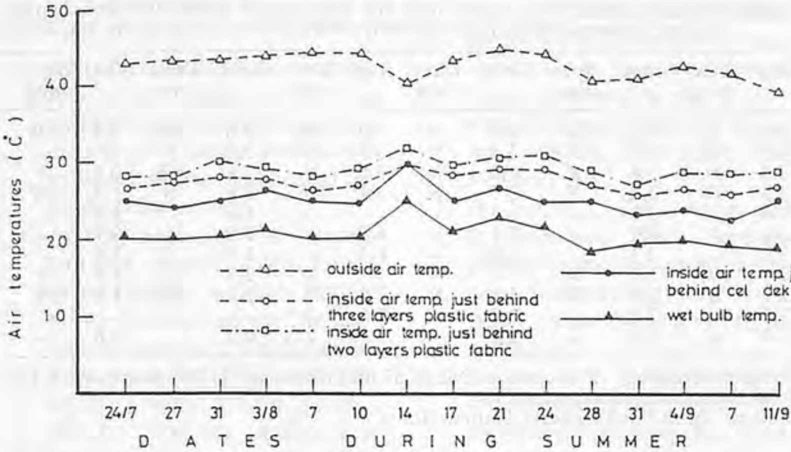

Fig. 3 Air temperatures outside experimental shed and just behind the 3 types of wetted pads.

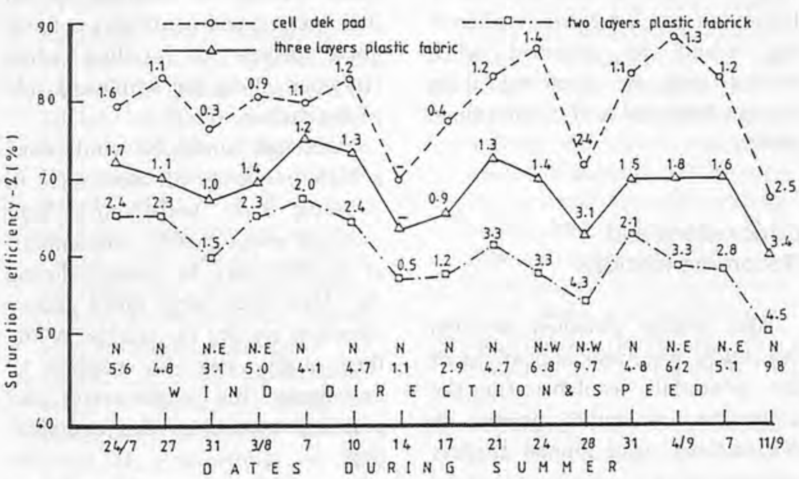

Fig. 4 Saturation efficiency (η) of the 3 types of wetted pads used in the experimental work.

$$\eta = \frac{t_o - t_i}{t_o - t_{wb}} \times 100\,\%$$

where,

t_o = outside dry bulb temperature

t_i = inside dry bulb temperature (just behind each wetted pad)

t_{wb} = wet bulb temperature

The values obtained for each type of pad during the whole experimental period are shown graphically in **Fig. 4**. Wind speed and direction and air velocities through the respective pads are indicated for the respective days.

As can be seen from **Table 1** and **Fig. 3** the outside dry bulb temperature varied between 39 and 45°C while the wet bulb temperature varied between 18.5 and 25°C throughout the experimental period. The best cooling, as indicated by the lowest inside dry bulb temperatures and the highest saturation efficiency; was obtained with the cel dek pad throughout the experimental period. The two-layer plastic fabric pad gave the least cooling, i.e., the highest inside dry bulb temperature, and the lowest saturation efficiency. The three-layer plastic fabric pad, on the other hand, gave intermediary values

Table 1 Outside Conditions Prevailing During Summer Months of 1985 and Degree of Evaporative Cooling Obtained as a Result of Wind Flow Through Three Different Types of Wetted Pads Stretched Across the Windward Side of an Open Dairy Cow Shed

Date	Outside conditions			Inside conditions								
				Cel Dek			Two-layer plastic fab.			Three-layer plastic fab.		
	t_{db} (1) °C	$t_{w.b}$ °C	Wind dir. & vel. m/s	t_{db} (2) °C	Air vel. m/s	Sat. eff. %	t_{db} (3) °C	Air vel. m/s	Sat. eff. %	t_{db} (4) °C	Air vel. m/s	Sat, eff. %
24/7	43.0	20.1	NE 5.6	25.0	0.6	73.6	28.0	2.4	65.5	26.5	1.7	72.0
27/7	43.5	20.0	N 4.6	24.0	1.6	82.9	28.0	2.3	65.9	27.0	1.1	70.0
31/7	43.5	20.5	NE 3.1	26.0	0.4	76.1	30.0	1.5	58.7	28.0	1.0	67.4
3/8	44.0	21.0	NE 5.0	25.5	1.2	80.4	29.0	2.3	65.2	28.0	1.4	69.6
7/8	44.5	20.0	N 4.1	25.0	1.1	79.6	28.5	2.0	65.3	26.0	1.2	75.5
10/8	44.5	20.5	N 4.7	24.5	1.4	83.3	29.0	2.4	64.6	27.0	1.3	72.9
14/8	40.5	25.5	E 1.1	30.0	–	70.0	32.0	0.5	56.6	30.0	–	63.3
17/8	43.0	21.0	N 2.9	26.0	0.4	77.3	29.5	1.2	56.8	28.5	0.9	65.9
21/8	45.0	23.0	N 4.7	26.8	1.2	82.7	31.5	3.3	61.4	29.0	1.3	72.7
24/8	44.5	22.0	NW6.8	25.0	1.4	86.7	31.5	3.3	57.8	28.8	1.4	69.8
28/8	41.0	18.5	NW9.7	25.0	2.4	71.0	29	4.3	53.3	27.0	3.1	62.2
31/8	41.0	19.5	E 4.8	23.0	1.1	83.7	27.5	2.1	62.8	26.0	1.5	69.8
4/9	43.0	20.0	NE 6.2	24.0	1.3	82.6	29.0	3.3	58.7	27.0	1.8	69.6
7/9	42.0	19.0	NE 5.1	23.0	1.2	82.6	28.5	2.8	58.7	26.0	1.6	69.6
11/9	39.0	19.0	N 9.8	25.5	2.5	67.5	29.0	4.5	50.0	27.0	3.4	60.0

Table 2 Monthly Mean Wind Speed (m/s) and Direction at Hofuf Research Station During Summer Months (May-October, 1969-1979) at 2.0 m Above Soil Surface*

May	Direction	June	Direction	July	Direction	Aug.	Direction	Sept.	Direction	Oct.	Direction
3.6	N	3.0	N	4.0	N	3.2	NE	3.0	NE	2.4	NW
4.5	NE	5.2	N	3.8	N	3.7	N	3.1	N	–	–
2.8	N	3.8	N	4.3	N	3.6	N	2.6	NE	2.6	N
3.3	SW	3.2	E	3.7	N	2.4	NE	2.6	N	1.4	SW
2.4	–	3.2	–	–	–	–	–	1.6	–	1.8	–
2.4	–	4.9	–	5.1	–	4.8	–	3.9	–	2.7	–
2.2	–	2.3	–	3.0	–	1.7	–	1.9	–	1.8	–
2.4	NW	1.7	N	–	–	–	–	2.3	N	1.4	E
3.1	N	2.4	SW	4.4	N	2.2	N	2.0	NE	1.5	NE
2.2	–	2.8	–	1.7	–	2.4	–	–	–	–	–
1.2	–	3.8	–	2.6	–	1.8	–	0.9	–	0.8	–

Direction frequency of occurance: North 57.6%; Northeast 21.2%; Northwest 6.1%; Total for northerly direction = 85%
*Source: Agricultural Research Station, Hofuf.

for dry bulb temperatures and saturation efficiency. Air velocity through the pads was lowest with the cel dek pad and highest with the two-layer plastic fabric pad.

Wind flow was mostly northerly, or, to a lesser extent, northeasterly throughout the study period. The instantaneous wind speed varied between 1.1 and 9.8 m/s during that period. As shown in **Figs. 3** and 4 the highest values of saturation efficiency were obtained when wind flow was northerly at speed varying between 3.5 and 6.5 m/s.

As shown in **Table 2** and graphically in **Fig. 5** the monthly mean wind velocity at the height of 2.0 m above ground, calculated for the years of 1969-1979 at Hofuf Agricultural Research Station is 3.0 m/s. This velocity is slightly less than the lower limit required for maximum cooling efficiency. However, it should be mentioned that any degree of cooling achieved during the hot part of the day in the summer would be desirable as a relief measure for the animals.

Table 2 and **Fig. 5-b** show that the frequency of northerly, northwesterly and northeasterly wind flow put together, amount to about 85% of the time during the summer. This situation would ensure, at least, that much frequency of cooling would be obtained when wetted pads are stretched along the northern side wall of the animal shelter.

Conclusions and Recommendations

The results obtained through this study gave clear indications of the potentials available for the utilization of wind power to evaporatively cool animal shelters under hot and arid climatic conditions. Corrugated cellulose, or cel dek, wetted pad could give a fairly good degree of cooling when stretched along the windward side of the shelter.

Although northerly winds have a high frequency of occurrance in Al-Hassa area, with fairly high monthly mean speeds, supplemental air fans may be needed during the days when wind speed and/or direction are not favourable. A further study may be needed to investigate the engineering and practical aspects of this combination.

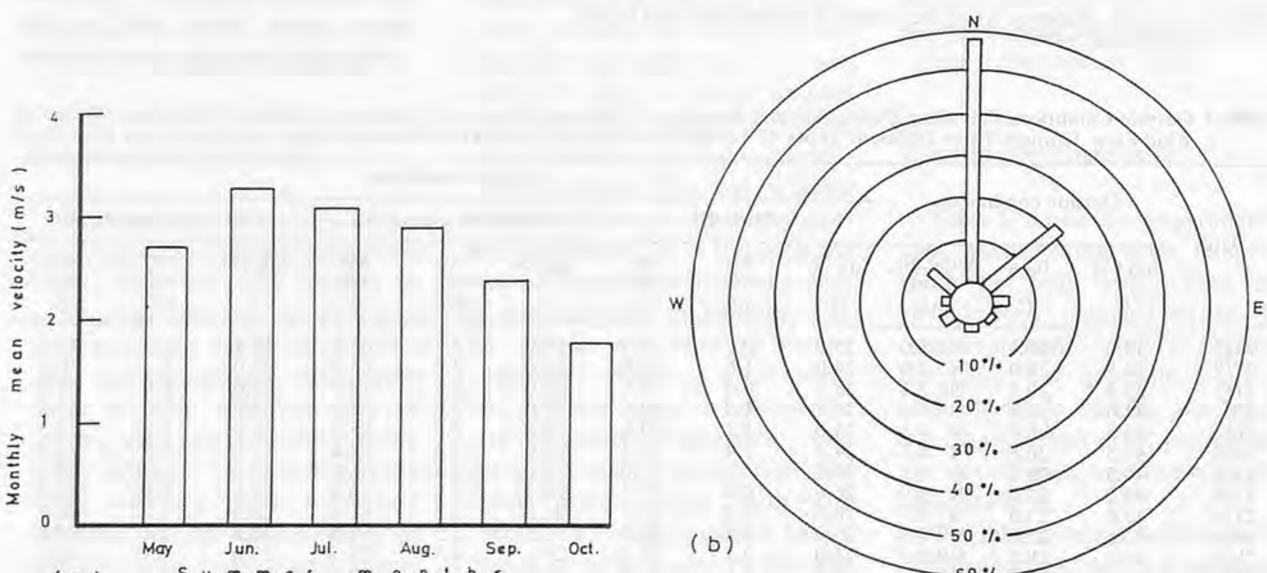

Fig. 5 (a) Monthly mean wind velocity (m/s) at 2.0m height; (b) frequency of wind directions (%) during summer months at Hofuf Agricultural Research Station for the years 1969-79.

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Microcomputer Simulation of Heat Transfer in Tropical Swine Housing

by

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Introduction

The rate of animal heat loss is dependent upon the temperature and air velocity surrounding the animal. The role of animal housing ventilation systems is to remove excess water vapor and heat when necessary to maintain optimum conditions for production. This is accomplished by optimizing ventilation opening size and location with respect to the thermal characteristics of building materials.

The design of naturally ventilated livestock buildings is difficult, mainly because of the uncontrolled variables found outside and inside the structure. This paper presents a simulation model that was designed to help evaluate the performance of an open swine building with respect to the total heat balance.

Background

The performance of a ventilation system can be measured in two ways: 1) by physically measuring the environmental factors, or 2) by monitoring various output criteria such as: level of pollution, operator welfare and livestock health and productivity. Experiments to determine the effects of various ventilation systems on air temperature and velocity at stock level were carried out by Carpenter (1974). Findlay et al (1948) developed a method for determining the adequacy of a ventilation system based on the concentration of CO_2 over that of fresh air, in closed housing. However, most structures used for animal housing in hot climates are open sided buildings that rely on natural ventilation for environmental control.

The purpose of a ventilation system is to remove the water vapor and excess heat from the building as it is produced by the animals, while maintaining a suitable temperature inside the structures. Pattie (1973), Kelly et al (1954), Bond et al (1969), Timmons (1976) and Beckett (1964), studied the thermal relationship between construction materials and the ventilation of animal housing, as well as the role of radiant energy in determining heat loads.

Poor environmental conditions adversely affect production. As the environmental temperature falls, the growth of young pigs becomes slow, and with further reduction in temperature, the efficiency of food conversion (weight gain per unit of food input) is reduced (Mangold, 1967). High air temperature also results in reduced rate of weight gain and reduced carcass quality of pigs and may also cause low reproductive performance. (McLean, 1969).

Past modeling work on heat flow has provided a basis for modeling the animal housing environment. A method for calculating heat gain and losses through building sections is presented in detail in the ASHRAE Handbook of Fundamentals, (1985), and is further described by Esmay (1982).

Designing buildings to create the necessary indoor thermal environment requires the manipulation of an extensive array of interacting variables defining building components, materials, orientation, geometry, occupancy and animal comfort requirements. The large number of variables and the complexity of their interaction have resulted in the need to make simplifying assumption in the thermal design process in order to develop manageable models (Buffington, 1975).

The application of the transmission matrix method with a simplified procedure for its use was developed by Albright et al (1974a, 1974b). The transmission matrix method relates the periodic temperature and heat flux on one side of a homogenous layer to the periodic temperature and heat flux on the other side of a layer by means of a transmission matrix where the temperatures are expressed in the form of a Fourier series. The convection and radiation heat transfer constants and the steady state conduction equation derived from Fourier's theoretical equation can be used to determine steady state conduction, convection and radiation heat transfer from the structure's surfaces. The differential equation developed by Fourier combined with material properties data, predicts conduction heat transfer and heat storage based on temperature differences (Kreith, 1966). In Albright's model, the heat transfer mechanisms are required to be linearly related to inside temperature for implementing the Fourier solution. This approach using a controlled air volume was the starting point in this research.

The sol-air temperature is the outside temperature that, in the absence of all radiation heat exchange, results in the same rate of heat exchange as would occur with the actual combination of incident solar radiation, radiant heat exchange with surroundings, and convective heat exchange.

The heat transfer can then be expressed as:

$$q/A = h_e (t_e - t_s)$$

where,

- q/A = Heat flux at a surface, W
- h_e = Heat transfer coefficient, W/m^2
- t_e = Sol-air temperature, C
- t_s = Surface temperature, C

Assuming that the sol-air temperature is proportional to the outside temperature and the heat transfer coefficient for solar radiation, another way of expressing the heat balance and temperature is:

$$t_e = t_o + \propto I_g/h_e - \Sigma R/h_e$$

$$q/A = \propto I_g + h_e (to - t_s) - \Sigma R$$

where:

- I_g = Incident solar radiation, W/m^2
- $\propto$ = Solar absorptance
- h_e = Heat transfer coefficient, W/m^2
- t_i = Inside temperature, °C
- t_s = Surface temperature, °C
- Σ = Surface emittance
- R = Difference between the radiation incident on the surface and the radiation emmitted by a black body, W/m^2

Frota et al (1984) suggest that the surface temperature can be assumed to be equal to the outside temperature, and then the term $h_e (t_i - t_s) - \Sigma R$ represents the heat exchange by longwave radiation and convection at the outer surface. Also, the ventilation coming into the building brings in a portion of the radiant heat load transferred from the ceiling and walls by convective heat transfer. This makes the heat flux associated with ventilation into the building proportional to the convection and thus to wind velocity. The heat flux of the air coming out of the building is, on the other hand, proportional to the rate of air exchange within the building.

Studies conducted by Frota et al (1984) and Croiset (1974) show that the total volume of air within the building changes slowly and depends on the outside and inside air velocity. However, even when outside air velocity equals zero the building air change remains above zero due to thermal convection and the movement of the animals.

The ventilation heat balance was expressed as:

$$Q_v = (\pm Qve \pm Qv_s)$$

where:

Qve is the air flux through the openings, as stated in ASHRAE (1985),

$$Qve = F \partial c t_o$$

and

$$F = E A v$$

where

- Qve = total heat transmitted into the building by ventilation air, W
- F = air flux through the building, m^3/s
- E = efficiency of openings
- A = area of openings, m^2
- v = wind velocity, m/s
- δ = air density, kg/m^3
- c = air specific heat, J/kg°C
- t_o = outside temperature, °C
- ti = inside temperature, °C

In this model, the opening efficiencies used were:

- E = 0.5 to 0.6, for wind direction perpendicular to the openings
- E = 0.25 to 0.35, for wind direction at an angle of other than 90° to the openings

The heat removed from the building by ventilation was expressed as:

$$Qvs = \xi N V (t_i - to)$$

where:

- Qvs = total heat removed by ventilation, W
- ξ = experimental constant, $W/m^3 °C$
- N = number of building air changes per minute,
- V = volume of the building, m^3
- t_i = inside temperature, °C

In a previous study by Naas (1986), N for open sides housing varied from 0.1 to 1.0, depending on the wind velocity. Air exchanges were assumed as follows: For wind velocities below 0.3 m/s, N = 0.1; for wind velocities higher than 0.3 m/s and lower than 1 m/s, N = 0.3; for wind velocities higher than 1.0 m/s and lower than 3.0 m/s, N = 0.4; and for air velocities higher than 3.0 m/s, N = 1.0.

The solar radiation energy, Q_S, was expressed by the incident solar heat loaded which is proportional to the roof's area and material. The indirect solar radiation was neglected.

$$Q_s = Q_{op}A_t$$

$$Q_{op} = \alpha R\, I_g + Ut,$$

$$U = 1/(1/h_e) + (1/K), \text{ and}$$
$$R = U/h_e$$

where:

Q_s = total solar heat, W
Q_{op} = quantity of radiant heat for opaque materials, W/m
α = coefficient of solar absorptivity
K = coefficient of global heat transmission, $W/m^2\,^\circ C$
h_e = coefficient of superficial thermal conductance, $W/m^2\,^\circ C$
I_g = global radiation intensity, W/m^2
t = temperature gradient, °C
A_t = area of roof, m^2

The total heat gain or loss by conduction was given by Koeningsberger et al (1977) as:

$$Q_c = \frac{\gamma}{e}\, t\, A_p$$

where.

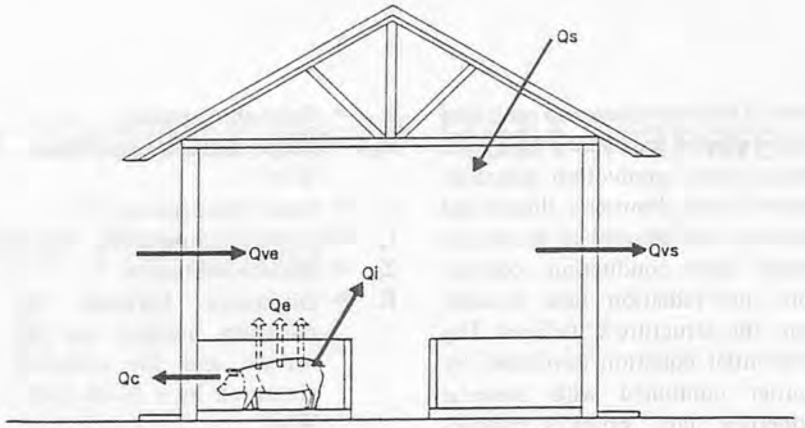
Q_c = total heat exchange by conduction, W
γ = coefficient of thermal conductance, $W/m^\circ C$
e = length of construction material, m
t = temperature gradient, °C
A_p = area of walls, m^2

A heat production model for growing pigs was developed by Bruce, et al (1979). It described the total heat transfer from a pig to the environment as:

$$Q_i = A[\![[1.0 + (A_f/A)((I_a - I_f)/(I_b + I_f)) - (A_c/A)](T_b - T_a) + EI_a]\!]/(I_a + I_b)$$
$$A = 0.09W^{0.67}$$
$$I_a = (5.3 + 15.7\,(V^{0.6}W^{-0.13}))^{-1}$$
$$I_b = 0.02W^{0.33}$$
$$I_f = I_{f45}\,(W/45)^{0.33}(5\,A_f/A)N^{0.5}$$

where.

A = Pig surface area, m^2



Qi = Heat produced by the pig   Qe = Heat generated by evaporation
Qs = Heat by solar radiation   Qve = Heat carried by ventilation to inside the building
Qc = Heat exchange by conduction   Qvs = Heat carried by ventilation to outside the building

Fig. 1 Heat sources involved in the open building heat balance analysis.

A_f = Pig surface area in contact with the floor, m^2
A_c = Pig surface area in contact with other pigs, m^2
I_a = Thermal resistance of air interface, m^2kW^{-1}
W = Live weight, kg
I_b = Tissue thermal resistance, m^2kW^{-1}
I_f = Effective thermal resistance of floor, m^2kW^{-1}
T_b = Deep-body temperature, °c
E = Latent heat production from skin, Wm^{-2}
N = Number of animals

Bruce also established that for live weights from 1.0 to 170.0 kg and for temperatures below the thermoneutral zone:

$$E = 8.0 + 0.07W$$

The latent heat production for high ambient temperatures and wet conditions is given by:

$$E = 75.6\,(V^{0.6}/W^{0.13})[T_s - T_a]$$

where T_s is the skin temperature. For temperatures within the thermoneutral zone,

$$T_s = 0.55\, T_i + 18$$

otherwise, $T_s = T_b$.

The total latent heat coefficient described by Bruce (1981) for temperatures above the upper critical temperature in wet conditions can be added to the denominator of I_a, then:

$$I_a = 1/5.3 + 91.3\,(u^{0.6}/W^{0.13})$$

The total latent heat production can be expressed as:

$$Q_e = Q_{ep}n + Q_{ea}, \text{ where,}$$
$$Q_{ep} = E\,[t_p - t_i]\,A, \text{ and}$$
$$Q_{ea} = \delta cvtA_m$$

where,

Q_e = Total evaporative heat exchange, W
Q_{ep} = Total latent heat per pig, W
Q_{ea} = Total sensible heat in the building, W
A = Pig surface area, m^2
v = Air velocity, m/s
W = Pig live weight, kg
δ = Air density, kg/m^3
c = Air specific heat, $j/kg^\circ C$
t = Temperature gradient, °C
A_m = Area of wet floor, m^2
n = Number of animals

The amount of heat balance for the building is then given by:

$$Q_i + Q_s \pm Q_c + (Q_{ve} - Q_{vs}) - Q_e = 0$$

where,

Q_i = Animal heat production, W
Q_s = Incident solar energy, W
Q_c = Heat gain or loss by conduction, W
Q_{ve} = Ventilation heat in, W

Table 1 Characteristics of Climate where the Studied Buildings are Located (Itatiba, Sao Paulo, Brazil, and Gainesville, Florida, USA)

Item	Itatiba	Gainesville
Latitude	23°37'S	29°44'N
Longitude	46°39'W	82°26'W
Average (kg/m³)	1.33 to 1.23	
Air specific heat – Ave (J/kg°C)	0.001	

Q_{VS} = Ventilation heat out, W

Q_e = Heat loss by evaporation, W

Fig. 1 shows the heat sources in an open swine building. The model reflects the following parameters;

1. Buildings with open sidewalls
2. External and internal temperatures
3. Mass of air exchanged through the building
4. Conduction heat exchange
5. Solar heat absorption through the roof
6. Sensible and latent heat generated in the building.

The following parameters are neglected in the model:

1. Fermentation heat production, and the
2. Heat stored in the building construction materials

Field Measurements and Results

Two warm-climate studies were conducted, one at Itatiba, Sao Paulo, Brazil and ther other at Gainesville, Florida, USA. Both buildings studied were partially open on the sides for natural ventilation. The thermal characteristics of both buildings were similar. The main difference was the roof material which was corrugated asbestos for the Brazilian experiment and steel sheet metal for the experiment in Florida.

Both short term studies to evaluate thermal behavior took place in swine finishing buildings. The building in Brazil contained 100 pigs with an occupance rate of 1.0 m²/pig, while in the other

Fig. 2A Front view of the studied Brazilian swine unit.

Fig. 2B Inside view of the studied Brazilian swine building.

Fig. 3A Front view of the studied American swine unit.

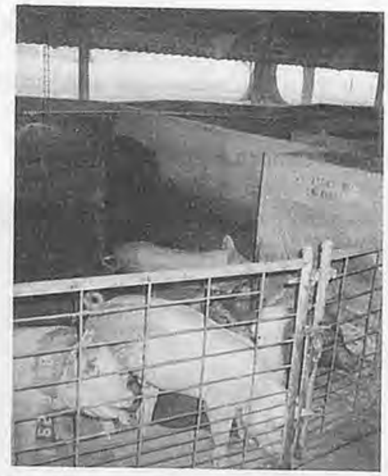


Fig. 3B Inside view of the American swine building.

building, there were 111 animals with the space rate around 0.9 m²/pig. The initial weight of the animals in both cases were in the range of 50-53 kg each.

The climatic characteristics used in the model are shown in **Table 1**. **Figs. 2** and **3** show pictures of both buildings. Inside temperatures were measured using thermocouples placed at an average height of 1.22 m to 1.45 m from the floor at the Gainesville swine unit. Thermometers at the same height were used in Brazilian study. The outside temperature, wind velocity, and solar radiation were measured at a nearby experimental station in both studies.

Microcomputer software was developed based on the mathematical model described here. The software was designed in a way that it can be used by professionals working with animal housing by allowing the user to evaluate the building from its overall heat balance. The model was validated for naturally ventilated buildings, which is the most common type of construction in animal housing in the tropics. A heat balance close to zero indicates that all heat coming into the building from all sources has been totally removed. In both buildings studied, the amount of heat removed by either evaporation or natural ventilation was not significant when compared to the total heat gain. However, the total heat balance by natural ventilation decreased with increasing outside wind speed as shown in **Figs. 4** and **5**. The reason for this behavior in the Gainesville study appears to be mainly the presence of obstructions within the upper level of the building. The swine house was located in a shaded area that reduced the amount of solar radiation incidence on the roof. The presence of trees nearby the house reduced the inlet ventilation effectiveness by lowering wind speed near the openings. In the building studied in Brazil, the procedure of hosing the animals during hot hours appeared to increase the heat removal instantaneously but did not affect the building behavior in a longer range.

The values of heat produced by the hogs were very high in both cases. According to Bruce (1981), in a hot environment the pig may be producing heat at a rate which is

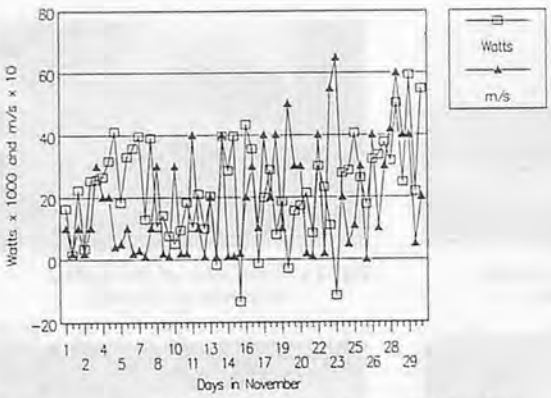


Fig. 4 Total heat balance and wind velocity, Itatiba, Sao Paulo, Brazil.

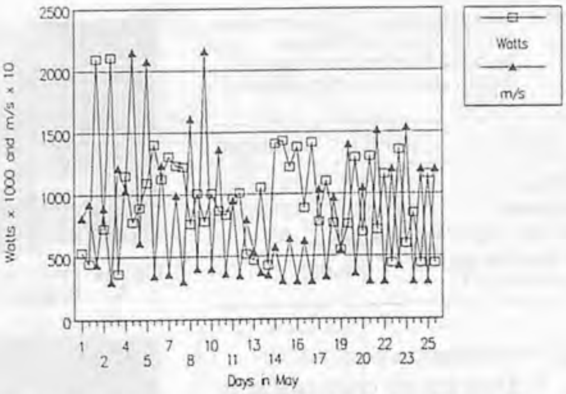


Fig. 5 Total heat balance and wind velocity, Gainesville, Florida, U.S.A.

greater than that at which it can be lost. In these hot conditions, the pig must minimize resistance to heat flows or at least minimize feed intake. This may mean little to the pig as a thermal biological machine, but in an agricultural business context is highly undesirable.

From the data, it can be pointed out that: 1) the model described and quantified the internal environment as produced by the interaction of climate, building characteristics and housed hogs; 2) the building at Gainesville showed almost no effective natural ventilation because of the small area of side openings; 3) the corrugated steel roof material used in Gainesville study provides a high solar heat load because of its high heat conductance (this heat load could be reduced with roof insulation, and in the building studied in Itatiba, natural ventilation was more effective because of the larger side openings) 4) running the model with simulated changes as mentioned above, the total heat balance decreased 85% and approached the ideal.

Further studies could show more clearly the influence of some parameters that were neglected here, such as the heat stored in the building and the heat production of waste fermentation. Also, the number of air renovation concept could be studied further in order to reflect the air movement within the building more accurately.

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A Quality Control Model for Oil Palm Fresh Fruit Bunches

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Abstract

Nigeria must improve the quality of its palm oil in order to regain a share of the world market that it once enjoyed. A computer-based quality control model was developed which can be used to affect harvesting and management practices in order to improve both the quality and the quantity of palm oil as determined by the free fatty acid content. The model allows to set a pricing policy at the mill end to encourage 'good' harvesting practices so as to increase the quantity and the quality of oil palm.

Introduction

Historically, oil palm has played an important part in the Nigerian economy. In 1900, when the total agricultural commodities amounted to 95.6% of total exports, the contribution made by palm oil and palm kernel alone was 81.6% or $2 242 000. This continued to be the pattern of export trade until the mid-1920's when increasing contributions were made by cocoa and groundnuts.

During the period 1959-65, commercial exports of palm oil and palm kernels averaged 163 000 and 414 000 t per annum, respectively. Exports of palm produce from Nigeria, therefore, constituted nearly 30% (palm oil) and 50% (palm kernel) of the world trade in these commodities. The production of palm oil in Nigeria reached its lowest ebb during the Nigerian civil war (1966-70). It was estimated in 1978 that Nigeria became a net importer of palm oil with 30 000 t worth $16 million. The forecast for 1980 was 200 000 t of oil and fat imports by Nigeria.

The prediction by The Standard Chartered Review (1978) about the decline in the production of palm oil was not taken seriously by Nigerian growers because the past performance of Nigeria in the world trade for palm oil had been excellent (Table 1). In 1961, Nigeria's percentage share in world production was the highest (39.9%). Nigeria continued to be the world's largest exporter of palm products till the inception of the civil war in 1966 when she lost the leadership to Malaysia.

Exportable palm oil and palm kernel must be of "first quality." A "first quality" palm kernel is that which is dry and hard while a "first quality" palm oil is that which contains no more than 5% free fatty acid (ffa), less than 2% by weight of dirt and water. The concept of the "first quality" is to produce palm which is safe for human consumption and which can compete favorably in the world market.

Nigerian palm oil producers must realize that a low ffa content

Table 1 Nigeria's Percentage Share in World Production of Palm Kernel for 1961-65, 1969-71 and 1978-80

Producing Region/Country	Percentage share of world total 1961-65	1969-71	1978-80
Nigeria	39.9	24.4	18.5
Zaire	10.4	8.4	4.3
Sierra Leone	5.3	5.1	1.7
Benin	3.5	3.5	2.7
Cameroon	3.5	3.5	2.7
Ivory Coast	1.7	1.6	1.7
Indonesia	3.2	4.2	6.7
Malaysia	2.8	8.4	28.0
Africa	76.0	62.0	41.1
Asia	6.0	15.1	37.6
South America	15.2	21.1	19.2
North Central America	2.8	1.8	1.1
Oceania	0.0*	–	1.0
World average annual production (Metric tons)	1,050,400	1,178,651	1,658,345

*Note: Insignificant share of world's total production.
Source: computed from F.A.O. Production Yearbook.

Table 2 Definition of Codes Associated with Degrees of Ripeness Based on Percentage of Detached Fruit

Code	Percent detached fruit	Degree of ripeness
0	None	Very unripe
1	One loose fruit to 10%	Unripe
2	10% to 20% of outer fruit	Under-ripe
3	20% to 40% of outer fruit	Just ripe
4	40% to 60% of outer fruit	Ripe
5	60% to 80% of outer fruit	Over-ripe
6	80% to 100% of outer fruit	Very over-ripe

is of utmost importance to refiners of edible oil palm. A good ambition would be to create a special Nigerian identity for its palm oil so that it will hold great attraction for edible oil refiners not only in Nigeria but even more in the overseas market.

It has been suggested by FAO (1974) that loss of world market of the Nigerian palm oil is due to the lack of quality as measured by the free fatty acid content. Therefore, there exists a need to devise mechanisms to improve the palm oil quality and quantity.

Objectives

The objective of this research was to develop a computer model which predicts the quality of oil palm fresh fruit bunches in an effort to help develop better management system to improve the quality.

The specific objectives were to accomplish the following:

1. To investigate the effects of harvesting parameters upon the quality and quantity of harvested oil palm fresh fruit bunches.
2. To make recommendations for optimum harvesting procedure to assure quality and quantity based on data available at the mill reception.
3. To evaluate pricing policy in the form of quality and quantity premiums to encourage 'good' harvesting practices.
4. To assess the economic impact on farmers due to various harvesting conditions.

Harvesting Studies

In order to develop the quality control model it was necessary to gather data regarding the effects of the various parameters upon the oil quality during a typical harvesting process. Many factors affect oil palm quality. However, this study was limited to harvesting factors.

Experimental Procedure

Typically in Nigeria, oil palm harvesting is performed with manual labor. The complete harvesting process consists of locating and severing the ripe bunches (bunches then fall to the ground); collection of the bunches and the loose fruit; and transportation of the fruit to the mill for processing. The harvesters decide on the bunch by counting the loose fruit at the base of the tree. They then sever the bunch with a harvesting chisel or a knife attached to a pole. For taller trees, they climb up the tree using a rope to sever the bunch with a chisel.

Data was collected to establish the correlation between the palm oil quality, quantity and the various parameters associated with the harvesting process. The following variables were recorded during a normal harvesting process:

a) The fruit bunch weight.
b) The tree age and height.
c) Number of loose fruits: Ripe fruits that fall at the base of the tree before harvesting a bunch.
d) Number of detached fruits: Fruits that are detached as the bunch falls after it is severed. It also includes those loose fruits that are on the bunch but practically detached.
e) Bunch code: Bunch codes indicate the degree of ripeness based on the percent detached fruits. The ripeness code and their definition are given in **Table 2**.
f) Time delay: The time between harvesting and processing.
g) Bunch color: From green to red.
h) Percent ripe color: The weighted average of different color of units on the same bunch.
i) Variety: Tenera, Dura, Pisifera.
j) Location: Elele and Cowan states and NIFOR.
k) Percent free fatty acid (ffa) content.

The variables listed above were divided into dependent and independent variables. Bunch weight and percent ffa were considered dependent and the rest were independent variables. One hundred and thirty-two tests were carried out at Nigerian Institute for Oil Palm Reserach (NIFOR), using fruit harvested from mature palms in three estates.

A three-month field investigation was undertaken in Nigeria to determine the influence of harvest operations on oil quality. Data regarding quality control measures were collected with reference to their relevance to the research objectives. There were three sources of data. Direct field measurements during the harvesting operation; interviews with oil palm growers; and the available documentation. Random samples of fruits from bunches at different degrees of ripeness were obtained from the field and subjected to ffa analysis. Three regions (Elele, Cowan, NIFOR) within the oil palm growing regions were selected. Three varieties were included in the studies. These were Dura, Pisifera, and a very common variety, Tenera. No special harvesting was organized for this study. Instead, the harvesters were accompanied and the number of detached fruits before and after harvesting each bunch were recorded. For the purpose of the study the detached fruits were those that dropped out of the bunch or those that could be easily detached by hand.

Data Analysis

The data were analyzed using step-wise linear regression technique. The Statistical Package for Social Sciences (SPSS) was used on a mainframe computer to complete the regression analysis.

To evaluate the effectiveness of judging maturity by the number of loose fruits, correlation was determined between the number of loose fruits, percent ripe color, and the ffa content of the oil. There was a high correlation between the number of loose fruit and the ffa content. The R^2 value was 0.966 at Elele; 0.975 at Cowen and NIFOR. The high correlation between the percent ripe color and the ffa content (R^2 = 0.814) indicated that determining maturity by color coding is a viable method. Time delay correlated highly with the mean ffa content (R^2 = 0.998) indicating the importance of processing immediately after harvest. The location did not significantly affect the ffa content. A parameter was sought which could be used to assess oil quality (ffa content) prior to processing and chemical analysis to determine ffa. The percentage of detached fruit at the mill correlated highly with the ffa content (R^2 = 0.962). This would allow a quick assessment of quality at the mill end and the implementation of a pricing policy based on the quality of oil. The mean bunch weight was highly correlated to the tree age as indicated by R^2 = 0.987. However, tree height did not correlate with the ffa content.

The Quality Control Model

Model Development

The following expressions obtained through regression analysis constituted the basis for the quality control model:

$$FFA = 0.614 + 0.018\,(R) \qquad (1)$$

where,
FFA = Percent free fatty acid
R = Percent detached fruits

$$FFA = 0.724 + 0.663\,(TD) \qquad (2)$$

where,
TD = time delay in days from harvesting to processing of bunches.

The following equation was developed based on the data given by Dufrane and Burger (1957):

$$OPM = 45.59 + 0.13\,(R) \qquad (3)$$

where,
OPM = Percent oil per mesocarp weight.

Commercial harvesting will continue to result in a mixture of bunches at various levels of ripeness of under-ripe (UR), ripe (RF) and over-ripe (VR) bunches. For this reason, the harvested fresh fruit bunches were classified under these three main degrees of ripeness. The corresponding fraction of detached fruit in a typical harvest composition were denoted by P1, P2 and P3, respectively. The average percentage detached fruit is given by:

$$DF = (WUR \times P1) + (WRF \times P2) + (WVR \times P3) \qquad (4)$$

where,
DF = Average percentage detached fruits.
W = Weight of bunches in a particular ripeness category.

The award of standard premium is represented in the following expression:

$$P'm = 1 + Pm\,(2 - FFA) \qquad (5)$$

where,
Pm = Standard premium.
P'm = Free fatty acid correction factor

For the choice of appropriate premium based on the percentage detached fruit and market price, the following function was maximized:

$$Pmt = K\,[1 + Pm\,(2 - FFA)] \times [0.456 + 0.0013R] \qquad (6)$$

where,
Pmt = Payment to farmer, dollars.
K = Bunch market price, dollars /kg.

Substituting Equation [1] in Equation (6), differentiating with respect to R, equating to zero and simplifying, we obtained:

$$Pm = 5.06 + 0.367R \qquad (7)$$

Bunch weight was expressed as a function of the tree age,

$$BW = -0.0257 + 129\,(AG) \qquad (8)$$

where,
BW = bunch weight, kg.
AB = Tree age, years.

The minimum harvesting standard was defined as:

$$MSTD = LF/(BW)$$

or

$$MSTD = LF/(-0.0257 + 1.29AG) \qquad (9)$$

where,
MSTD = Minimum harvesting standard (Number of loose fruit/kg bunch weight).
LF = Loose fruit at the base of the palm before harvesting.

Fruit condition was measured by the severity of bruising at the mill reception. The bunches were classified according to the following level of bruising:

a) unbruised
b) moderately bruised
c) severely bruised

The model consisted of a main program and 10 sub-routines in the BASIC language (Meshak-Hart, 1984). The program prompts the user to enter the day's premium, the name of the farmer, the plantation, state or origin, the variety of the bunch, the number or weight of detached fruit, time delay in days, the fruit condition (level of bruising) and the age of the palm. The percentage detached fruit determines the bunch code and the percentage free fatty acid. The final level of ffa is influenced by the factors like time delay and the condition of the fruit. Using the bunch code, the program searches a table of information to find the pricing data appropriate to that bunch code. The price of the bunch is modified by the ffa correction factor. Bunches with code numbers 3 and 4 are awarded standard premium. The standard premium is either positive or negative, depending on the desired percentage of ffa. The day's premium is used to calculate quantity premium. If this quantity of bunch code numbers 3 and 4 are equal to or greater than the thresholds for those bunch coded numbers, a quantity premium is awarded. It is important to note that the standard premium (if applicable) is applied first to calculate the bunch price, then the quantity premium, if applicable, is applied to this price.

Table 3 Simulated Fresh Fruit Bunches at Mill Reception for Tenera Variety

Sample No. 1	Bunch number 1	2	3	4	5
1. Detached fruit (Wt. or number)	1 (W)	2 (W)	4 (W)	6 (W)	8 (W)
2. Bunch weight, kg	18	18	18	18	18
3. Time delay, days	0	0	0	0	0
4. Bunch condition	(U)	(M)	(S)	(S)	(S)
5. Age of palm, yrs.	16	16	16	16	16
a. Degree of ripeness	Unripe	Under ripe	Just ripe	Ripe	Over ripe
b. Percent FFA	0.78	1.35	1.89	2.23	2.57
c. Probable color	Yellow green or 40% ripe color	Yellow orange or 50% ripe color	Orange or 70% ripe color	Red orange or 80% ripe color	Red or 90% ripe color
d. Std. premium, $	0.0	0.0	0.00118	0.00148	−0.00296
e. Subtotal, $	0.2664	1.0656	2.0128	0.19092	1.0064
f. Extra amt. due, $			0.0222	0.0444	0.0636

Total amount due farmer	$6.26
Quantity premium	$0.0
Harvest composition	40:40:20
Oil per mesocarp	48.84%
Loss due to unripe harvest	$479.52/ha/annum
Loss due to over ripe harvest	None

Simulation Results and Discussion

The system simulation output of the farmers' supply of fresh fruit bunches (ffb) as delivered at the mill was:

1. The stage of ripeness of the bunches measured in terms of percentage detached fruit.
2. The quality of the bunches, determined by the fatty acid content.
3. The premium award based on the quality of the bunch determined primarily by the level of ffa, as influenced by the degree of ripeness, handling and other field factors.
4. The award of quantity premium based on the ability to supply or deliver a predetermined quantity of fresh fruit bunches (ffb) with the specified degree of ripeness and the percent free fatty acid content within the desired limit.
5. The percentage ripe color of the bunch.
6. Analysis of harvest composition in terms of ripe, unripe and overripe.

The quantity premium may vary daily depending on the establishments goals and objectives. **Table 3** shows a typical output of the simulation model. Simulation results of the effects of ripeness on percent oil per mesocarp and percent ffa content show that the oil content of underripe bunches is low and this increases as the bunches move to the stage of optimum ripeness through increased percentage of detached fruit. The ffa content also increases with the increased detached fruit. The harvesting interval determines the spread of degree of ripeness in the crop, while the minimum standard determines the minimum level of ripeness. Since the change in ffa with respect to detached fruit is linear, the harvesting interval and harvesting minimum standard can be varied to any combination which will give the number of detached fruit per bunch appropriate for the required ffa. However, in the case of oil yield, the relationship between the harvesting system is not very straightforward because of the discrepancies as to when the oil synthesis in the bunch terminates. From the simulation, any bunches having less than 25% detached fruit will contain less oil than those with greater than 25% detached fruit. The closer a bunch is to zero detached fruit, the lower will be its oil content.

As a compromise for simplicity of the harvesting instructions, a minimum criterion of 12 loose fruits may be suggested which may be combined with the assessment of ripeness by the consideration of color. The color of the outer fruit should be at least 70% ripe for Tenera. Thus, besides counting or weighing loose fruits, the harvester must also consider the color of the bunch. However, judging the color of the bunch from the ground before cutting is rather difficult. A harvesting interval of 7 days, which is common throughout the palm belt, is considered practical.

Although, the two factors, quantity and quality, are inextricably related, the harvesting criterion is directly most important to oil quantity and indirectly to quality. This is because undamaged ripe fruits contain low ffa and the damage causes quality deterioration. For example, the Tenera variety contains as low as 1.29%

ffa when unbruised and processed the same day and the fresh fruit bunch is valued at $2.46. When moderately bruised and delayed for three days, the free fatty acid rises to 2.40% and the bunch value drops to $2.07. If it were possible to avoid damage entirely, then maximum oil quantity could be obtained without quality degradation through ffa increase, but at present the greater amount of oil derived from fruit is accompanied by higher ffa values. The higher the loose fruit number, the higher the ffa content.

Fig. 1 further conveys the idea that quality control begins in the field because as far as ffa content is concerned, the influences of harvesting, handling standards, and timing of fruit flow to the mill are of paramount importance if oil of low ffa is to be produced. The effect of time delay on the fruit becomes critical when the bunch or fruitlets have suffered some degree of bruising or damage.

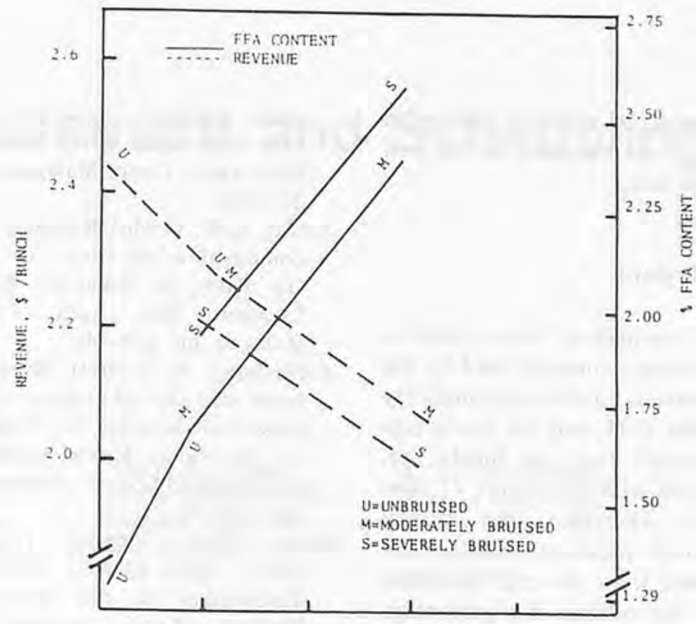

Fig. 1 Simulated effect of time delay and fruit condition on quality and value (Tenera).

Table 4 Simulated Effect of Time after Harvest on the Quality and Value of Palm Oil for Different Harvest Composition

	Sensitivity Analysis Runs		
	1	2	3
Harvest composition	25:50:25	20:60:20	15:70:15
Detached fruit, %	28.75	29.00	29.25
FFA content, %	1.13	1.36	1.14
Oil in mesocarp, %	49.32	49.36	49.39
Damage level	Unbruised	Moderately bruised	Severely bruised
Delay time in days			
0.5 FFA content, %	1.09	1.49	1.69
Value, $	2.28	2.16	2.09
1.0 FFA content, %	1.26	1.66	2.09
Value, $	2.23	2.10	2.04
2.0 FFA content, %	1.59	1.99	2.19
Value, $	2.13	2.00	1.92

Sensitivity Analysis

Sensitivity analysis was made to identify the degree of dependence of this model response to various input variables. The examples of these test results are presented in Table 4.

The model is sensitive to the effect of time delay on quality and value of the fresh fruit bunches. The sensitivity of the effect of the bunch condition on its quality and value is very high and has an overriding effect on the time delay. It is important to transport the fresh fruit bunches to the mill as soon as possible, it is more important to avoid bruising and damage as far as possible at all stages from the time of harvesting to the time of fruit sterilization.

The objective of oil palm cultivation is to produce the highest yield of good quality palm oil per unit area in the most economical way. The last consideration requires harvesting with an interval of several days. Consequently the crop will consist of bunches at different stages of ripeness. Therefore, the aim of harvesting is to get a crop with a composition as near as possible to ideal. Regular analysis of crop composition is a means of quality control. Under estate or plantation environment, the control can be affected at the collection points in the field in order to check the discipline of the harvesters, and to ensure that the minimum ripeness criteria are being obeyed.

The assessment of the incoming crop quality on daily basis and the analysis of a farmer's supply by this model is very useful both to the mill manager and the grower. One may also account for changes in oil and ffa content. Similarly, compiled monthly report to a farmer or supplier could also be of assistance in making adjustments where necessary.

Since there are many variable conditions, such as variety of planting, age at planting, climate, training and experience of the harvesters, etc., it is difficult to get experimental evidence upon which to base a definite ripeness criterion. Therefore, a decision on the minimum ripeness criterion and harvesting cycle for a certain planting should be made by trial and error. For this, harvest analysis data may be used. Once the right criterion and cycle are found, these may be adjusted later when required as indicated by harvest analysis data.

Conclusions

1. The number of loose fruits, a criterion commonly used by the harvesters to determine maturity in the field, and the percentage detached fruit are highly correlated with the degree of ripeness. Therefore, the quality control measures can be enforced from the mill reception end by relating the percentage detached fruit at the mill to the number of loose fruit at the base of the tree.
2. Altough the change in color is highly correlated to change in ffa content, color alone cannot be used as a ripeness criterion, especially by inexperienced harvesters because of the variation in color within bunches in the same class of ripeness.
3. The control of percentage detached fruit alone does not affect the choice of appropriate premium and, therefore, has little or no effect on the revenue accruing to the farmer.
4. The quality control model can supply information necessary to make management decisions related to adjustment of the harvesting system. The model can predict a yield in terms of quantity (oil in mesocarp) and quality (percent ffa content).
5. Based on the simulation results, the most important requirement for obtaining oil of low ffa content from ripe fruit is to avoid bruising and damage as far as possible at all stages from harvesting to processing.

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Watering Requirement and Scheduling of Date Palm

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Abstract

The consumptive use of date palm (*CV Khalas*) was determined. A field plot technique was applied using a neutron moisture probe and tentiometers to monitor the soil water potential changes and the water depletion from the root zone as a guide for irrigation timing.

The climatic data prevailing during the growing season was used to predict potential evapotranspiration using three empirical equations to adjust the crop coefficient in the area. Correlation between measured actual evapotranspiration and actual evaporation rate measured from Class A evaporation pan was made to determine the monthly pan coefficient in the area. Recommendations about the amount of water needed for irrigation during the season, an irrigation frequency were provided for proper water management of date palms in Al-Hassa.

Introduction

Information concerning water requirement of crops is necessary for designing irrigation system and managing water properly. The climatic, plant and soil factors affect the consumptive use of plants.

There is a lack of data on the water requirement and irrigation scheduling of date palm in Saudi Arabia. The pertinent literature on the subject is very limited. However, the date palm tree is known to withstand water stress and high salinity level, but nevertheless it is reported to be sensitive to irrigation and drainage management, (Ayers and Westoot 1976, Abou-Khalid et al 1982).

Preliminary field surverys conducted in Al-Hassa have indicated that over-irrigation of the palm is very common. Inspite of the high water table, generally farmers believe that more water leads to better crop establishment and more yield. The farmers are reluctant to lose the scheduled share of water which is supplied by the Al-Hassa Irrigation and Drainage Authority (HIDA).

Over-irrigation undoubtedly results in waste of water and soil deterioration whereas poor irrigation and water stress depress vegetative growth and reduce production (Abou-Khalid et al 1982).

Furr and Armstrong (1958a) found that the consumptive use of Khadrawi palm at Indio, California, to be about 5 ft/year or 15200 m^3/ha and that application of 6, 10 or 14 ft per year did not cause significant differences in growth and yield. Pilsbury (1937, 1941) reported that water use of Deglet Noor at Coachella Valley, California did not exceed 6 ft/year or 18300 m^3/ha.

Objectives

The aim of this study was:

(1) To work out requirements of date palm under Al-Hassa conditions with the following objectives:
(2) To measure the actual evapotranspiration (ET_a) or (ET_{crop}) of common varieties of date palm.
(3) To correlate the (ET_a) with the potential evapotranspiration (ET_p) or ET_o).
(4) To correlate evapotranspiration and evaporation rates to determine the monthly pan coefficient in the area.
(5) To work out the optimum watering requirement and scheduling of date palm irrigation under local conditions.

Materials and Methods

In the farm selected for this study, irrigation and drainage systems are designed and managed by HIDA. Seventeen-year old date palms (variety *Khalas*) were grown at 6 m x 6 m spacing with no inter-

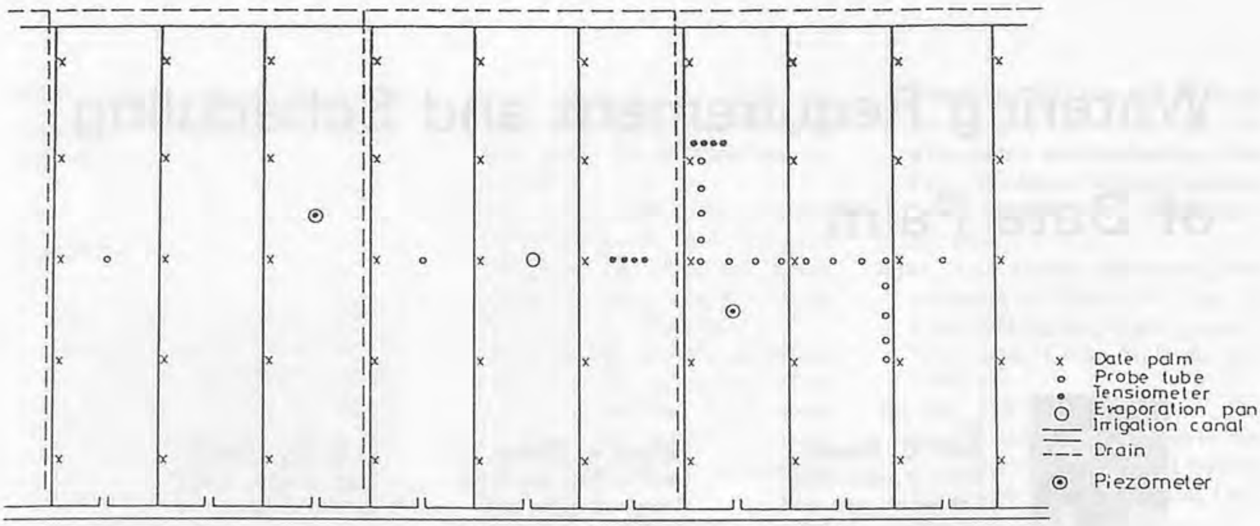

Fig. 1 Layout of date palm experimental field.

cropping. The layout of experiment is shown in **Fig. 1**. Access tubes for the neutron probe were located in the illustrated positions with their lower ends being carefully covered with polyethylene sheets. The 2-meter tubes were located in the predetermined pattern **(Fig. 1)**. This enabled proper monitoring in moisture level of the soil profile along the effective root zone, depth as well as sideways following their lateral expansion. Two sets of four tensiometers each, were installed at varying depth starting from near the date palm trunk and between adjacent rows of palm trees for recording changes in soil moisture potential and water depletion. The gravimetric technique was also employed for confirmation of the results. Water table fluctuations during an irrigation cycle were recorded from the piezometric tubes installed in the direction of water flow in drainage ditch. In addition, a standard Class A evaporative pan was located at the center of the orchard to reflect the microclimate, affecting evaporation from the soil surface and as well as evapotranspiration.

During the irrigation cycle at least two sets of readings were recorded; one just prior to watering and another a day after watering to identify moisture changes at the lower and upper limits of water storage, respectively.

However, because of the short irrigation intervals and, consequently, high water table, the field measurements were limited to the period of January and February, which could be a good representative of repetitive irrigation cycles during winter period.

Results and Discussions

Soil Moisture Relationship

Calculation of the amount of water available to the plants and hence prediction of the water requirement (D_{iw}) are only amenable to the knowledge of the amount of water held by the soil at various tensions. Moreover, the irrigation interval could be defined when the appropriate data is collected regarding consumptive use and the depletion percentage of available water.

The soil moisture percent at various tensions for the surface (0-25 cm) and sub-surface (25-100 cm) layers were obtained using the pressure plate apparatus and the corresponding curves were plotted **(Fig. 2)**. Soil physical characteristics related to the available water are given in **Table 1**. The total available water within 1 m of an effective root zone amounted to an equivalent depth of about 126 mm.

Since soil moisture content near the wilting point is not readily available to the plant, it is a well accepted practise to consider about 60% of the total available water as a portion which is the most easily extractable by the plants.

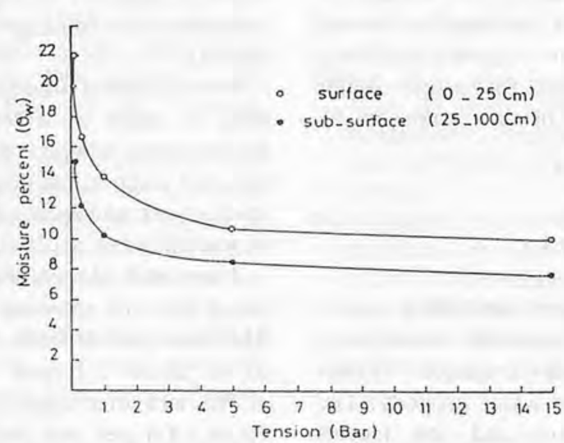

Fig. 2 Soil moisture-tension curves for surface and sub-surface soil.

Table 1 Soil Characteristics as Related to Available Water

Depth cm	Texture	Bulk density g/cm³	Pore space %	F.C. % by volume	F.C. mm	P.W.P. % by volume	P.W.P. mm	A.W. % by volume	A.W. mm
0-25	Sandy loam	1.5	42.3	33.00	82.5	15.0	37.5	18.0	45
25-100	Sandy	1.4	46.2	21.7	162.8	10.9	81.9	10.8	80.9

Water Use and Irrigation Scheduling

The neutron probe allowed for proper measurements of the changes in moisture during each irrigation cycle.

The lower limit of water storage in the root zone was recorded prior to watering, whereas the upper limit (or F.C.) was recorded one day after irrigation. This process was continued for successive cycles during the months of January and February. This procedure allowed for quantifying the amount of allowable depletion from field capacity and hence the net amount of water to be applied was identified.

The soil moisture fluctuations within the effective root zone of the date palm during the irrigation cycles is shown in **Fig. 3**. The equivalent depth of moisture (available water %) is plotted as a function of time, i.e., date. The variation of moisture depletion from one irrigation cycle to another could be attributed to the changes in the environmental conditions. The average daily consumptive use (ET_a) was computed by dividing the difference of the equivalent depth of moisture content between the upper and lower limits for each irrigation cycle into the number of days the cycle would have taken. The relation between the actual evapotranspiration (ET_a) and the time, i.e., date is illustrated in **Fig. 4**. A drop in (ET_a) during the third irrigation cycle during the last week of January indicates a low temperature spell during that period.

It is apparent from **Figs. 3 and 4** that the farmer allows a seven-day irrigation interval for the date palm trees during winter period. This means that he allows only about 15-20% of the available water to be depleted before the next irrigation will top up the field to its upper limit of storage capacity. Obviously the excess water will then be drained to waste.

However, if the irrigation is delayed till about 60% of the available soil moisture is depleted (i.e. about 0.6 to 0.7 bar) then irrigation interval could be extended to 25 days during the winter period (January-February). By doing so large quantities of water which would have otherwise been wasted could be saved. This irrigation cycle of 25 days interval which has been based on actual field measurements is illustrated in **Fig. 5**. In another study, Aseed et al (1982) used 11 years of agrometeorological data for calculating potential evapotranspiration (ET_p) in some field and vegetable crops under Al-Hassa conditions. In the present study the same data was used for fully grown date palm trees. The potential evapotranspiration rates (ET_p) as defined by three of the well known empirical equations, namely, the modified Blaney-Criddle, the Jensen-Haise and the

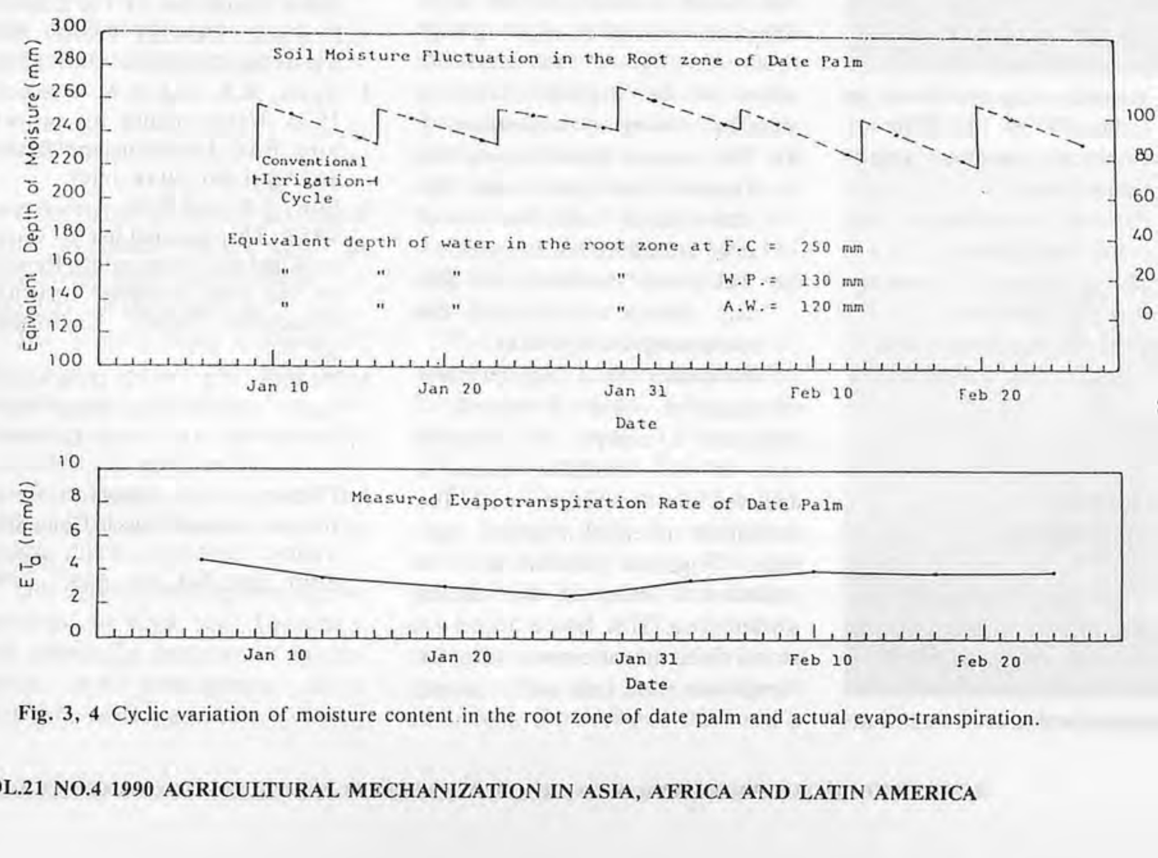

Fig. 3, 4 Cyclic variation of moisture content in the root zone of date palm and actual evapo-transpiration.

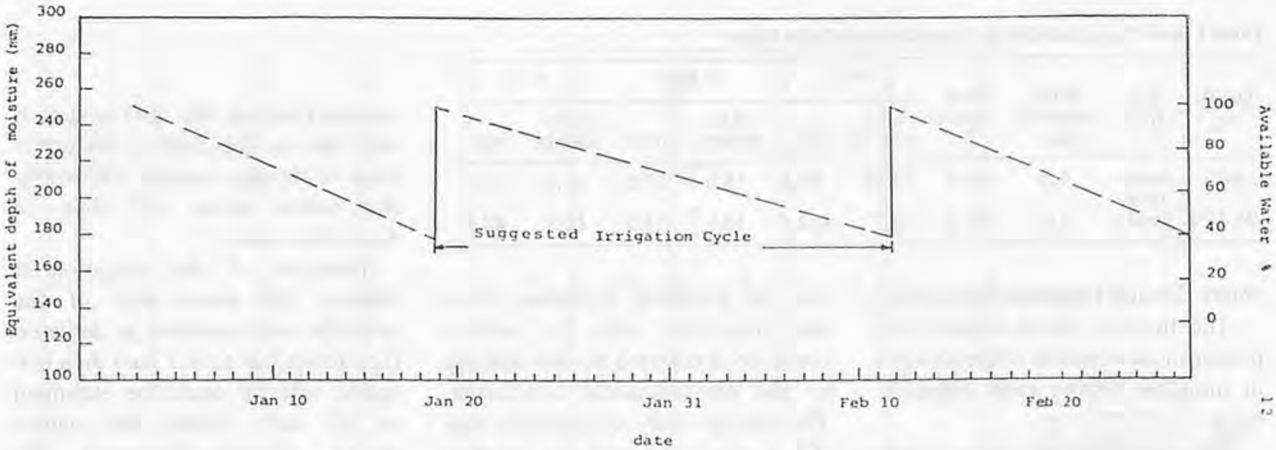

Fig. 5 Suggested irrigation cycle based on actual field measurement.

Penman, were computed during the January-February period. The Class A pan evaporation (E_{pan}) was also computed for the same period. Then (ET_p) and (E_{pan}) were correlated to the actual measured evapotranspiration (ET_a) for date palm, respectively, and the corresponding adjusted crop factors (K_c) and pan coefficient (K_{pan}) were obtained following the simple relations:

$$(ET_a)_{Date} = K_c \times ET_p \qquad (1)$$

and

$$(ET_a)_{Date} = K_{pan} \times E_{pan} \qquad (2)$$

where:

$(ET_a)_{Date}$ = the actual evapotranspiration for date palm.

K_c = Monthly crop coefficient as estimated by the different empirical equations (mentioned above).

ET_p = Potential or reference crop evapotranspiration.

K_{pan} = Monthly class 'A' evaporation pan coefficient.

E_{pan} = Class 'A' pan evaporation.

The results are presented in **Table 2**.

Conclusion and Recommendations

An irrigation experiment was conducted in a pre-selected date palm orchard cropped with 17 years old *Khalas* variety with no intercropping and spaced 6 m x 6 m.

Table 2 Actual Evapotranspiration (ET_a) as Correlated to Potential Evapotranspiration (ET_p) and Measured Evapotration Rate (E_{pan}).

Month	ET_a mm/day	Mod. Blaney-Criddle		Jensen-Haise		Penman		E_{pan} mm/day	K_{pan}
		ET_p	K_c	ET_p	K_c	ET_p	K_c		
Jan.	3.5	3.0	1.17	2.56	1.37	2.61	1.34	4.5	0.78
Feb.	3.7	3.42	1.08	4.36	0.85	4.14	0.89	7.2	0.51

A field plot technique was applied using the neutron scattering technique for following the moisture fluctuations and depletion within the effective root zone.

The conventional irrigation interval practised during the winter period of January and February is 7 days. This is illustrated graphically in **Fig. 3**. This implies that the farmer commences the next irrigation cycle after allowing only about 15-20% of the available water to be depleted. This is mainly attributed to two reasons:

(i) The general belief among the farmers that more water for date palms leads to better crop establishment and yield.

(ii) The farmer's reluctance to skip any chance of obtaining the water supplied by HIDA.

This means that a large quantity of irrigation water is wasted. If irrigation is delayed till about a 60% of the available water is depleted in accordance with the commonly accepted irrigation practices. Irrigation interval will be extended to about 25 days during winter time. This fact is based on actual field measurements (**Fig. 5**). Hence water and time will be saved.

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Design Specification of a Date Palm Service Machine

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Abstract

Date palm is a major crop in Saudi Arabia. The present hand methods of culture are slow, expensive and dangerous for the workers.

The Agricultural Engineering Department of King Saud University has initiated a program on the Design and Development of a Date Palm Service Machine. This paper outlines the main features of the machine which should provide the required performance. The prototype machine is now being constructed and will be tested in 1989.

Introduction

Date palm is one of the major crops in Saudi Arabia with an estimated total crop yield of 400 000 t of dates per year.

The present hand methods of date palm culture are slow, expensive and dangerous for the workers so it is considered that some form of mechanization could be introduced to improve the efficiency and output of the farmers.

The Agricultural Engineering Department of King Saud University has initiated a programme on the design and development of a date palm service machine.

The programme started with a survey of typical date farms in Saudi Arabia to find out what performance characteristics should be incorporated in the machine (1).

From this survey the specifications of the machine were determined. This paper outlines the main features of the machine.

Design and Dimensions

A survey was carried out on 19 farms chosen to be representative of the range of typical farms and soil conditions likely to be most commonly found. From this survey the overall dimensions of the machine were chosen so that the machine would be suitable for most farm situations. Fig. 1 shows the machine in the transport position with the basket in the folded up position.

The principal dimensions are: overall length, 5.5 m; overall width, 2.1 m; overall height, 2.7 m; wheel base, 3.5 m; track 1.75 m; and underneath clearance, 500 mm;

Fig. 2 shows the machine in the field position with the stabilizers in the extended position. With the boom fully extended, the basket can reach trees in the following positions: tree height 10 m, row spacing, 7 m; and tree spacing in row, 5 m. For trees of this height and spacing the machine can reach 6 trees from one position as the top chassis has 360° movement and can reach in all directions. For a single tree the maximum height of reach is 14 m. The machine can reach 98% of all the trees found in the survey.

Fig. 1 Date palm service machine in transport position.

Fig. 2 The machine in field position.

The basket is U-shaped in the plan view and can be angled sideways through 180° so that it can fit round a tree just below the crown of leaves. From this position the operator should be able to reach all the bunches of dates easily.

The dimensions are: width, 2.10 m, height, 1.70 m, tree space – width 0.75 m, length 1.10 m.

In the floor are two smaller baskets to contain the dates, of dimensions: width, 52 cm; length, 93 cm; depth, 50 cm; which can be lowered to the ground by hydraulic winch.

Structure

The material selected for the main structure must be of high strength to enable a light weight machine with a high payload capacity to be designed.

A readily weldable high strength structural mild steel was chosen which has easy manufacturing characteristics. The particular type selected was RQ1701 with a yield strength of 690 MN/m^2. It is easy to cut with standard gas cutting equipment and in the thickness selected no preheating or post heating is required. It has good bending characteristics and can be bent cold by normal equipment but requires about 70% higher power compared with ordinary mild steel. A bend radius of three times the plate thickness was used for the bent parts of the structures.

RQT plate can be easily welded using the main hydrogen controlled arc welding processes. We selected the manual metal arc method as being the most suitable for the prototype construction – no preheating is required for the range of thickness which were used. The weld leg length was chosen to keep the heat inputs within the required range to maintain toughness in the heat affected zone.

The welding consumables chosen to give matching strength for the RQT 701 was Oerlikon Tenacito 80.

The following sizes were used:

Item	Size	Welding current
Root runs	2.5 mm dia	70 amps
General welds	3.2 mm dia	130 amps
Main structural welds	4 mm dia	160 amps

Other types of steel were used for certain parts, the joints between dissimilar metals of a high strength were made using Oerlikon Inox DW consumables. This is a stainless steel rod 29% Cr, 9% Ni with a Rutile flux giving 30% delta ferrite in the weld metal.

Mechanical Properties

Main yield stress (.2% proof stress)	690 MN/m^2
Tensile strength	790-930 mn/m^2
Min. elongation	18%
Brinell hardness range	240/300
Min. Charpy V-notch impact (longitudinal)	273 at – 45°C
Shear yeild stress	approx. 50% of yield stress
Fatigue strength	approx 50% of tensile stress
Bend test	180° round radius of 1.5 thickness
Density	7.85 g/cc
Modulus of elasticity	190-210 GN/m^2

Chemical Properties (Principal constituents)

Carbon	0.2%
Silicon	0.5%
Manganese	1.5%

Most of the structure was made of 6 mm thick material stressed to 400 MN/m^2 with a factor of safety of 2.5, or more, on estimated static loads.

The Hydraulic System

All the functions of the machine are powered by a hydraulic system and driven by a Perkins 4-cylinder diesel engine. The power of the engine was selected from the estimated ground conditions, slope and travel speed required. The 52 kW engine can provide the following performance: under soft ground conditions with the machine in four wheel drive it can climb a slope of 45°, (100%) at a speed of 4 km/h at a working pressure of 325 bar. If traction is not limited 25% more torque is available at the drive wheels at the maximum relief valve pressure but at a lower forward speed. This will allow a steeper slope on poorer ground conditions to be negotiated in the field.

When the transmission is in two wheel drive and the motors in half displacement the machine can travel at 25 km/h on a hard flat surface (normal paved road): maximum possible speed is 30 kg/h (very smooth road with no payload).

When the machine is in the field position the main transmission pump is set to 'no flow' the auxilliary pumps can then be used to operate the stabilizers, boom lift, rotor, telescope and basket rotor.

The pumps are sized so that the stabilizers can be deployed in 35 sec. The boom can elevate and telescope in 25 sec and the whole unit can be rotated through 360° in 60 sec. The ram sizes have been chosen so that with the boom fully extended and arranged to pick 2.5 m high trees, one operator with 200 kg of dates can be carried in the basket at the maximum system pressure of 200 bar. At steeper angles of the boom larger loads can be carried due to the improved mechanical advantage of the rams.

Figs. 3, 4 and 5 show the hydraulic circuits. **Fig.** 3 shows the main circuit above the turntable.

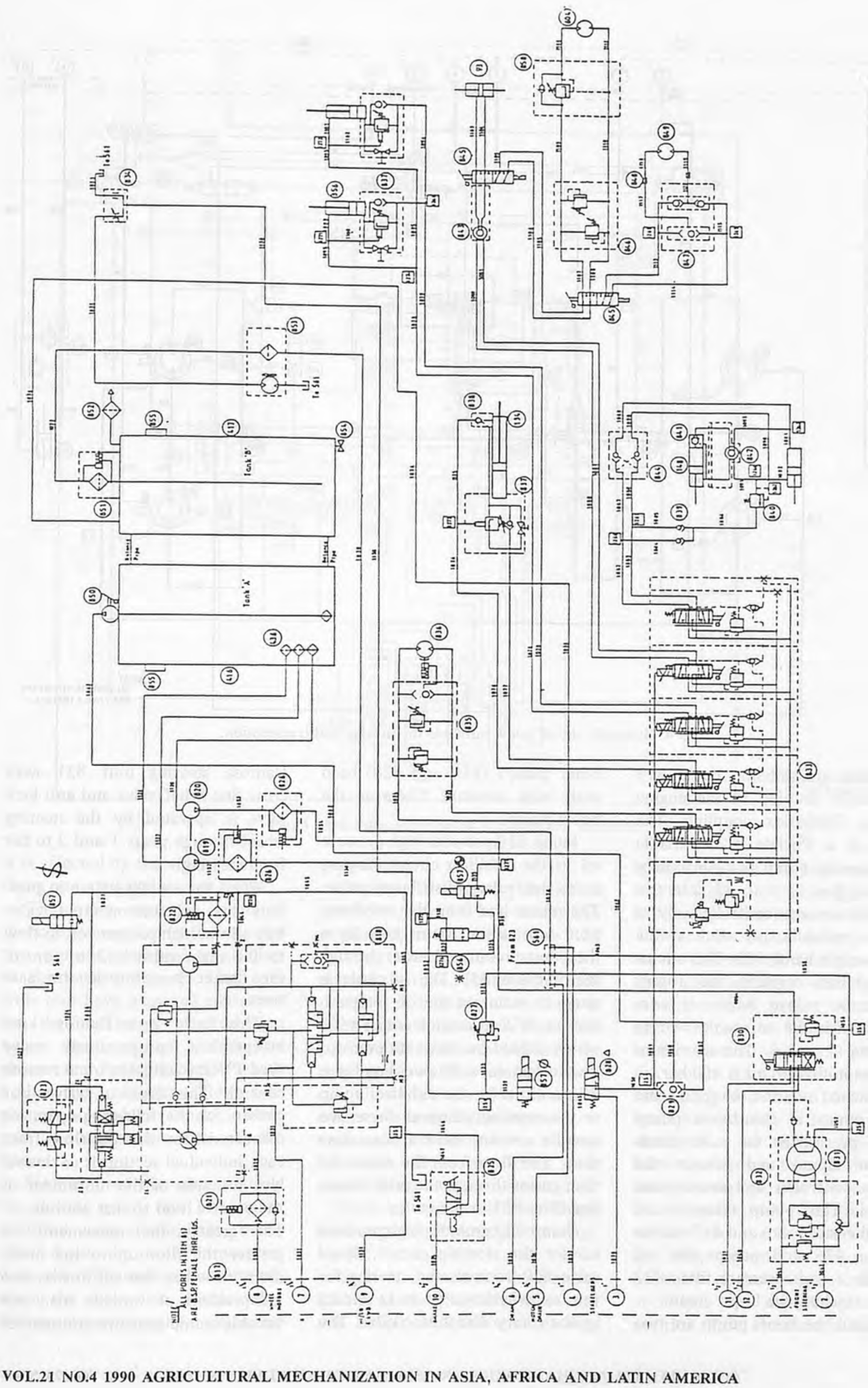

Fig. 3 Main hydraulic circuit above turntable.

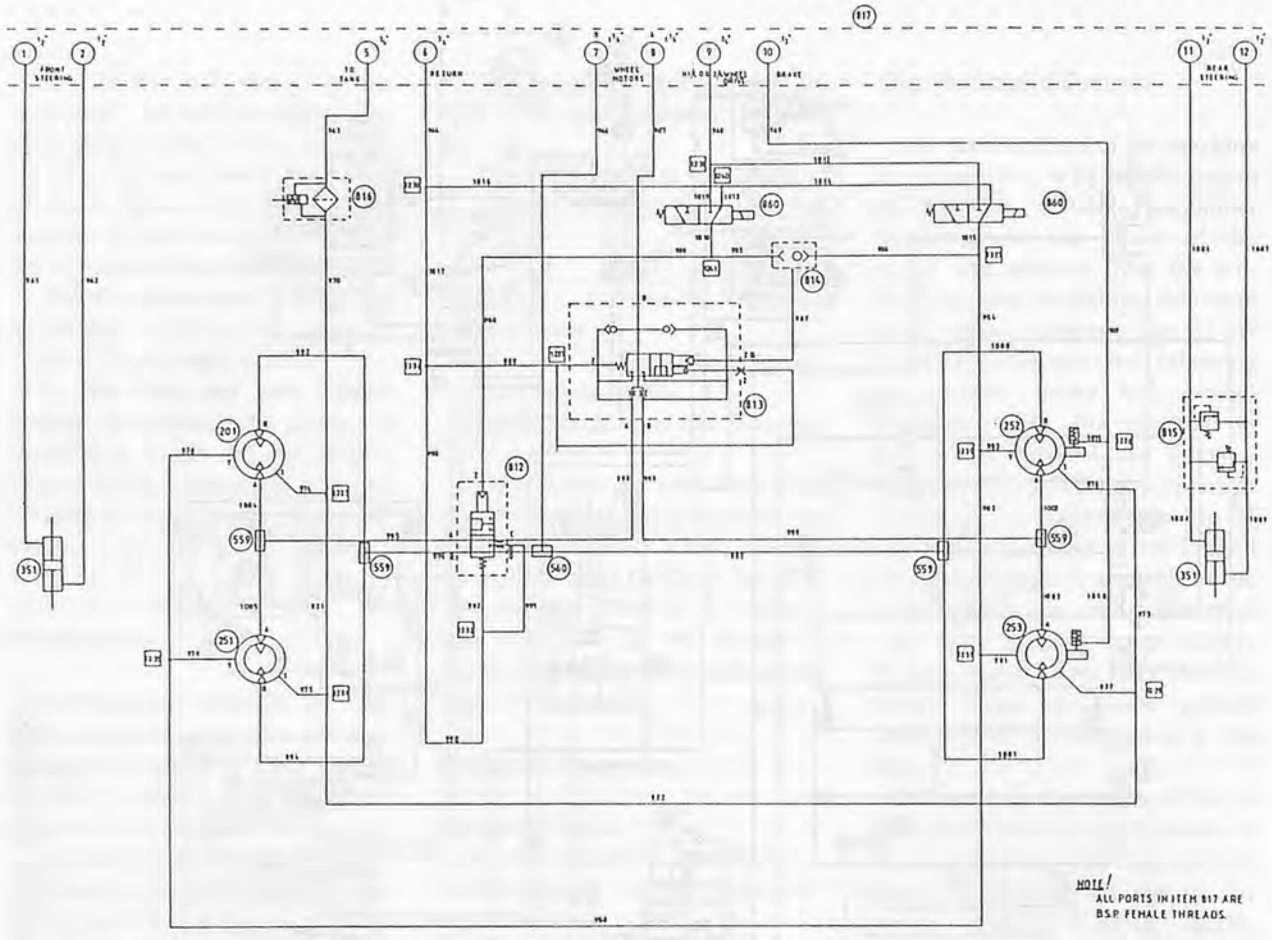

Fig. 4 Hydraulic circuit below turntable for steering and transmission.

The main transmission pump 818 is directly coupled to the engine with a Centraflex coupling. The pump is a Poclain H23 variable displacement pump giving infinitely variable flow of 0 to 85 cc/rev in both directions controlled by a remote hydraulic joy stick at the driver's right hand, 823. This circuit then passes through the rotary distributor valuve which is concentric with the turntable bearing at ports 7 and 8. The maximum pressure in this circuit is 450 bar.

Attached to the back of the main pump is the boost pump which pressurizes the main transmission circuit and powers the remote controller and swash plate control. This pump takes its oil from the tanks 416 and 417 via the strainer 436 and pumps the oil through a high pressure filter 822 before reaching the boost circuit.

Behind the boost pump are two other pumps (819 and 820) both with high pressure filters as the boost pump.

Pump 819 provides high pressure oil to the stabilizer circuit via port 3 in the rotary distributor valve. The return line from the stabilizers port 4 joins the return lines from the other circuits and passes through the oil cooler 853. The oil cooler is sized to maintain the oil temperature at 70°C at an ambient of 45°C which should be adequate even for the hottest days. The cooling fan is driven either by the stabilizer pump or the steering pump as these two circuits are not used at the same time. The flow from the oil cooler then passes through the main return line filter 851 to the tank.

Pump 820 provides high pressure oil for the steering circuit. Spool valve 830 controls the steering for the rear wheels via ports 11 and 12 in the rotary distributor valve. The Danfoss steering unit 831 with cross line relief valve and anti-kick valve is operated by the steering wheel through ports 1 and 2 to the front steering.

When the stabilizers are in position the solenoid-operated valve 828 allows high pressure oil to flow to the main valve 833 to control the basket positions in the date trees.

This valve is a Danfoss load independent proportional valve type PVG60 with electrical remote control. This type of valve was chosen for the following operating characteristics: the oil flow from each individual section is exclusively a function of the movement of the control lever to that section.
The greater the movement the greater the flow up to the maximum value set. The oil flow is also independent of variable load and variable pump pressure and neither

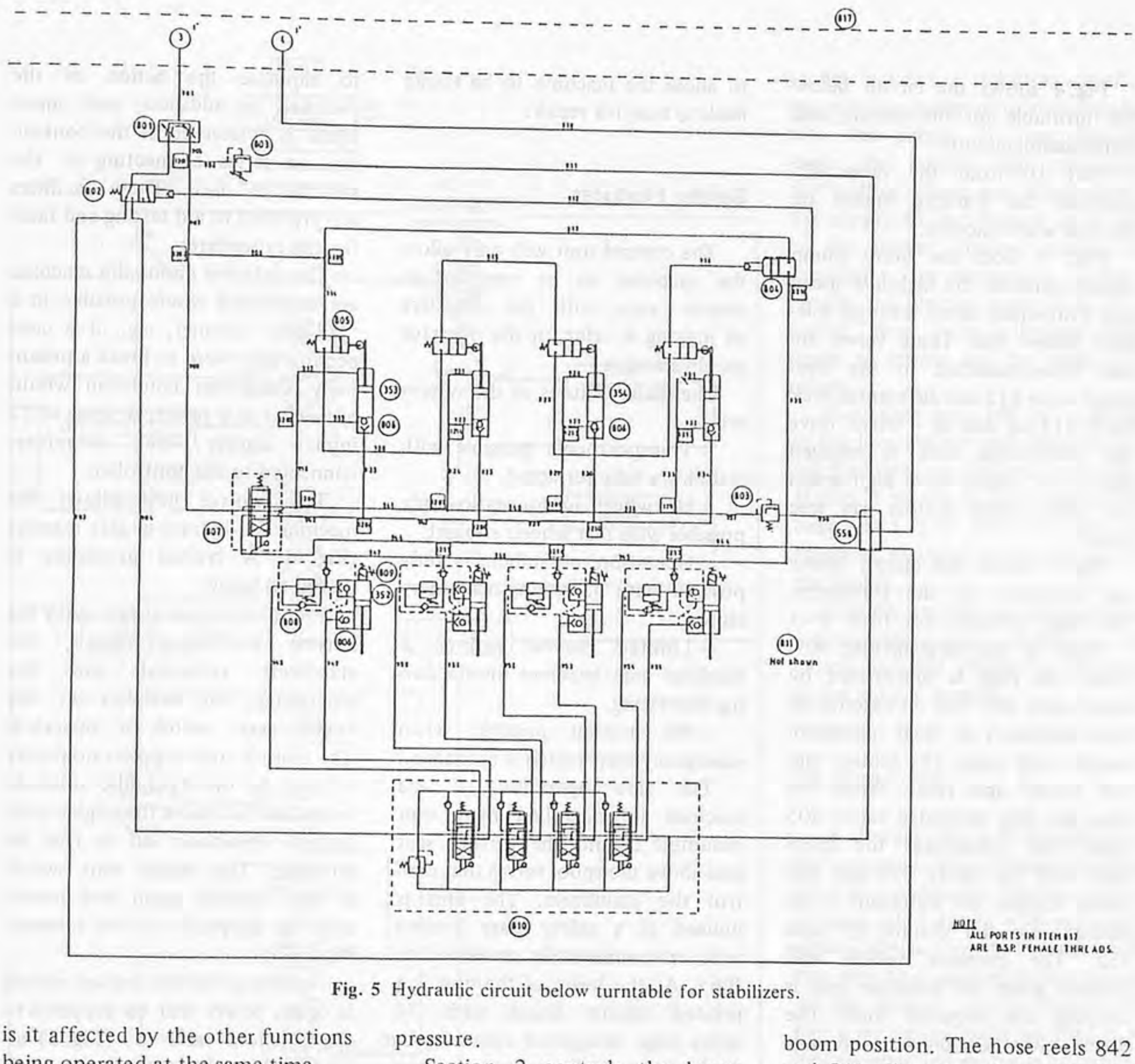

Fig. 5 Hydraulic circuit below turntable for stabilizers.

is it affected by the other functions being operated at the same time.

The valve may be operated through its mechanical lever or by the remote electrical controllers in the basket. The electrical controls also have a special control to set the maximum oil flow and hence speed of that circuit and also a ramp function control which limits the maximum flow rate change to reduce shock loading and sudden movements of the basket.

Section 1 of the valve controls the slewing motor 836. The motor is fitted with a spring-on brake which holds the motor in position until the oil pressure holds it off when the brake line shuttle valve 835 is activated by the control line pressure.

Section 2 controls the boom telescope ram 134. It is fitted with a pilot operated check valve 838 and an over centre valve with manual override. These valves lock the ram in position when there is no pressure in the supply pipes. If a pipe breaks the ram will stop in that position, the manual override allows the ram to be closed in a controlled way if this happens.

Section 3 controls the two boom lift rams. These are fitted with similar valves and manual override.

Section 4 controls the basket horizontal angle through the acuator 93.

Section 5 controls the parallel acuator rams 148 which ensure that the basket is horizontal at any boom position. The hose reels 842 and 843 allow the oil supply pipes to telescope with the main boom.

When the basket is in position on the date tree Section 4 circuit is then diverted via valve 845 to drive the small basket winch 604 which is used to lower the dates to the ground. Valve 858 prevents the winch from over-running and descending too fast if the basket has a heavy bunch in it. Valve 845 diverts the oil to the hydraulic hand tool circuit through the flow direction regulator 847 to the hand tool motor 849. The regulator ensures that the hand tool motor can only operate in the correct direction as the pressure could be in either pipe depending on the position of the electrical controller.

Fig. 4 shows the circuit below the turntable for the steering and transmission circuits.

Port 10 from the valve 825 controls the parking brakes on the rear wheel motors.

Port 9 from the boost pump circuit controls the high/low speed and four-wheel drive through solenoid valves 860. These valves are also interconnected to the free-wheel valve 812 and differential lock valve 813 so that in 4 wheel drive the differential lock is engaged while in 2 wheel drive high speed the front wheel motors can free wheel.

Fig. 5 shows the circuit below the turntable for the stabilizers. The high pressure oil from Port 3 flows to the flow divider 801. When the pipe is pressurized by spool valve 807 the oil extends all four stabilizers to their maximum length with rams 353 (sides) and 354 (front and rear). When the rams are fully extended valves 805 open, this pressurizes the spool valve 810 via valves 804 and 802 which enables the stabilizers to be pushed into the ground by rams 352. The pressure switch will indicate when the stabilizer ram is carrying the required load. The check valves 806 prevent the rams from collapsing.

Valve 810 is used to lift the stabilizers, when lifted valve 807 can then retract them back into the machine.

The various solenoid-operated valves are interlocked by the safety circuit so that the machine must be operated in the correct sequence for safe and reliable operation.

In the event of a main engine failure, i.e., no hydraulic or electrical power, the boom circuits could be operated by the manual pump 850 on tank A to bring the basket to the ground and fold up the machine to the transport position. The spring-on brakes on the rear wheel motors can be held off mechanically with a special tool to allow the machine to be towed back to base for repair.

Safety Features

The control unit will only allow the machine to be operated in certain ways with the objective of making it safer for the operator and bystanders.

The main features of the system are:

– Transport only possible with stabilizers fully retracted.

– Hi wheel motor ratio only possible with rear wheels straight.

– Operation of stabilizers only possible with harvesting machinery closed.

– Limited harvest actions if machine base becomes unsafe during harvesting.

– No motion possible when emergency stop switch is activated.

The safe operation of the machine is controlled by a unit mounted behind the driver's seat and above the spool valves that control the stabilizers. The unit is housed in a safety glass fronted unit, environmentally protected to IP65. At the heart of the unit is a printed circuit board with 74 series logic integrated circuits producing outputs from various input signals. Input signals are received by the unit via switches located about the machine. Outputs produced by the unit are used to operate hydraulic solenoid valves, electric circuits and warnings (audio and visual).

A 12-volt supply from the vehicle battery connected to the unit is used to supply the banks of relays for the output signals and a DC/DC converter to produce a stable 5 volt supply for the integrated circuits and their inputs.

Test points on the input, intermediate and output signal lines are incorporated into the control circuit as well as dual-in-line (DIL) switches on the input signal lines to simulate the action of the switches. In addition, each input signal is connected at the controller, no series connecting of the switches is used. These facilities are provided to aid testing and fault finding procedures.

The switches about the machine are connected where possible in a "fail-safe" manner, e.g., if a connecting wire were to break a potentially dangerous condition would not occur as a result. A total of 22 input signals are, therefore, connected to the controller.

The control unit allows the machine to operate in safe manner (**Fig. 6**). A typical procedure is described below.

From a position of rest, with the harvest machinery closed, the stabilizers retracted and the emergency stop switches set, the engine start switch is operated. The control unit supplies no power to any of the hydraulic solenoid valves and activates the engine start circuit. Hydraulic oil is free to circulate. The engine start switch is then opened again and power may be supplied to the solenoid valves.

Assuming that the harvest switch is open, power will be supplied to the solenoid valve ($) (**Fig. 3**) allowing the vehicle to move. With the rear wheels straight, high or low ratio of the wheel motors may be selected. If this is not the case only low ratio may be selected.

At the desired harvest switch is closed (harvest position) and the control unit now supplies power only to hydraulic valves (ϕ, $*$, $\oplus$) (**Fig. 3**) allowing the stabilizers to be operated. As the stabilizers advance an audible alarm operates and continues to do so until all the stabilizers carry a safe load and the chassis is level. To aid this operation, 8 light emitting diodes (LED) are visible through the control unit glass panel. Located in plan view of the machine, they indicate stabilizers that are below pressure (red

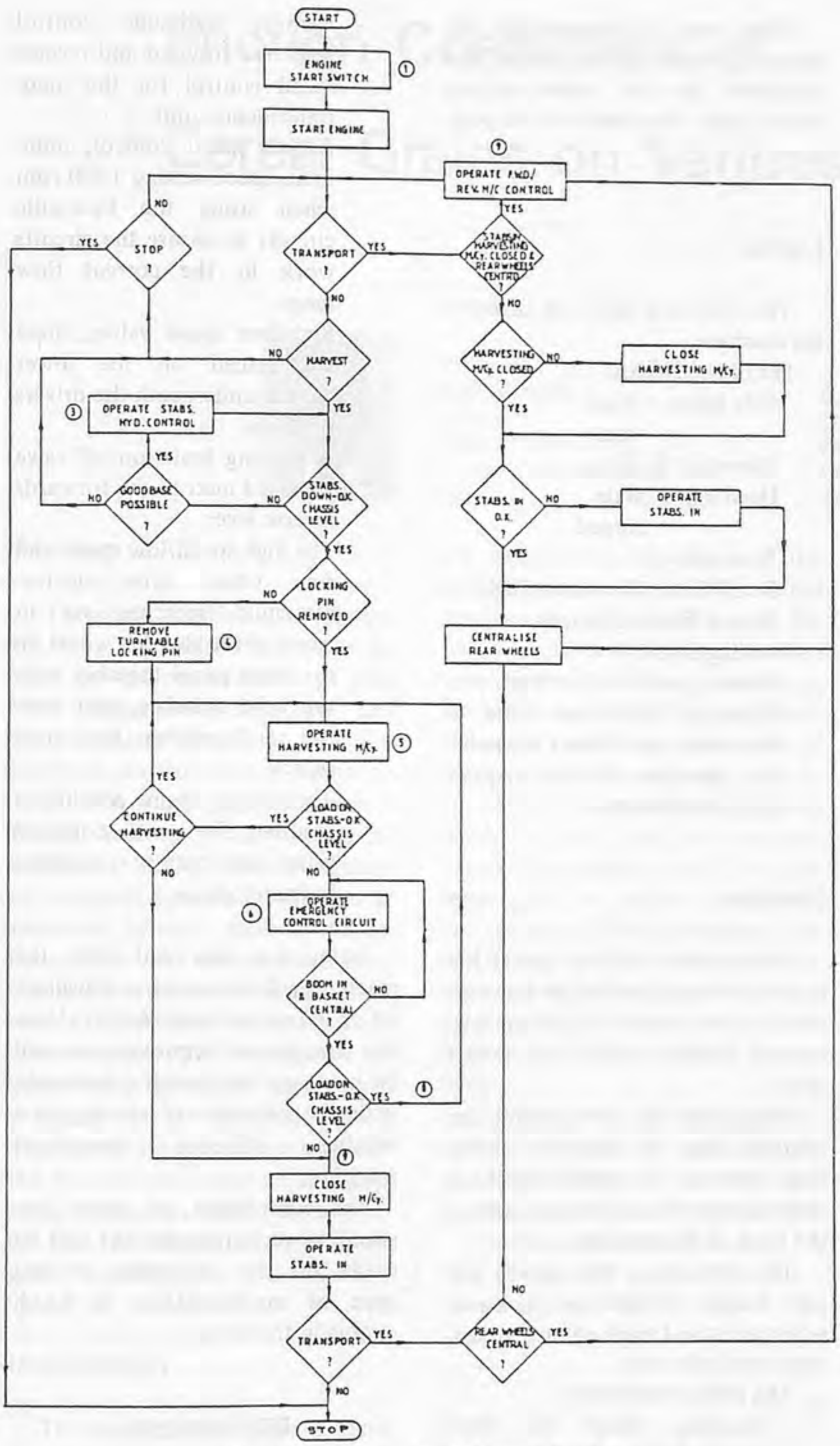

Fig. 6 Flow chart of safety control unit.

LED) and "low" areas of the chassis (amber LED).

With the chassis level and all the stabilizers carrying a satisfactory load, removal of the turntable pin (lever next to driver's seat) allows the control unit to supply power to the harvesting solenoid valve (Δ) and the electric controls in the basket. Harvesting can now commence, controlling the actions from the basket.

The load on the stabilizers and the level of the chassis is monitored to detect when a stabilizer experiences a low pressure or the chassis tilts too much. If this should occur the control unit operates the audible alarm and disconnects the supply to the electric controls in the basket. Instead power is supplied to the emergency control circuit, the electric controls in the basket now only allowing the boom to retract and the basket to rotate.

Harvesting may still be possible in this location but with the harvesting machine in a different position. If this is so the audible alarm will cease and full control will be returned to the electric controls in the basket.

If this is not the case the harvesting machinery must continue to be closed and the stabilizers adjusted or the vehicle moved.

Slewing Ring

A slewing ring is fitted between the top and bottom chassis to allow for 360° continuous rotation. It is a crossed roller design with seals and grease lubrication. On the outside is ring gear to engage with the pinion on the slewing motor. The motor has a spring-on brake so that it is locked when the motor is not under pressure, i.e., when it is not rotating the ring.

The ring can carry an axial load of 6 tonnes and a moment of 15 tonne metres which will give an acceptable factor of safety when the machine is used on rough ground conditions.

Concentric with the slewing ring is a hydraulic rotary distributor valve and electrical slip ring assembly. The rotary valve has a 12-way port system with a hard chrome piston and PTFE seals with O ring energizers. The maximum intermittent peak pressure is 450 bar to match the Poclain hydrostatic transmission characteristics.

The electric slip ring assembly is

attached to the top of the rotary hydraulic distributor and has 16 ways with a 3 amp rating at DC for the control and lighting circuits on the bottom chassis. It is fitted in a sealed housing to IP55 standard.

Weights

With the basket in the fully extended position 200 kg of dates and one operator can be carried. The floor baskets can hold 50 kg of dates to be lowered to the ground.

On either side of the boom on the top chassis are two payload containers with a total capacity of approximately 1 tonne of dates.

Tyres

The tyres are suitable for good traction in sandy soils and good wear life on the road. The tyres chosen are 12.00 R20 sand tyres at an inflation pressure of 1 bar. Tyres of this size, together with the underneath chassis clearance of 500 mm will enable the machine to cross the normal infield irrigation channels and bunds at the changes in levels. Larger channels can be crossed using two channel planks provided with the machine. The maximum width of channel that can be crossed is normally 2 m depending on how strong the sides are.

Hand Tools

The operator in the basket is provided with a number of hydraulically powered hand tools to ease his work load.

The following are provided:

50 cm chain saw
30 cm bar pole saw, 2 m handle
30 cm circular saw, 2 m handle
Weed trimmer, 2 m handle

They can be plugged into the hydraulic outlet in the basket and controlled by the basket angling circuit after the basket is in position.

Lights

The following lights are fitted to the machine:—

Set of road lights:—
Side lights — front
rear
Direction flashers
Head lights, main
dipped
Rear stop
Red/White side warning light
Rotary flashing beacon

Working lights
Three quartz iodine high performance lights are fitted to the boom and basket to enable the operator to work in poor light conditions.

Controls

The operator in the basket has a row of electrohydraulic controls for the slew, boom lift, boom telescope, basket angle and power tools.

The driver on the ground can override these by using the mechanical levers on the main valve bank situated near the main pump unit at the back of the machine.

The driver has a fully sprung seat with height, forward and back rear adjustment and angle of back adjustment and side arms.

The main controls are:

- Steering wheel for front wheels using a Danfoss hydrostatic power steering unit.
- Spool valve for rear steering to give sideways or opposite steering as required. This control can only be used when the transmission is in low speed setting.
- Remote hydraulic control lever for forward and reverse speed control for the main transmission unit.
- Engine speed control, minimum speed setting 1800 rpm when using the hydraulic circuits to ensure the circuits work in the correct flow range.
- Stabilizer spool valves, these are placed on the lower chassis underneath the drivers position.
- A parking brake on/off valve is placed next to the forward/reverse lever.
- The high speed/low speed and four wheel drive electro-hydraulic switches are in front of the steering wheel on the main panel together with the light switches, horn button and engine key start switch.
- There is an engine revolution counter, fuel tank contents gauge and battery condition indicator gauge.

Later this year and next, the machine will be tested and evaluated on farms in Saudi Arabia. Various changes and improvements will be made as the situation demands, with the objective of arriving at a reliable effective prototype machine.

On completion of these programmes recommendations will be made on the suitability of this type of mechanization in Saudi Arabia in the future.

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Friction Coefficient of Cereal Grains on Various Surfaces

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Abstract

The static coefficient of friction of three materials which could be used in the construction of soils were determined for oats and shelled maize (corn) at different moisture contents within a range of 10-20% (w.b.). In general, the coefficient increased with increasing moisture content, except for maize on concrete for which, changes in moisture content seemed not to have effect. The values varied from 0.216 for mild steel on the driest oats to 0.598 for concrete on the wettest maize. The coefficients for maize were generally higher than for oats for the materials tested. The tests were carried out by rotating the annular plates on the grain surface using an open tray and recording the maximum shear stress due to friction.

Introduction

The prediction of load exerted on the walls of silos by grains is undertaken by the use of various equations. The coefficient of friction between the grain and the wall is one of the most important parameters in these equations. The values of the friction coefficients of materials generally used to construct farm silos are often conflicting because the variations in the physical properties of the stored product that have an effect on the friction coefficient are seldom defined (Lawton, 1980). For example, Brubaker and Pos (1965) evaluated the static coefficient of friction of barley at 14.3% moisture content (w.b.) on concrete (steel trowel finish) as 0.57 and on concrete (wood float finish) as 0.51 for the same grain at similar conditions, and Lawton (1980) evaluated the coefficient as 0.247 for concrete (steel trowel finish) and 0.269 for concrete (wood float surface) differences of 57% and 47%, respectively.

The objectives of this paper are:

(a) To evaluate the static coefficient of friction between oats and maize and various silo walling materials; and

(b) To investigate the effect moisture content has on the static coefficient of friction for the grains on the materials.

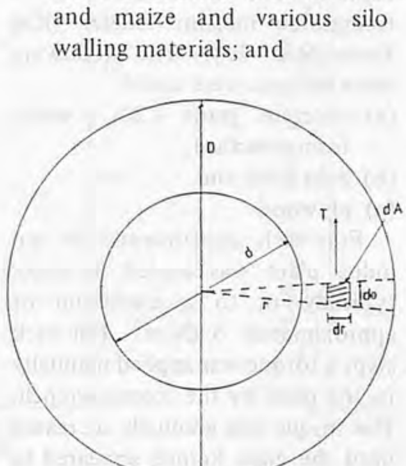

Fig. 1 Annulus friction plate.

Theory

The method used in the experiments was outlined by Lawton (1980). If the annulus plate illustrated in Fig. 1 is placed on top of a mass of grain and an increasing couple applied to it, then a typical stress-strain curve as illustrated in Fig. 2 can be obtained. During the initial period of increasing shear stress, and subsequent movement of the plate, the grains moved initially and came to rest in a preferred orientation, with their long axes tending to parallel with the direction of motion of the plate. An increase in shear stress results in slip-stick movement of

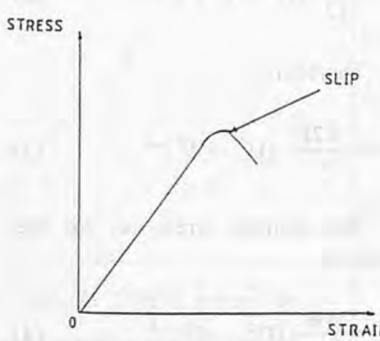

Fig. 2 Classical stress-strain curve.

the grain until the peak of a classical stress-strain curve is reached (Fig. 2). Subsequently, a relaxation of stress occurs which implies a transition from static to dynamic friction.

Lawton (1980) postulates that a condition of homogeneous friction does not exist at any time, but rather the friction reaction to the applied stress consists of three components, i.e., initial rolling friction, static friction, and dynamic friction. The force required to move the plate across the grain is, therefore, a sum of the friction reactions from each kernel in the sample. This sum is a combination of the three components described above, and depends on the conditions of stress at each kernel.

For annulus plate illustrated in Fig. 1. If:

- τ = shear stress due to friction opposing the annulus rotation.
- σ = normal stress on the annulus plate
- D = outer diameter of the annulus plate
- d = inner diameter of the annulus plate
- F = total couple due to friction
- r = radius
- θ = angular displacement
- W = weight of the annulus plate

Then for an element of the plate

$$F = \tau \int_0^{2\pi} \int_{d/2}^{D/2} r^2 \, dr \, dQ \quad . \ (1)$$

$$= \frac{\pi\tau}{12} (D^3 - d^3) \ldots\ldots\ldots \ (2)$$

Therefore,

$$\tau = \frac{12F}{\pi} (D^3 - d^3)^{-1} \quad \ldots\ldots \ (3)$$

The normal stress, σ, on the plate is,

$$\sigma = \frac{4W}{\pi} (D^2 - d^2)^{-1} \quad \ldots\ldots \ (4)$$

Lawton (1980) fitted the regression equation (5) on test data,

$$\tau = A + \mu\sigma \quad \ldots\ldots\ldots\ldots \ (5)$$

Plotting τ versus σ on linear coordinates, μ is evaluated as the slope of the curve and A the intercept.

Experimental Procedures

An annular friction plate as described by Lawton (1980) was used for the experiments (Fig. 3). The plate had an inside and outside diameters of 0.225 m and 0.450 m, respectively. The plates were fixed to a frame incorporating a platform supporting the loading weights. The loads were added to the platform in a symmetrical manner and in increments up to a maximum. This framework was, in turn, connected by means of a square drive shaft, designed to eliminate any side thrust, to a torque wrench, with an indicating pointer and scale. The grain sample was contained in a 0.7 m by 0.65 m open tray with a height of 100 mm.

The grains were conditioned to the required moisture content by rewetting or drying and then allowed to equilibrate for 12 h as per Brubaker and Pos (1965). Moisture content was determined by a Kongskilde moisture meter (KM TesterOMK IV). The following three surfaces were tested:

(a) concrete grade C20 - wood former surface;
(b) mild steel; and
(c) plywood

For each experiment, the annulus plate was loaded in steps, typically 6, to a maximum of approximately 5 kN/m². For each step, a torque was applied manually to the plate by the torque wrench. The torque was gradually increased until the grain kernels appeared to have stopped rolling and had taken their preferred orientation. At this point the applied torque was relaxed slightly and momentarily and then increased until the maximum was attained. Immediately after the attainment of the maximum torque, a condition of dynamic friction existed and the torque necessary to maintain a given strain rate was observed to decrease. The peak torque reading was recorded from the torque wrench and equations (3) and (4) used to calculate the shear stress (τ) and normal stress (σ), respectively. Two replications of each experiment were conducted.

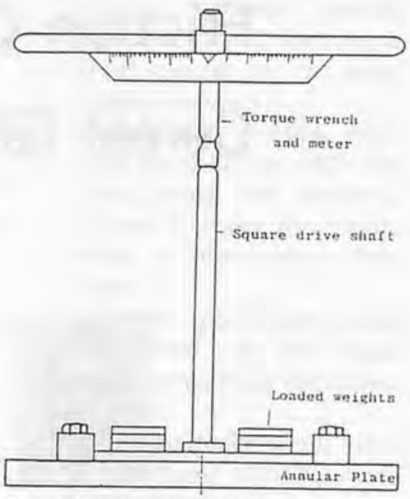

Fig. 3 Friction test apparatus.

Results

The mean values of shear stress (τ) were plotted against the normal stress (σ), as described above. Using equation (5), the value of the static coefficient of friction (μ) was then evaluated. Figs. 4 to 9 are plots of τ versus σ, while Tables 1 to 3 outline the values of μ obtained.

Discussion

From the study, it is evident that the static coefficient of friction (μ) is significantly influenced by the moisture content of the grain. The coefficient of friction

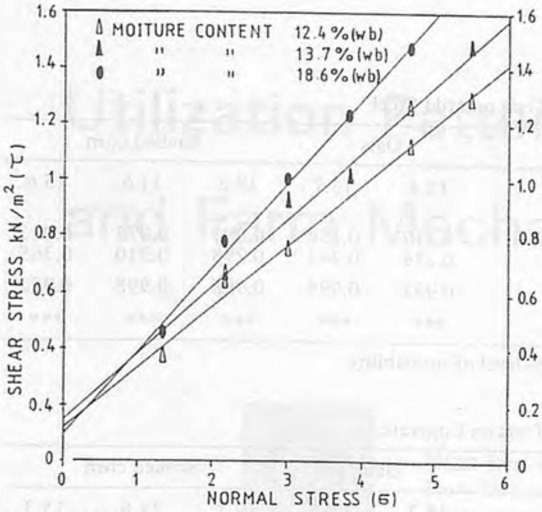

Fig. 4 Shear stress vs normal stress for oats on mild steel at various moisture content.

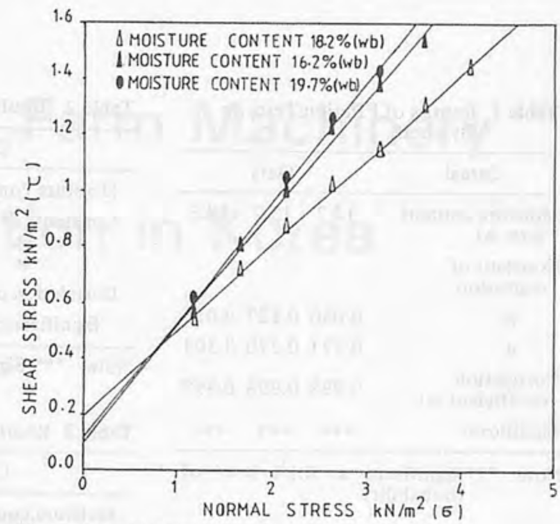

Fig. 5 Shear stress vs normal stress for oats on concrete at various moisture contents.

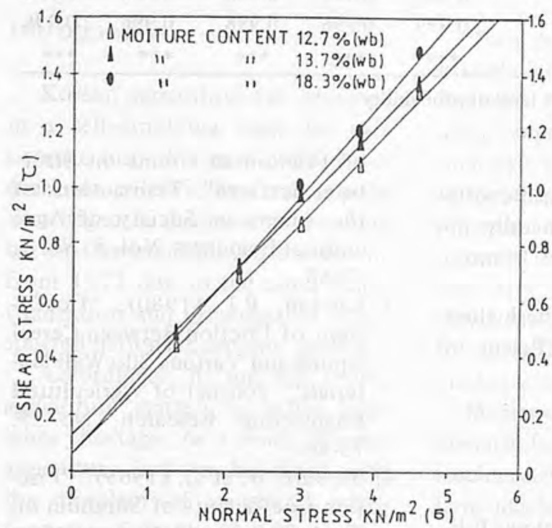

Fig. 6 Shear stress vs normal stress for oats on plywood at various moisture contents.

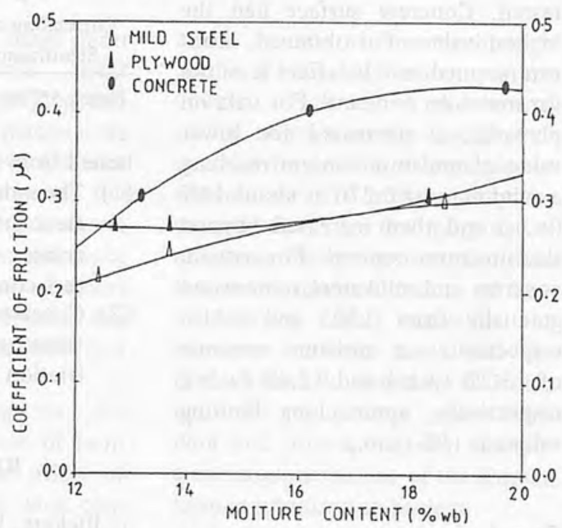

Fig. 7 Variation of coefficient of friction with grain moisture content for oats on various surfaces.

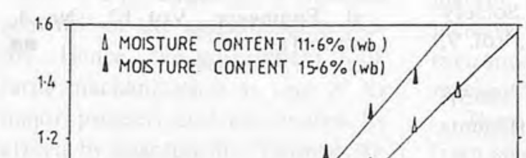

Fig. 8 Shear stress vs normal stress for maize on mild steel at various moisture contents.

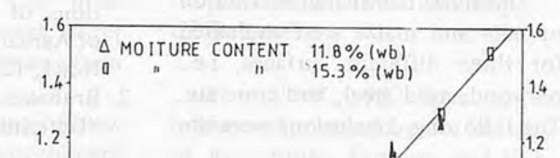

Fig. 9 Shear stress vs normal stress for corn on concrete at various moisture contents.

Table 1 Results of Friction Tests on Plywood

Cereal	Oats		
Moisture content % (w.b)	12.7	13.7	18.3
Constant of regression			
A	0.060	0.127	0.056
μ	0.271	0.270	0.304
Correlation coefficient (r)	0.998	0.998	0.999
Significant	***	***	***

Note: ***Significant at 0.1% level of probability

Table 2 Results of Friction Tests on Mild Steel

Cereal	Oats			Shelled corn	
Moisture content % (w.b)	12.4	13.7	18.6	11.6	15.6
Constants of regression					
A	0.119	0.150	0.093	0.073	0.053
μ	0.216	0.241	0.298	0.310	0.365
Correlation coefficient (r)	0.992	0.998	0.998	0.998	0.992
Significance	***	***	***	***	***

Note. *** Significant at 0.1% level of probability

Table 3 Results of Friction Tests on Concrete

Cereal	Oats			Shelled corn	
Moisture content % (w.b)	13.2	16.2	19.7	11.8	15.3
Constants of regression					
A	0.198	0.123	0.105	−0.164	−0.159
μ	0.305	0.401	0.428	0.598	0.598
Correlation coefficient (r)	0.999	0.996	0.998	0.996	0.996
Significance	***	***	***	***	***

Note: ***Significant at 0.1% level of probability

generally increased with an increase in moisture content of the grains tested. Concrete surface had the highest value of μ obtained. Moisture seemed not to affect μ values for maize on concrete. For oats on plywood, μ decreased for lower value of moisture content reaching a minimum of 0.270 at about 14% (w.b.) and then increased beyond this moisture content. For oats on concrete and mild steel, μ increased gradually from 0.305 and 0.216, respectively, at moisture contents of 13.2% (w.b.) and 12.4% (w.b.), respectively, approaching limiting values at 18% (w.b.).

Conclusion

The static coefficient of friction of oats and maize were evaluated for three different surfaces, i.e., plywood, mild steel, and concrete. The following conclusions were obtained from the study:

(1) The value of the static coefficient of friction generally increases with increases in moisture content.
(2) Concrete exhibited the highest values of static coefficient of friction.

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Utilization Pattern of Farm Machinery and Farm Mechanization in Korea

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Introduction

Korean agriculture has remained in a self-supplying stage for subsistence until the mid-1960s. However, since 1967 the farm population began to decline and the number of farmers followed the decline from 1977 due to the rapid industrialization and urbanization which spurred national economic growth.

Accordingly, in the late 1970s, agriculture started to suffer from labor shortage. As a result, Korean agriculture had to be faced with the problem of structural transformation from the "land – productivity – oriented growth" to the "labor – productivity – oriented growth" of the agricultural economy. Hence, the government took farm mechanization as one of its major projects and accelerated its efforts by enacting the "Farm Mechanization Promotion Act" as a legal foundation for further farm mechanization projects in 1978.

As a result, the number of power tillers increased to 738 000, one unit per 2.4 households in 1989, and the number of total farm machineries increased to 2 million and 364 000, 1.3 units per farm household. As the number of farm machineries increased, the share of operating cost of farm machineries in total farm management cost also increased.

Thus in the 1980s, many farm households experienced great financial difficulty in buying and using expensive farm machineries such as tractors, combines and rice transplanters. Furthermore, as the pressure of opening agricultural imports has grown stronger since the late 1980s, most farmers faced many serious problems due to the more unstable agricultural market situation.

Moreover, according to the liberalization of the price of farm machineries in 1988, the prices of farm machineries, which were controlled from 1983 by the government began to increase for free market competition. This price increase made the farmers suffer even more in buying and using farm machineries.

There is another point of view from some parts of the government that machineries have been already over-supplied such that their use has been decreasing and that this phenomenon has become a major cause of increasing farm household debt. On the other hand, some farmers are complaining that they can hardly get the necessary farm machineries on time for their demand, hence unable to meet the timeliness of cultivation.

These has been no research work done yet on a comprehensive survey of the actual state of farm mechanization, the use of farm machineries and farm household economy in the country. Park et al did several partial surveys on the use of farm machineries and farm management expenditure. The present study was carried out for the purpose of analyzing the current status of farm mechanization and the use of farm machineries, and analyzing the relations between them and the farm household economy in Korea in order to present some basic data and information for the efficient implimentation of the Korean farm mechanization project.

Objectives and Methodology of Survey

A total of 2 932 farm households were selected by the Ministry of Agriculture, Forestry and Fisheries (MAFF) to collect information on farm household income, production costs, household management expenses, etc. These farm households are distributed by zones as follows: semi-plain, 1 105; hilly, 802; plain, 700; and suburban, 325.

The MAFF survey team visited with the sample farm households and collected information through personal interviews with farmers. The data collection was conducted according to regions for 12 months from December 1, 1988 to November 30, 1989.

Results and Discussions

General Situation

The average number of persons per farm houehold was 4.28 of which 2.33 persons were actually engaged in farming. The smallest family sizes were found in the plain region. The farm households had an average of 1.19 ha which is 0.02 ha larger than the national average of 1.17 ha. The average farm household income was 8 130 000 won. Of this total, agricultural income was 4 192 000 won which is 60% of the total.

Farm Machinery Available

Some 53% of the total number of households surveyed owned power tillers, 2% tractors, 14% rice transplanters, 5% binders, and 3% combines. These figures are greater than the 1989 national average by 11% for power tillers, 0.2% for tractors, 7.7% for rice transplanters, 2.2% for binders and 1.1% for combines.

By regions, the highest percentage value was found in the plain and the semi-plain, suburban, and hilly region, in that order.

Utilization of Farm Machinery

Table 2 shows the days and areas worked by the major farm machineries. Power tillers and rice transplanters had the largest amount of use in plain; tractor, in suburban; combines, in semi-plain; and binders in the hilly region.

Power tillers and tractors – The average annual working days of tractors were 48.7 of which 16.3 (10.9 ha) were for plowing; 16.7 for (10.9 ha) for levelling; 3.0 (1.2 ha) for pest and disease control, 11.4 for transporting and 1.3 for other miscellaneous work. Some 77.1% of the total working days was used for custom work or cooperative work. However, the

Table 1 Number of Persons, Cultivated Land Holding and Income per Farm Household

Item	No. of family (Person)			Farm workers (person)	Cultivated land holding (ha)				Income (1000, won)*		
	Total	Male	Female		Total	Pady	Upland	Others	Total	Farm income	Non-farm income
Average	4.28	2.11	2.17	2.33	1.19	0.81	0.30	0.08	8,130	4,912	3,218
Suburban	4.53	2.22	2.31	2.31	0.92	0.62	0.22	0.08	8,962	4,236	4,726
Plain	4.22	2.07	2.15	2.28	1.24	0.94	0.22	0.08	8,450	5,486	2,964
Semi-plain	4.26	2.11	2.15	2.38	1.21	0.82	0.31	0.08	8,266	5,045	3,221
Hilly	4.27	2.08	2.19	2.30	1.19	0.72	0.40	0.07	7,373	4,498	2,875

* 1US dollar = 700 won

Table 2 Days and Areas Worked by Major Machineries

Machine	Region	Average	Suburban	Plain	Semi-plain	Hilly
Power-tillers	Working day (day)	day 57.8 (14.1)	53.3 (13.0)	64.5 (15.9)	55.9 (13.7)	55.7 (13.3)
	Area (ha)	ha (3.7)	(3.6)	(3.7)	(3.6)	(3.7)
Tractors	Working day (day)	48.7 (33.0)	68.8 (44.6)	57.0 (39.9)	34.3 (22.5)	35.3 (21.5)
	Area (ha)	21.8	31.4	26.0	14.6	15.0
Rice trans-planters	Working day (day)	8.2	7.9	8.5	7.9	8.5
	Area (ha)	4.6	4.9	5.1	4.1	4.5
Binders	Working day (day)	5.9	5.4	6.2	3.6	6.9
	Area (ha)	2.2	1.7	2.3	1.7	2.5
Combines	Working day (day)	20.6	19.9	20.4	21.3	18.6
	Area (ha)	13.9	14.4	13.3	14.7	11.4

Note: Figures in parentheses represent the sum of plowing and rotary work by power tillers or tractors.

type of work performed was simple and working time was short.

Power tillers were used at an average annual rate of 57.8 days of which, 7.0 (1.72 ha) were for plowing; 7.1 (1.93 ha) for levelling; 9.8 (5.41 ha) for pest and disease control; 2.3 (0.82 ha) for threshing; 2.1 for pumping; 24.5 for transporting; and 5 days for other miscellaneous work. Since power tillers were mainly used for the owners' farm, the percentage of self work was 71.0% of the total work done.

Rice transplanters and harvesters – Rice transplanters were used at an average rate of 8.2 days a year and the average area worked by the machine was 4.6 ha, of which, 1.6 was for self work and 3.0 ha for custom work. The ratio of custom work to the total work done was 65.2%, which implies that rice transplanters were used mainly for custom work or cooperative purposes.

Binders were used at an average annual rate of 5.9 days and the average worked area was 2.2 ha of which 1.3 was for self work and 0.9 for custom work. The ratio of the self work was 59.1% indicating that binders were mainly used for self work. Combines were used at an average rate of 20.6 days a year and average worked area was 13.9 ha of which, 2.0 was for self work and 11.9 was for custom work. The custom work ratio was 86.6%. Combines were mainly used for cooperative utilization purposes. The use of combines was 3.5 times greater than that of binders. The greater use of the combines may be attributable to farmers' preference for particular machines for easy and convenient work.

Income and Expenses in Farm Machinery Use – **Table 3** shows the results of farm machinery management analysis based on custom work income and expenses. The income taken into account were cash receipt from the custom work and indirect cash from doing farmer's own work, both of which were estimated by multiplying the total area worked by machine as custom work fee. Expenses can be divided into fixed and variable costs. The fixed costs included depreciation, interest on farm machinery investment, etc. The variable costs included repair costs, fuel costs, labor charges, costs for communications, etc.

Power tillers, tractors, rice transplanters and combines made a profit with an exception of binders. Wages for farm labor increased by 27% from 1985 to 1988 while the rates of custom work increased only by 8% for plowing and leveling, and by 17% for transplanting during the same period.

The rate for combine harvesting even decreased by 7%. This relatively higher increase in wages over the custom rate has contributed to stabilizing the wages for farm labor and keeping the prices of agricultural products at a low level.

This also made a positive effect on farm household economy.

Table 3 Expenses in the Use of Farm Machineries in 1989

Machine		Power tillers	Tractors	Rice trans-planters	Binders	Combines
Income (A)	Custom work	won 748,856	1,953,697	527,525	263,724	2,892,327
Ex-penses (B)	Total	559,616	1,895,611	412,990	312,930	1,931,426
	Fixed cost	248,967	1,243,145	267,161	220,400	1,237,609
	Repair	52,667	124,683	26,591	14,433	196,337
	Fuel	38,341	113,733	13,581	8,575	72,490
	Labor charge	259,247	414,000	105,419	51,791	423,704
	Others	394	50	238	17,731	1,286
Profit and loss (A – B)		149,240	58,356	114,535	△ 49,206	960,901

Note: 1 US dollar = 700 won

Table 4 Farm Management Expenses and Costs for Agricultural Machines, 1984-88 (Unit: 1,000 won)

Item \ Year	1984	Rate %	1985	Rate %	1986	Rate %	1987	Rate %	1988	Rate %
Farm management	1,578		1,778		1,942		1,968		2,134	
Machines	139	8.8 (20.2)	158	8.9 (20.9)	176	9.1 (22.3)	197	10.0 (23.7)	236	10.2 (23.6)
Fixed capital	6,046		5,815		5,509		5,798		7,327	
Machines	590	9.8 (27.1)	620	10.7 (26.9)	665	12.1 (27.3)	657	11.3 (29.4)	965	13.2
Debt	1,784	100	2,024		2,192		2,390		3,131	
Machines	260	14.6	268	13.2	270	12.3	276	11.6	440	14.1

Note: Values in parentheses indicate the corresponding values in Japan.

Investments on Farm Machineries and Farm Household Economy

Table 4 shows an analysis on farm management expenses, costs for the use of farm machineries, fixed farm household outlays, the capitals for farm equipment, farm household debts, and debts caused by farm equipment during the period of 1984 to 1988.

This analysis investigated the economic impact of farm machinery on the household economy.

The costs for the use of farm machineries to the total farm management expenses increased from 8.8% in 1984 to 10.2% in 1988. This figure is at a low level when compared with that of Japan which is 23.6% a level which Japan achieved in 1975.

The percentage of the farm machinery outlay to the total fixed farm household capitals was 13.2%, which still remains at low level when compared with that of Japan (29.4%) in 1987.

The debts caused by the use of farm machineries decreased from 14.6% in 1984 to 11.6% in 1987 and increased again in 1988 to 14.1% of the total farm household debts, reflecting still low and insufficient investments on farm machines. The debts due to the farm machineries must be conceived as a debt for production investment.

Population of Farm Machineries and Degrees of Farm Mechanization

Population of farm machineries

– **Table 5** shows the number of major farm machineries per 100 farm households and increase rate based on government statistics for the respective farm machines and farm households. Defining the number of machines per 100 farm household as a dissemination rate of the machineries and designating it in percentage, the dissemination rates of pwer tillers, rice transplanters, combines and grain dryers were 41.7%, 6.3%, 1.9%, and 0.8% respectively, as of 1989. These rates are lower than those of Japan in the early 1970s.

However, the rates of rice transplanters and combines are similar to those in the Republic of China in the early 1980s.

In the 1980s, the highest increasing rate in farm machinery dissemination was that of combines followed by rice transplanters, tractors, binders and power tillers.

The increasing rates in the second half of the 1980s are less than those in the first half of the same year.

Extent of Farm Mechanization – **Table 6** shows the mechanized farm work performed in 1989 at the cultivated land of the sampled farm households. The percentage of the area worked by machine to the total land area, designated as mechanization rate, was 81.7% for plowing and leveling, of which 21.3% is by tractors and 69.4% by power tillers. About 90% of the cultivated land is mechanized in the plain and suburban areas. However, 33.9% of the hilly areas is still farmed using animal power. The mechanization rate of rice transplanting is 66.3% indicating a still low level.

As much as 55.8% of the cultivated land in the hilly area is still transplanted manually. The mechanization rate of pest and disease control is 87.5% of which 1.8% was by airplane and 86.4% is power sprayers. The mechanization rate of harvesting was 62.1% of which 51.2% is by combines and 10.9% is by binders and reapers. As much as 60.6% of the hilly areas is still worked by manpower for harvesting. In general, the plain area is mechanized more than the semi-plain, suburban and hilly areas.

Table 5 Dissemination Rate of Farm Machineries

Item / Machines	Dissemination rate (%) 1981	1985	1989	Average annual rate (%) 1981-'85	1985-'89	1981-'89
Power tillers	17.3	30.6	41.7	17.4	8.8	13.2
Tractors	0.2	0.6	1.8	35.8	29.2	33.9
Rice transplanters	0.8	2.2	6.3	34.5	31.5	32.5
Combines	0.1	0.6	1.9	43.1	36.6	38.7
Grain dryers	0.1	0.8	0.8	24.6	32.0	26.0

Table 6 Mechanization Rate, 1989

(Unit: %)

Work	Machines	Average	Suburban	Plain	Semi-plain	Hilly
Ploweing and leveling	Tractor	12.3	10.9	21.5	11.8	4.0
	Power tiller	69.4	79.5	69.2	71.9	62.1
	Animal	18.3	9.6	9.3	16.3	33.9
Transplanting	Rice transplanter	66.3	66.8	83.6	67.8	43.3
	Manual transplanting	33.7	33.2	16.4	32.2	56.7
Pest and disease control	Aeroplane	1.0	3.0	1.2	1.1	—
	Power sprayer	86.4	84.5	91.0	88.5	76.5
	Manual sprayer	12.6	12.5	7.8	18.4	23.5
Harvesting	Combine	51.2	54.2	76.6	51.4	20.8
	Binder	10.9	6.9	6.1	10.2	19.4
	Manual sickle	37.9	38.9	17.3	38.4	60.6
Drying	Grain dryer	12.5	13.5	19.0	12.6	4.3

Summary

The objective of this study was to measure the current status of farm mechanization and its investment by analyzing the results of a survey conducted in 1989 on farm machinery use and mechanized farming acreage.

In summary the findings are:

1. Use of power tillers and binders are generally limited to own farming work. However, tractors, rice transplanters, and combines are utilized more extensively for custom work and joint utilization with neighboring farmers.

2. The number of tractors per 100 farm households is 1.8 units, rice transplanters 6.3 units and combines 1.9 units being equivalent to those of Japan in the early 1970, or, for the cases of rice transplanters and harvesters, of Taiwan in the early 1980s.

3. The percentage of area worked by machineries to the total farm area is 81.7% in plowing and leveling; 66.3% in transplanting; 87.5% in pest and disease control in 62.1% in harvesting; 12.5% in drying. Mechanization for rice transplanting, harvesting and drying still remains relatively at a low level.

4. Expenditures for farm machinery and implements are about 10.2% of the total farm management expenditures (23.6% in Japan), and 13.2% of the total farm household asset belongs to farm machinery and implement (29.4% in Japan).

(Continued on page 75)

Production of Amorphous Silica from Rice Husk in a Vertical Furnace

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Abstract

The results of studies on acid leaching of rice husk and its subsequent combustion in a vertical furnace reveal that leaching of husk in 1 (N) HCl removed all metallic impurities present in it. Acid treatment of rice husks prior to combustion does not affect the structural nature (amorphicity) of the sillica produced. The use of forced draught during combustion of husk as well as an increase in the bed thickness do not help in reducing either time or energy required for production of amorphous white ash. From the standpoint of amorphicity of silica produced, minimum time, energy requirement and cost of production, a furnace temperature of 500°C and combustion time of 6 h with natural draught for a bed thickness of 14 cm are considered optimum for conversion rice husk into white amorphous silica.

Introduction

The major traditional use of husk as fuel to provide energy for rice mill operation has diminished as diesel and electricity have replaced the steam power. Only a small part of the total husk produced in the country is now being used as fuel to generate steam for parboiling and drying operations in some rice mills. However, the resulting high carbon ash creates further disposal problem. Therefore, the only alternative left for complete and effective utilization of rice husk is to convert it into some value added products (Banerjee et al, 1985, Chakraverty et al, 1985 and Mishra et al, 1985). The main components of rice husk are cellulose, lignin and silica. Recently rice husk silica has been identified as a unique source of high grade amorphous silica. No other agricultural residues contain as much silica as rice husk which is around 20%. The silica present in rice husk, being of biogenic origin, is inherently amorphous. However, it may be transformed into a more stable crystalline form when it is subjected to high temperature. The amorphous silica obtained from controlled combustion of rice husk at lower temperature is chemically more reactive and useful than crystalline silica. That is why the ash-silica (char) obtained from commercial husk fired furnace is of little use.

Amorphous silica can be used in various industries like glass, rubber and ceramics. Now it is realized that the high grade rice husk silica could be an attractive raw material for the production of pure silicon which is essentially used in photovoltaic and semiconductor industries for manufacturing solar cells, transistors, integrated circuits and microchips.

The importance of rice husk white ash as a source of pure amorphous silica has now been realized all over the world. Some studies have been undertaken to characterize this silica in comparison with the commercial silica (Ibrahim et al, 1980 and Hamad and Khattab, 1981). However, the optimum combustion conditions of rice husk for production of amorphous white ash are not well established as yet.

Therefore, the present study was undertaken with the following main objective: to determine the optimum conditions for combustion of rice husk to produce amorphous white ash.

Materials and Methods

The set-up mainly consisted of an electrical furnace in conjunction with a temperature controller. A portable blower was used to blow air inside the furnace during some of the combustion experiments. The instruments used for measurement of various parameters were a temperature recorder, an energy meter and a pitot tube in combination with a micromanometer.

The furnace as shown in Fig. 1 was specially designed and fabri-

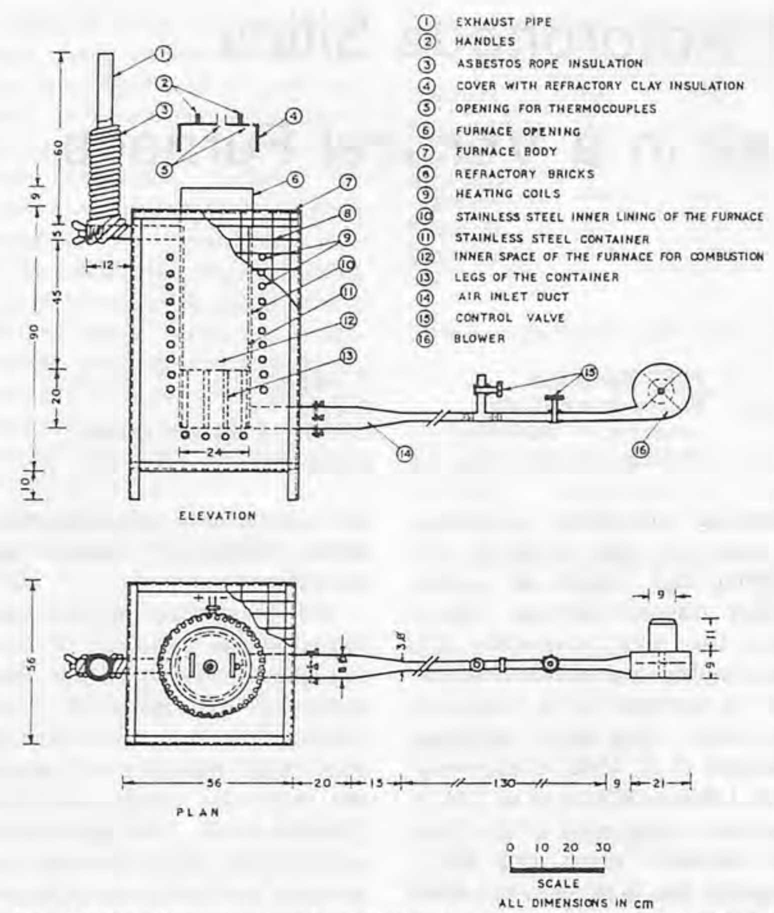

Fig. 1 Electric furnace for combustion of husk to produce amorphous white ash.

cated to conduct the combustion studies of husk. The furnace wall was insulated with refractory bricks of 15 cm thickness. The inner wall was lined with 18 gauge stainless steel sheet. Ten heating coils, each having a resistance of 30 ohms/m, were securely fastened on the wall of the furnace making slots in the refractory bricks. An opening at the bottom of the furnace wall in connection with a long G.I. pipe of 3 cm diameter (o.d.) was used as an air duct. Fresh air was blown into the furnace through this duct with the help of a small centrifugal blower. The opening at the upper end of the furnace wall was connected to an exhaust pipe. The mild steel cover at the top of the furnace was also insulated with refractory clay. The base of the furnace was perforated to provide passage of the air through the husk during combustion. The furnace was mounted on a slotted angle iron frame and covered with 20 gauge G.I. sheet all around. The furnace was operated by 220V stabilized supply. The power connection to the furnace was given from the three phase main supply through an energy meter (3 phase, 25A, 220V) and an external relay contactor (3 phase, 25A, 220V).

Rice husk was obtained from a modern Satake rice mill of 0.5 t/h capacity. It was thoroughly washed with water to clean and, subsequently, sun-dried to a moisture content of about 10% (w.b.). This clean unground rice husk was then used for combustion studies. The husk was charged initially into the furnace at room temperature with its air inlet closed. The furnace temperature was then slowly raised to the desired level. The valves of the air inlet duct were opened to allow the flow of air (natural or forced draught) into the furnace only after complete escape of volatile matters. Natural flow of air was continued till the end of the combustion experiment whereas the flow of forced air was stopped as the bed temperature decreased from the set temperature.

To determine the residual carbon content of the ash obtained from the combustion studies, about 1 g of the ash was taken in a silica crucible and transferred inside the muffle furnace maintained at 700°C and kept there for 8 h. The loss in weight was taken as the residual carbon present in the ash. The structural analysis of ash-silica was conducted from X-ray diffraction studies using a X-ray diffractometer (Model CCON-1500, USSR, Mo$k\alpha$ radiation).

Results and Discussion

This study was undertaken with clean unground husk of 14 cm bed thickness and with natural draught. The effects of the furnace set temperatures of 350, 400, 450, 500 and 550°C on husk bed temperature and time required for production of white ash were studied. The combustion of material at these temperatures was performed according to the following procedure: (i) Husk was charged into the furnace at room temperature with its air inlet closed; (ii) The furnace temperature was then raised and set at the desired level; (iii) After complete escape of volatile matters, as visually observed, the air inlet was opened; and (iv) Combustion was continued till the whole mass turned white.

The temperature of husk bed vs time plots as recorded during the entire combustion period at various furnace set temperatures are shown in Figs. 2 through 6. These figures show that the furnace tem-

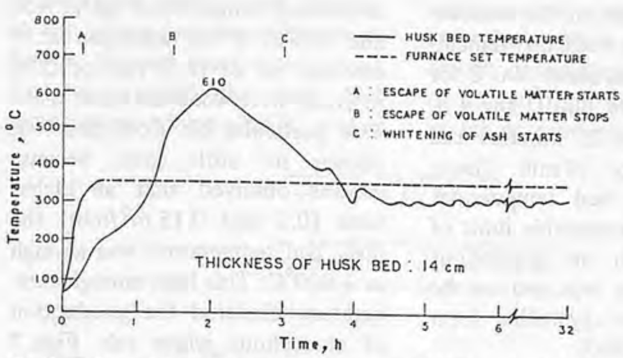

Fig. 2 Effect of furnace temperature set at 350°C on husk bed temperature and time required for complete combustion with natural draft.

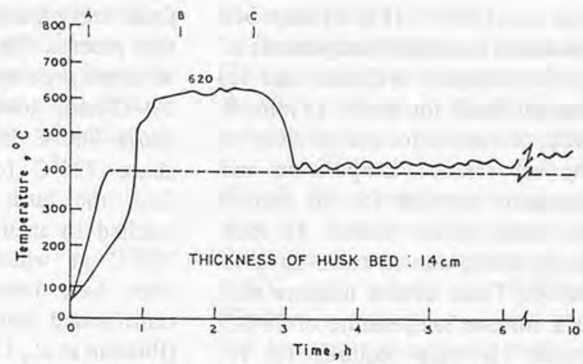

Fig. 3 Effect of furnace temperature set at 400°C on husk bed temperature and time required for complete combustion with natural draught.

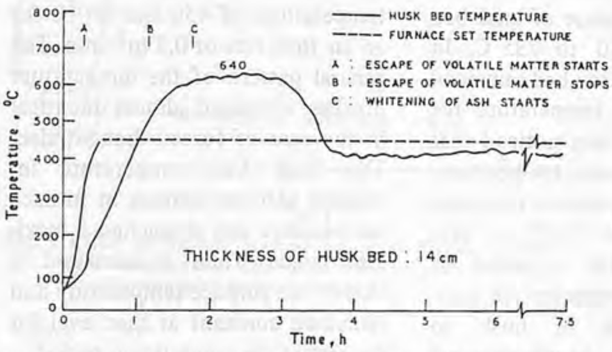

Fig. 4 Effect of furnace temperature set at 450°C on husk bed temperature and time required for complete combustion with natural draught.

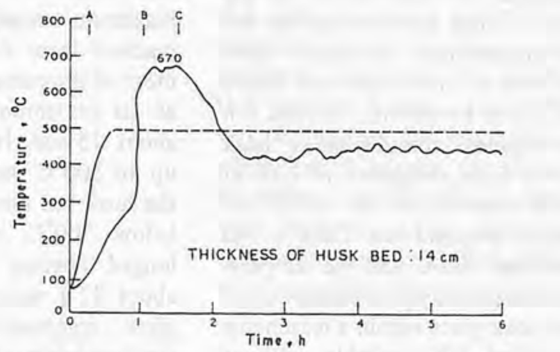

Fig. 5 Effect of furnace temperature set at 500°C on husk bed temperature and time required for complete combustion with natural draught.

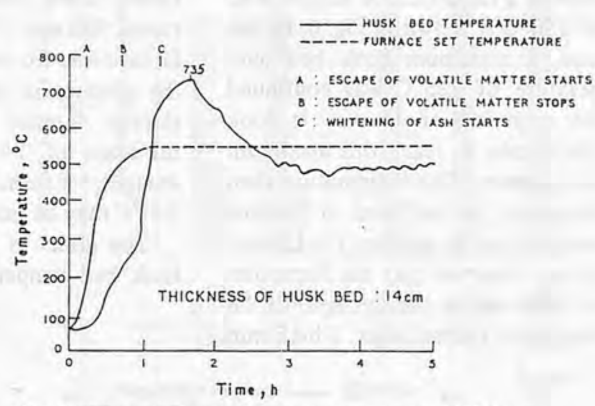

Fig. 6 Effect of furnace temperature set at 550°C on husk bed temperature and time required for complete combustion with natural draught.

peratures slowly increased and reached the set value in about half an hour. On the other hand, the husk bed temperature increased with an increase in furnace temperature. It reached a maximum value and then decreased to a level close to the furnace temperature. The bed temperature remained almost constant at this level until the combustion was completed. The points A, B and C in the figures correspond to a few observations made during combustion expreiment. The distance between A and B in the time axis corresponds to the duration for which volatile matters escaped from the husk. The point 'C' represents the approximate time when the top layer of the husk bed became white. It was observed in all these cases that volatile matters from husk started escaping out around 250°C. The time required for complete escape of volatile matters decreased with an increase in the furnace temperature. At furnace temperatures 350° and 400°C, it took 1 h-15 min, for escape of volatile matters. While at 450°C, this time requirement was 55 min, the corresponding value at 500 and 550°C was 30 minutes. Figs. 2 through 6 also indicate that the general pattern of the husk bed temperature profiles was similar to all furnace temperatures. However, some changes could be noticed in their shapes which might be due to certain changes in the combustion process at various furnace temperatures.

When the furnace temperature

was set at 500°C (**Fig. 5**) husk bed reached a maximum temperature of 670°C within 1 h-15 min and remained fixed for about 15 min. It then decreased to a level close to the set furnace temperature and remained constant for the rest of the combustion period. It took about 1 h-45 min to come down to 500°C. These results indicate that at a furnace temperature of 500°C about 3 h were required for removal of most of the carbon in the husk. It took 1 h-30 min for formation of white ash on the top layer of husk bed. In this case the bed temperature remained above 500°C for 1 h-30 min and above 600°C for 1 h-20 min. It took 6 h for complete combustion of husk at 500°C as compared to 10 h at 400°C and 7.5 h at 450°C of furnace temperatures. Thus, it was clear that 500°C was the temperature where complete combustion of husk took place within a reasonable period of 6 h probably without any change in quality of the silica.

The husk bed temperature vs time at a fixed furnace temperature of 550°C is shown in **Fig. 6**. In this case, a maximum husk bed temperature of 735°C was continued for a period of 15 min. It took 1 h-30 min to reach this maximum temperature. The temperature then decreased to the level of furnace temperature in another 1 h-15 min. It was observed that the formation of white ash on the top layer of the husk bed started after 1 h-15 min from the initiation of the combustion process. The husk bed remained at temperatures above 500°C for 1 h-45 min, above 600°C for 1 h, above 700°C for 25 minutes and above 735°C for 10 min. Therefore, the husk bed temperature reached to an undesirable limit of 725°C at which the amorphous silica have been reported to be transformed into crystalline form (Ibrahim et al., 1980).

The above results indicate that by increasing the furnace temperature from 350 to 550°C, the maximum temperature of husk bed reached from 610 to 735°C. In most of the cases, the bed remained at its maximum temperature for about 15 min. It was noticed that up to 500°C furnace temperature, the husk bed temperature remained below 700°C. At 350°C a prolonged heating for a period of about 32 h was necessary for complete combustion of husk to produce white ash. At other typical furnace temperatures, in the range 400 to 550°C, the corresponding times varied from 10 to 5 h. Between 500 and 550°C, the time difference was 1 h only. Therefore, for the production of white ash in an electric furnace for a husk bed thickness of 14 cm with natural draught, a furnace temperature of 500°C may be taken as optimum.

The effect of forced draught on husk bed temperature was studied at furnace temperature set at 450 and 500°C. A bed thickness of 14 cm and an air flow rate of 0.05 m^3/min were used in both cases. This particular air flow rate was chosen in both cases because it was observed that at higher rates (0.1 and 0.15 m^3/min) the husk bed temperature was as high as 1 000°C. This high enough temperature hindered the production of amorphous white ash. **Figs. 7** and 8 show the variation in bed temperature with time during combustion of husk at the furnace temperatures of 450 and 500°C for an air flow rate of 0.5 m^3/min. The general pattern of the temperature profiles remained almost identical in the case of forced draught also. The husk bed temperature increased with an increase in furnace temperature and it reached a maximum value. Then it decreased to that of the furnace temperature and remained constant at that level for the rest of the combustion period.

Fig. 8 shows that at a furnace temperature of 500°C with forced draught, the husk bed temperature was as high as 740°C within 2 h-15 min. The bed temperature remained above 725°C for 10 min. The total time required for the production of white ash from the whole mass was 7 h. It was, therefore, apparent that there was no additional advantage over the total time required for the production

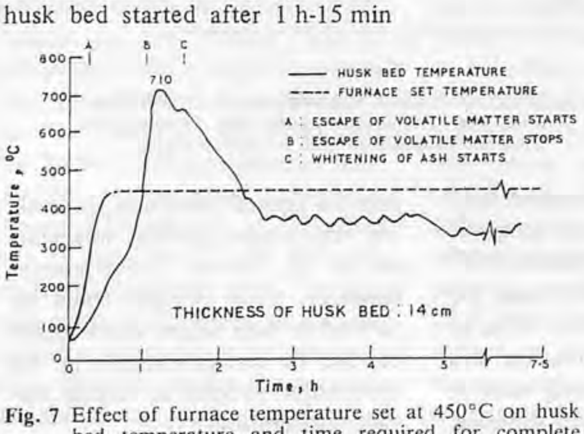

Fig. 7 Effect of furnace temperature set at 450°C on husk bed temperature and time required for complete combustion with forced draught.

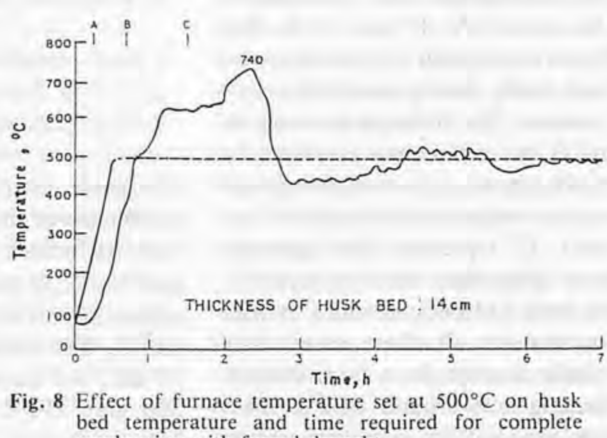

Fig. 8 Effect of furnace temperature set at 500°C on husk bed temperature and time required for complete combustion with forced draught.

of white ash with forced draught at the above furnace temperature. Rather it took more time (about 1 h) and raised the husk bed temperature above 725°C which was detrimental to the production amorphous white ash. Hence, the forced draught even at a low rate of 0.05 m^3/min was not beneficial as far as production of white ash was concerned.

The effect of husk bed thickness (28 cm) on its bed temperature and time of production of white ash was studied at a furnace temperature of 500°C with natural draught (Fig. 9). These results are compared with the corresponding results at the same furnace temperature of 500°C with natural air flow in Fig. 11. It was observed that the bed temperature increased with an increase of furnace temperature like in all other cases up to 680°C. Then it decreased only to 620°C and again increased to 710°C. It remained above the furnace temperature throughout the combustion process. A total period of 9 h was required for the production of white ash from the whole mass. When these results were compared with those at 14 cm husk bed thickness under identical conditions of burning (Fig. 11), it was observed

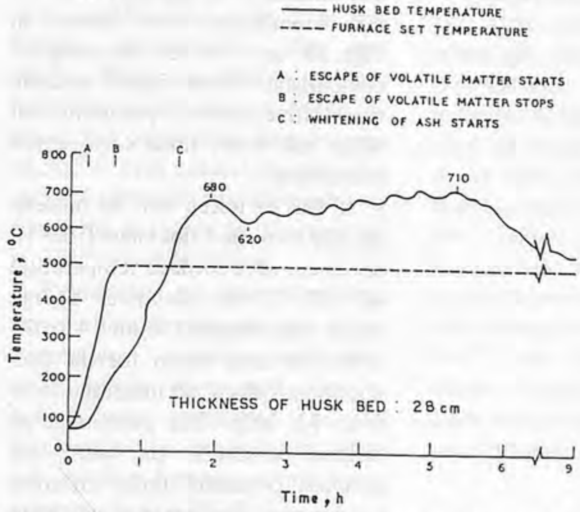

Fig. 9 Effect of furnace temperature set at 500°C on husk bed temperature and time required for complete combustion with natural draught.

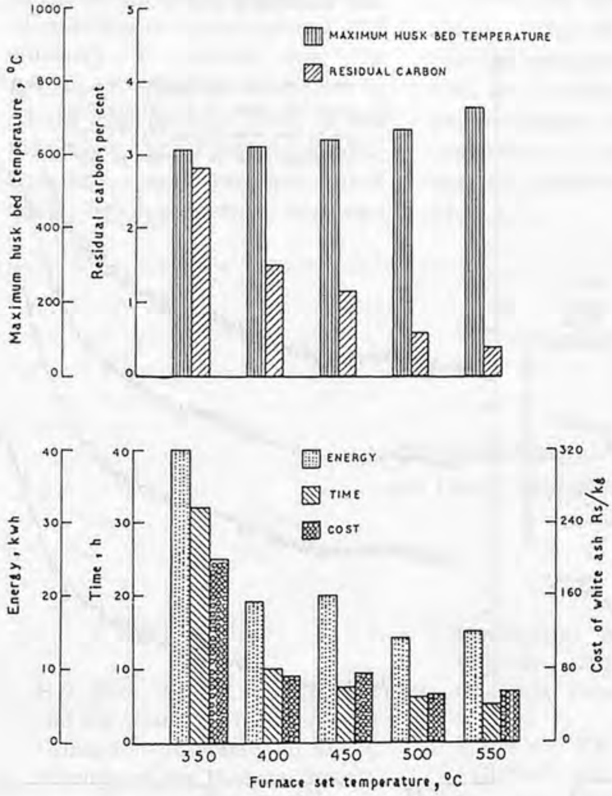

Fig. 10 Effect of furnace set temperature on time and energy spent and cost for production of amorphous white ash from rice husk and on the residual carbon in white ash. Husk bed thickness: 14 cm, natural airflow, sample weight: 500 g.

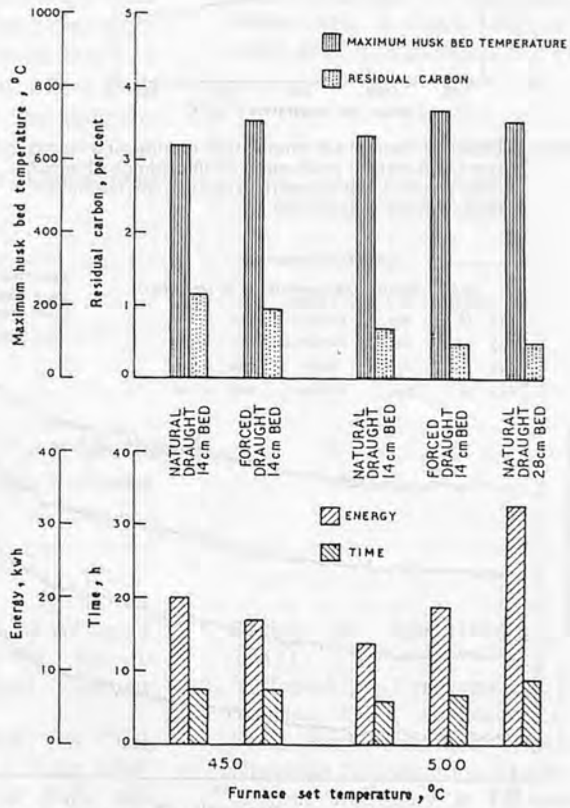

Fig. 11 Effect of forced draught and husk bed thickness (at 500°C) on the time and energy spent for the production of amorphous white ash from rice husk and on the residual carbon in white ash.

that the total combustion time increased from 6 to 9 h when the bed thickness was doubled. The temperature of the bed remained above 700°C for a longer period (1 h-30 min) in the latter case. Therefore, by increasing the bed thickness at 500°C furnace temperature the production capacity can be increased to a certain extent, the retention of the strict amorphous nature of the ash cannot be assured.

The time and energy spent and the residual carbon in the white ash obtained for different combustion conditions are shown in **Figs. 10** and **11** for the sake of comparison. These figures indicate the relative costs of production of white ash under these combustion conditions.

It will be noted that by increasing the husk bed thickness from 14 to 28 cm at a furnace temperature of 500°C, the electrical energy spent was enhanced from 14 to 33 kWh, the time taken for the production of white ash increased from 6 to 9 h only. The percentage of residual carbon in the white ash samples, obtained under different combustion experiments are given in **Figs. 10 and 11**. The results show that the residual carbon in white ash decreased from 2.8 to 0.37%

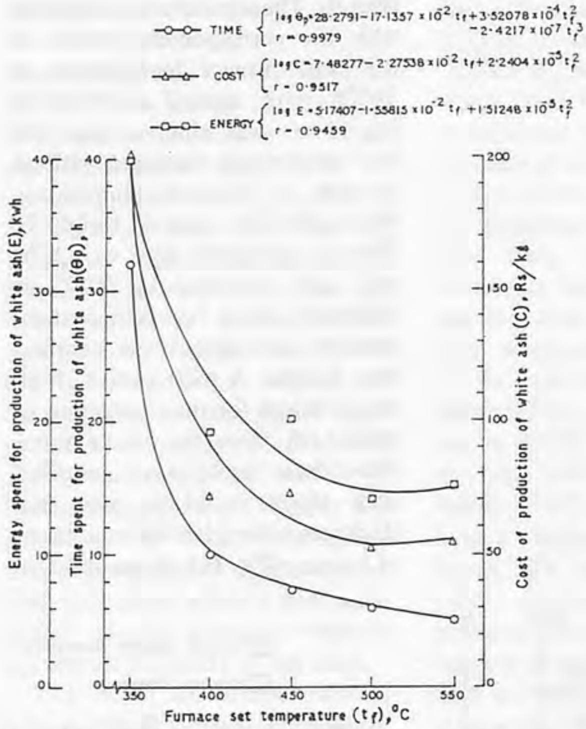

Fig. 12 Effect of furnace set temperature on time and energy spent and cost for production of amorphous white ash from rice husk. Husk bed thickness: 14 cm, natural air-flow, sample weight: 500 g.

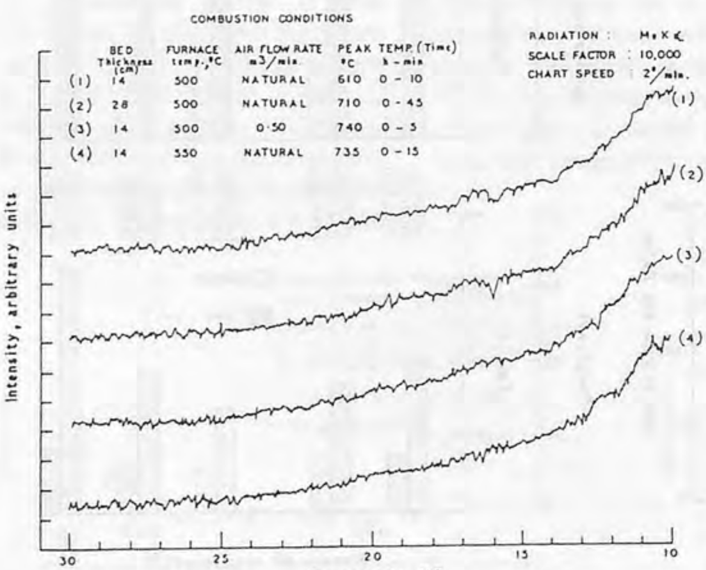

Fig. 13 X-ray diffractograms of white ash obtained from combustion of husk at different conditions.

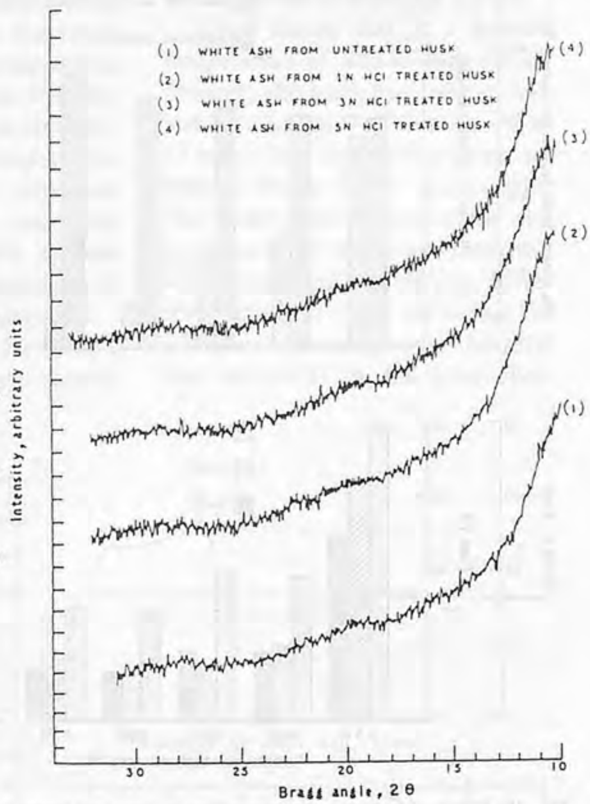

Fig. 14 X-ray diffractograms of white ash obtained from HCl leached husk (40 mesh) at a combustion temperature of 700°C.

as the furnace temperatures increased from 350 to 550°C (for 14 cm husk bed thickness and natural draught). The variation in the residual carbon was not much in the white ash samples obtained from combustion of husk at the furnace temperatures 500 and 550°C. When the husk bed thickness was increased from 14 to 28 cm at the combustion temperature of 500°C with natural draught, the residual carbon in the white ash was found to be more in the case of more husk bed thickness.

Regression equations relating furnace temperature to each of the parameters, namely; production time, energy spent and cost involved were developed for the production of amorphous white ash at the furnace temperatures ranging from 350-550°C for a husk bed thickness of 14 cm under a natural draught. These equations are given in **Fig. 12**. The high values of co-efficient of correlation 'r' and student's 't' indicate that the developed equations were good fit to the experimental data. It was seen from **Fig. 12** that the production time, energy spent and cost of white ash production decreased sharply as the furnace temperature increased from 350 to 450°. However, at temperature above 450°C the decreases in these parameters were not significant.

Figs. 13 and 14 show some typical X-ray diffractograms of the white ash obtained from combustion of husk under the conditions indicated in the figures. The appearance of broad diffraction pattern in all the X-ray diffractorograms indicate that the silica in all white ash samples was amorphous. Though the husk bed temperature in all the above combustion conditions except in (i) increased beyond 700°C, the X-ray analysis of the white ash produced at those conditions did not reveal the presence of any crystallinity in silica.

Conclusion

Within the limits of the present studies, it can be stated that a furnace set temperature of 500°C, a husk bed thickness of 14 cm and a natural draught are the optimum conditions of combustion of rice husk for production of amorphous white ash.

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Utilization Pattern of Farm Machinery and Farm Mechanization in Korea

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Optimum Farm Planning by Linear Programming for Tarai Belt of Nepal

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Abstract

In order to suggest an optimum farm planning to increase the profit per unit farm area for the Tarai belt of Nepal, this particular study was conducted. A linear programming technique (LP) was used to determine the optimum farm planning. Analysis was carried for two different sizes of farms – model farm 1 with 5 ha land area and model farm 2 with 1.5 ha land area. The problem was written in a standard LP format by identifying an objective function and different constrains viz. land, labour, capital, personnel, institutional and husbandry. It was then solved on a microcomputer. It was revealed that for the 1.5 ha model if farmers adopt the suggested cropping would lead to about 3.5 times more profit than the present profit and the cropping intensity could be increased from present level of 13.5% to 280%. Similarly, farmers with 5 ha of farm land could increase profit by 2.7 times than the present profit by optimum cropping. In this case cropping intensity could be increased from present level of 135% to 214%.

Introduction

The heterogeneous physiography of Nepal divides it into three markedly different parallel ecological belts viz. the Tarai, the Hills and the Mountains which cover 23, 44, and 34% of the area, respectively. The Tarai is a narrow strip of flat terrain which starts from the southern foothills of the Churia range and merges into the Gangetic plain to the south. The plain is overlaid by fertile alluvium brought by the Himalayan rivers.

Agriculture is by far the most important and largest sector in the Nepalese economy in terms of gross domestic product, national employment, export earnings and raw material supply to industries. It generates about two-thirds of the GDP and represents some 80% of total merchandise exports. More than 90% of the total labour force in the country are engaged in agriculture and allied pursuits (Khoju, 1983). Crop production is a domminant agricultural activity. Food grains constitute about 80% of Nepal's agricultural GDP. Almost 90% of the cropped area is under cereals while cash crops account for the remaining 10%. The most widely grown crop is paddy which covers about 47% of the total cropped area, followed by maize and wheat which account for 21% and 16%, respectively (Anon, 1986).

Agricultural technology and practices in Nepal are highly traditional characterized by almost complete reliance on vagaries of weather, minimal use of external inputs such as improved seeds, fertilizers etc., negligible mechanization and low cropping intensity. However, there is a great potential of increasing food production by increasing cropping intensity and use of improved production technologies.

In view of the low level of rural economy and stagnant agricultural productivity, Nepal is facing a challenge greater than ever before to meet the food grain requirements of its rapidly increasing population. In this context, it is important that each individual farm unit which constitute the basic functional component of the national farming system, must be able to utilize the resources available to it in the most profitable and effective manner. Each individual farm unit must prepare an optimum farm plan satisfying the various resource constraints it is subjected to. With this view in mind this particular study was undertaken. The linear programming (LP) technique was used for preparing an optimum farm plan.

Farming Systems in Tarai

Farm Size and Operations

Table 1 Land Holding Pattern of Tarai

Size of holding (ha)	Holding area (% of total)	No. of households (% of total)	Average holding (ha)
No land	–	0.46	–
0 – 0.5	45.20	2.76	0.1
0.5 – 1.0	12.96	6.52	0.74
1.0 – 2.0	17.80	16.97	1.40
3.0 – 4.0	5.09	11.93	3.45
5.0 – 10.0	4.62	20.40	6.50
Above 10.0	1.23	16.66	20.00
Total	100.00	100.00	1.47

Source: Anon (1986).

Table 2 Area under Principal Crops in Tarai

Crop	Area ('000' ha)	% of total area
Paddy	1033.3	61.1
Maize	213.7	12.6
Wheat	249.1	14.7
Millets	18.8	1.1
Barley	6.6	0.4
Potato	10.4	0.6
Sugarcane	23.5	1.4
Oilseeds	92.6	5.5
Tobacco	6.4	0.4
Jute	36.0	2.2

Source: Anon (1983).

A typical farming unit in the Tarai includes five family members cultivating about 0.5 ha of land (FAO, 1982). The farmer serves as a manager as well as proprietor providing all labour, capital and management. The farms are typically small in size (**Table 1**) in which most or all of the labourers are family members. The head of the household is himself is the sole supplier of risk capital. Generally, the farmer gives importance in growing food crops rather than producing cash crops. A higher percentage of the farm households with a smaller size of land holding has resulted in growing cereal grains for family subsistence, even though the physical conditions favour growing cash crops.

Main Crops and Cropping Patterns

Crop production (**Table 2**) in Tarai is dominated by rice and wheat which in 1981-82 accounted for 61 and 15% of the total cropped area, respectively. Wheat is the most important winter crop grown under irrigated as well as rainfed conditions. Where year-round irrigation is available, farmers prefer to grow two rice crops in a year. Where irrigation is available after monsoon, there seems to be a preference to grow winter wheat following the main paddy crop. Where rainfall is the only source of irrigation, the main crop will nearly always be paddy planted at the onset of the monsoon.

Cultivation Practices

The average cropping intensity has been estimated to be 146% for irrigated land and 135% for unirrigated areas (Anon, 1982). The fertilizer use is concentrated largely in areas with reliable irrigation. The major power source for soil tillage, threshing, and on-farm and rural transport are draught animals; while planting, weeding and other maintenance chores, and harvesting are all carried out by mannual labour.

Cost and Returns Analysis

The cost and return analysis for various crops were calculated by using the following prevailing prices and standards.

Labour charge per man-day of 8 h working was assumed to be Rs. 15. The labour charge for a pair of bullocks (excluding the ploughman) was taken as Rs. 15 per day. Investment cost on a pair of bullocks was taken to be Rs. 2000, service life as 5 years and salvage value as Rs. 500. Investment cost on tools and implements was assumed to be Rs. 1000, service life as 10 years and salvage value as Rs. 100. The rate of interest on fixed as well as working capital was assumed to be 16% per annum. Interest on fixed capital as well as working capital and depreciation per crop has been calculated assuming two crops per year except for sugarcane to which charges are the same as annual charges. The average yield, market price, human labour and bullock labour requirement for different crops are given in **Table 3**. The average yield is in conformity with the yields recorded for Tarai. Market price represents the latest farm gate price for the product. The human labour and bullock labour requirements for different field operations and for different crops were calculated (Wallace,

Table 3 Average Yield, Market Price, Human and Bullock Labour Requirement of Various Farm Crops

Crop	Average yield (kg/ha)	Market price (Rs.)	Human labour required (mandays)	Bullock labour required (mandays)
Early paddy	1 150	3.50	111	41
Main paddy (UI)	1 350	3.50	109	45
Main paddy (I)	1 700	3.50	127	38
Wheat (UI)	800	3.50	55	26
Wheat (I)	1 400	3.50	108	45
Maize	1 600	3.00	170	25
Potato	4 000	3.00	215	65
Lentil	295	10.00	59	22
Cauliflower	4 500	2.50	163	33
Peas	450	12.00	161	98
Gram	600	5.00	104	59
Mustard	500	8.00	42	38
Sugarcane	30 000	0.50	51	17

*1 US$ = 21.7 Nepalese Rupees; UI = Unirrigated; I = Irrigated.

Table 4 Cost and Return per Hectare of Various Tarai Crops

Enterprise	Variable cost (Rs.)	Fixed cost (Rs.)	Total cost (Rs.)	Gross income (Rs.)	Gross margin (Rs.)	Net profit (Rs.)
Early paddy	2 782	521	3303	4 075	1 293	772
Main paddy (UI)	3 106	548	3 654	4 785	1 679	1 131
Main paddy (I)	3 475	577	4 052	6 020	2 545	1 968
Wheat (UI)	1 439	414	1 853	2 840	1 401	987
Wheat (I)	3 220	557	3 777	4 960	1 740	1 183
Maize	2 960	536	3 496	4 800	1 840	1 304
Potato	8 130	1 049	9 079	12 000	3 870	2 921
Lentil	1 690	434	2 124	2 950	1 260	826
Cauliflower	6 435	814	7 249	11 250	4 815	4 001
Peas	3 570	585	4 155	5 400	1 830	1 245
Gram	1 460	416	1 876	3 000	1 540	1 124
Mustard	1 909	452	2 361	4 000	2 091	1 639
Sugarcane	10 390	2 260	12 650	16 000	4 610	2 350

Remark: UI = Unirrigated; I = Irrigated. Source: Anon (1978).

1986).

The cost and returns per ha for different farm crops were computed for each crop using cost of different inputs. Table 4 gives the cost and return per ha for various crops in Tarai.

Farm receipts relate mainly to the crop production. The livestock enterprises, fruits and other allied enterprises constitute only a minor portion of the total farm business income and hence have not been taken into account (Anon, 1971). Since much of the crop cultivation is carried on under rainfed condition, the average cropping intensity is assumed to be 135% with 100% area under unirrigated paddy in rainy season and 35% area under unirrigated wheat in winter. Hence, from the cost and returns analysis presented earlier, the net return to a farmer per ha was Rs. 1477 out of which paddy contributed Rs. 1131 and wheat, Rs. 346.

Farm Planning and Linear Programming

From the viewpoint of the individual farmer and his family, the primary purpose of farm planning is to help them to determine a more productive, efficient and profitable way to utilize the available resources. From the aggregative point of view, the economic welfare of the entire country is enhanced by the achievement of increased productivity and higher earnings per farm resulting from the most profitable utilization of the country's limited resources.

Linear Programming

The general linear programming model may be expressed in a mathematical language as follows:

Maximize (or minimize)

$$Z = C_1X_1 + C_2X_2 + \ldots\ldots + C_nX_n \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Subject to constraints,

$$A_{i1}X_{i1} + A_{i2}X_{i2} + \ldots\ldots + A_{in}X_{in} \; [\leqslant, =, \geqslant] \; b_i \ldots\ldots (2)$$

where C_j, A_{ij} and b_i are constants, only one of the operators $[\leqslant, =, \geqslant]$ holds for a particular constraint and

$$X_1, X_2 \ldots\ldots\ldots X_n \geqslant 0 \; \ldots\ldots (3)$$

X_j variables are decision variables a_{ij}, b_i and c_j are parameters of the model

$i = 1, 2, 3, \ldots\ldots\ldots, m$

$j = 1, 2, 3, \ldots\ldots\ldots, n$

Mathematical Planning Model for Tarai Farms

Two farm sizes were chosen for the planning purpose – Model Farm 1 with 5 ha of land (the medium size farm holding) and Model Farm 2 with 1.5 ha of land (the average farm size of Tarai). Based on the findings that the contribution of livestock enterprise in the overall economy of Tarai, these model farms were assumed to be purely crop production farms (Anon, 1982). In all, 13 crop production enterprises have been considered feasible under normal Tarai conditions. The farm plans have been prepared for a period of one year, since normally one cycle of crop rotation is complete in one year; and these plans could be repeated again in the following year with modifications, if necessary. Table 5 presents the important planning data obtained from the cost and returns analysis.

Table 5 Data Used for Farm Planning

Enterprise	Net profit per ha (Rs.)	Requirement per ha: Working capital (Rs.)	Improved seeds (kg)	Fertilizers (kg)
Early paddy	772	2 782	–	–
Main paddy (UI)	1 131	3 104	–	–
Main paddy (I)	1 968	3 475	58	100
Wheat (UI)	987	3 475	–	–
Wheat (I)	1 183	3 220	70	90
Maize	1 304	2 960	–	–
Potato	2 921	8 130	–	–
Lentil	826	1 690	–	–
Cauliflower	4 001	6 435	–	100
Peas	1 245	3 570	–	–
Gram	1 124	1 460	–	–
Mustard	1 639	1 909	–	–
Sugarcane	2 350	10 390	–	300

UI = Unirrigated; I = Irrigated.

Mathematical Formulation

Assuming X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, and X_{13} be the hectarage under Early paddy, Main Paddy Unirrigated, Main Paddy Irrigated, Wheat Unirrigated, Wheat Irrigated, Maize, Potato, Lentil, Cauliflower, Peas, Gram, Mustard and Sugarcane, respectively, and from the data in **Table 4**, an objective function was written as below.

Maximize:

$$Z = 772X_1 + 1131X_2 + 1968X_3 + 987X_4 + 1183X_5 + 1304X_6 + 2921X_7 + 826X_8 + 4001X_9 + 1245X_{10} + 1124X_{11} + 1639X_{12} + 2350X_{13} \quad \ldots (4)$$

Constraints

The constraints have been grouped into the following six categories:

Land constraints – The feasible farm crops were broadly grouped into annual crops (i.e., crops which occupy the land for almost a complete year), and seasonal crops (i.e., crops which remain in the field for a certain period in the year). The seasonal crops were further classified into summer crops, rainy season crops and winter season crops. Among the crop enterprises considered, sugarcane is an annual crop; early paddy and maize are summer crops; main paddy and gram are rainy season crops; and wheat, potato, cauliflower, lentil, peas, mustard are winter crops. The crop calendar is shown in **Fig. 1**. An overlap of 15 days was assumed admissible in farming activities. Based on these assumptions four land constraints each were formulated for Model Farm 1 and 2.

Labour constraints – It was assumed that the farmer with 5 ha farm has total three family labourer available for farm activities while the farmer with 1.5 ha land has only two economically active family labourer. The farmer with 5 ha can hire labourer at the rate of 5 labourers per day in March, July and November and 2 labourers per day during December (during peak seasons, i.e., during ploughing, sowing, transplanting and harvesting). Similarly, the farmer with 1.5 ha can employ 3 labourers per day during March, July and November and 2 labourers per day during December. The availability of hired labour was assumed considering the current trend, migration of labour from hills and from Indo-Nepal border areas.

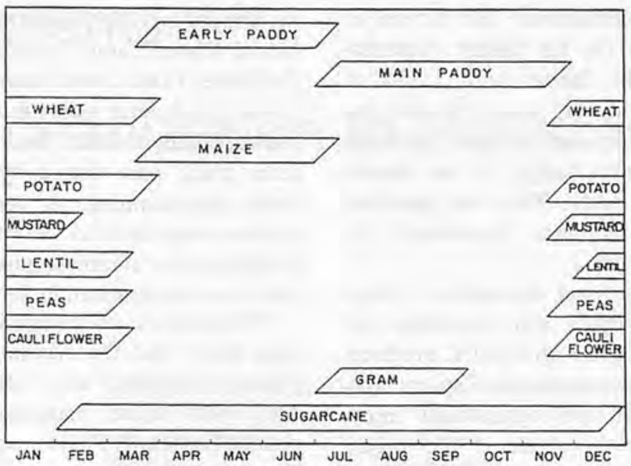

Fig. 1 Crop calender for Tarai belt of Nepal.

The monthly labour requirements for different crops are presented in **Table 6**. The labour requirement for different farm operations were computed. With these data, 12 labour constraints each were formulated mathematically for both the Model Farms 1 and 2.

Capital constraints – External sources of financing in a limited cash flow economy of Nepal plays a vital role in strengthening agricultural development. Most of the farmers, particularly small ones, are unable to manage from one harvest to another without borrowing. It has, therefore, been assumed that agricultural credit is the source of working capital for the farmers (Anon, 1982). It was also assumed that the farmer can receive up to 40% of his land value. Assuming a stratum of three crops per year, total working capital per season is one-third of the total available capital. The land value was assumed to be Rs. 24 000 per ha. Based on the above assumptions and data given in **Table 5**, four capital constraints were identified for each model farm.

Personal constraints – It was assumed that the farmer with 5 ha farm wants to grow at least 0.25

Table 6 Monthly Labour Requirement for Different Crops

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Early paddy	–	–	78	4	8	8	13	–	–	–	–	–
Main paddy (UI)	–	–	–	–	–	–	80	1	7	7	14	–
Main paddy (I)	–	–	–	–	–	–	70	2	11	10	34	–
Wheat (UI)	–	–	29	–	–	–	–	–	–	–	–	26
Wheat (I)	15	12	38	–	–	–	–	–	–	–	–	33
Maize	–	–	49	16	16	16	73	–	–	–	–	–
Potato	29	25	58	–	–	–	–	–	–	–	78	25
Lentil	1	–	20	–	–	–	–	–	–	–	–	20
Cauliflower	20	23	42	–	–	–	–	–	–	–	56	20
Peas	–	–	41	–	–	–	–	–	–	–	–	63
Gram	–	–	–	–	–	–	14	–	37	–	–	–
Mustard	4	31	–	–	–	–	–	–	–	–	21	3
Sugarcane	–	42	8	8	8	6	12	8	10	10	10	41

UI = Unirrigated; I = Irrigated.

ha of cauliflower and 0.5 ha of mustard for his family consumption. The farmer with 1.5 ha of land, however, does not have any personal choice. As such, personal constraints apply to the Model Farm 1 only. Thus two personal constraints were formulated for Model Farm 1.

Institutional constraints – Supply of inputs and possibilities of marketing the agricultural products have been considered. Reports indicate that the Agricultural Input Corporation which is the major supplier of improved seeds, fertilizers, etc. has not been able to supply the necessary inputs in required quantities (Wallace, 1986). Based on these findings, it was assumed that the farmer with 5 ha can receive up to 200 kg of HYV paddy seeds, 200 kg of HYV wheat seeds and 300 kg of fertilizer in each crop season. Similarly, the farmer with 1.5 ha can purchase 100 kg of HYV paddy seeds, 100 kg of HYV wheat seeds, and 150 kg of fertilizer in each crop season. From the marketing point of view, it was assumed that the Model Farm 1 should not grow more than 2 ha of cauliflower and 1 ha of peas. Market restrictions, however, do not apply to the farmer with 1.5 ha of land. Thus for Model Farm 1 and 2, seven and five institutional constraints were formulated.

Husbandry constraints – For preserving the long term fertility and conditions of land, it was assumed that at least one crop hectare of land will be kept fallow. Also, from rotational point of view, at least 0.5 ha of leguminous crop, i.e., gram must be grown. These restrictions, however, are not applicable to the Model Farm 2. Thus three husbandry constraints were identified for Model Farm 1 only.

Optimal Farm Plans

Altogether 32 constraints for Model Farm 1 and 25 constraints for Model Farm 2 were formulated. These constraints were written in standard (LP) format. The optimal farm plans were found by using linear programming. A computer software was used to solve this LP problem on a microcomputer. The results are summarized in **Table 7**.

The analysis of optimum planning show that the maximum net returns for Model Farm 1 would be Rs. 19 900 while maximum net returns for Model Farm 2 would be Rs. 7 800. In the proposed optimum farm planning, for Model Farm 1, early paddy, irrigated main paddy, unirrigated wheat, lentil, cauliflower, gram, mustard and sugarcane were proposed to grow. More than 50% of the area was allocated to main paddy. The next priority crops were found to be early paddy and gram. It was suggested that no area should be allocated to main unirrigated paddy, irrigated wheat, maize, potato and peas. For Model Farm 2, analysis suggested that area should be allocated to early paddy, main irrigated paddy, maize, cauliflower, mustard and sugarcane, while no area should be allocated to unirrigated paddy, both unirrigated and irrigated wheat, potato, lentil, peas and gram. For this model farm it was again suggested that more than 50% of the area should be allocated to main irrigated paddy.

With the new optimum cropping pattern obtained in this study it was found that the cropping intensity for Model Farm 1 and 2 could be increased up to 214% and 280%, respectively. The cropping intensity was estimated by the following formula.

Cropping Intensity = Cropped Area x 100 / Land Area . . . . . (5)

Table 7 Optimal Farm Plans for Model Farm 1 and Model Farm 2

Crop	Model Farm 1 Area (ha)	Model Farm 2 Area (ha)
Early paddy	1.5	0.7
Main paddy (UI)	–	–
Main paddy (I)	2.8	1.4
Wheat (UI)	1.1	–
Wheat (I)	–	–
Maize	–	0.6
Potato	–	–
Lentil	1.0	–
Cauliflower	1.8	0.5
Peas	–	–
Gram	1.4	–
Mustard	0.5	0.9
Sugarcane	0.6	0.1
Total cropped area	10.7	4.2

UI = Unirrigated; I = Irrigated.

Conclusion

Under the present situation, a Tarai farmer with 1.5 ha farm size earns an income of Rs. 2 216 whereas if he executes his farming activities as per the farm plan worked out in this study, he could intensify cropping from the present level of 135% to 280% and could expect a profit as high as Rs. 7 800 – almost three and half times the present value. Similarly, a farmer with 5 ha farm size, who presently received a profit of Rs. 7 385 per annum may increase the cropping intensity from 135% to 214% and expect a profit as high as Rs. 19 900 – almost 2.7 times the present value, if he undertakes the farm business as per the optimal plan computed in this study. Thus if the farmers in Tarai implement the farm plan as worked out in this study, their annual income would increase significantly. It will improve their economical, social and cultural status.

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Analysis of Problems of Agricultural Mechanization in Pakistan

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Abstract

The study was undertaken to analyse the various problems in the way of promotion of agricultural mechanization in Pakistan. It has been found that, in the country, tractorization is prominent comparative to the real mechanization. Selective mechanization easing and speeding the operations previously dependent on manual and bullock power prevails. Farmers mainly own and use cultivator, scraping blade, trolley and thresher with tractor despite the high level of awareness about the improved agricultural machinery. Financial constraint is the major impediment in the promotion of agricultural mechanization in Pakistan.

Introduction

Agricultural mechanization is recognized throughout the world as a crucial factor influencing farm productivity both directly and indirectly. Farm mechanization started in Pakistan with the introduction of tractors in the country. In 1947, there were about 500 tractors in Pakistan (Ansari et al, 1984). The population increased to 35 333 tractors in 1971-72 (NCA report, 1988). Onward, yearly import quantum and cumulative total tractors in the country up to 1986-87 are given in **Table 1**.

As per "Pakistan Census of Agricultural Machinery, 1984," it is important to note that out of 204 846 tractors imported into the country up to 1983/84, only 155 047 tractors were actually operating at the farms in that year. Out of the balance some have been written off or lying unserviceable and others were working in the non-farm sectors. The practice of hiring out of tractors has become very common. The farmers who do not own tractors are also able to get their fields cultivated by hiring tractors from others. Out of 138.64 million hours worked by on-the-farms operating 155 047 tractors during 1984, the time self-utilized and rented to others were 77 and 23%, respectively.

The role of the tractor in mechanization is just to function as a source of power and give propulsion to the attached implements /machinery. It is the implement which has direct bearing on crop production. So far, Pakistan has experienced only selective mechanization featuring ease and speed of operations previously dependent on manual and bullock power. The most popular package consists of a tractor and a cultivator, scraping blade, trolley and thresher.

This study has been carried out to analyze the various implications in the way of agricultural mechanization in Pakistan.

Table 1 Number of Tractors, 1971-1987

Year	Imported	Cumulative total
1971-72	4 224	35 333
1972-73	1 847	37 180
1973-74	5 216	42 396
1974-75	7 190	49 586
1975-76	10 809	60 395
1976-77	15 554	75 949
1977-78	11 902	87 851
1978-79	15 178	103 029
1979-80	19 313	122 342
1980-81	16 137	138 479
1981-82	19 293	157 772
1982-83	22 913	180 685
1983-84	24 161	204 846
1984-85	31 246	236 092
1985-86	24 815	260 907
1986-87	22 241	283 148

Source: NCA report, 1988.

Methodology

In the present study, data on tractors imported in the country as presented in the Report of National Commission on Agriculture published by the Ministry of Food and Agriculture, Government of Pakistan, 1988 together with on-the-farm operating tractors as given in Pakistan Census of Agricultural Machinery, 1984 has been analyzed in conjunction with the information available in the study carried out by M/s Innerview Karachi for M/s Millat Tractor, Ltd., the authorized dealer of Massey Ferguson tractor in Pakistan. Financial analysis has been undertaken and major constraints impeding the promotion of agricultural mechanization highlighted. In the end, suggestions to promote agricultural mechanization in the country have been detailed.

Results and Discussion

Tractor-implement Use Pattern

The population of the mostly used implements and their percent strength in relation to on-the-farm operating tractors (155 047 Nos.) is given in Table 2.

It is evident from above statistics that:

Farmers mainly own and use cultivator, thresher, trolley and scraping blade. Their population in relation to operating tractors are 93.50%, 50.07%, 62.92% and 44.51%, respectively.

The adoption level of other improved implements is drastically low. Their population ranges between 0.06 to 4.64 Nos. per 100 tractors in the country.

Superimposing the tractor-implement use pattern with the rate of import of tractors in the country, it becomes clear that, so far, there has been more trend towards tractorization and less importance attached to real mechanization.

Table 2 Population of the Mostly Used Implements

Implement	Number	Population of implements over operating tractors (%)
Cultivator	144 970	93.50
Moldboard plow	7 201	4.64
Disc plow	6 299	4.06
Chisel	1 486	0.96
Ripper/sub-soiler	712	0.46
Rotavator	2 101	1.36
Scrapper	69 004	44.51
Bar harrow	1 747	1.13
Disc harrow	6 297	4.06
Ridger	4 684	3.02
Border disc	555	0.36
Rabi drill	5 566	3.59
Kharif drill	5 519	3.56
Row crop planter	109	0.07
Rice planter	87	0.06
Potato planter	427	0.28
Fertilizer broadcaster	288	0.19
Tractor-mounted sprayer	2 639	1.70
Reaper	709	0.46
Cutter binder	403	0.26
Thresher	77 626	50.07
Combine harvester		
i) Pull type	445	0.29
ii) Self-propelled	179	0.12
Trolley	97 550	62.92
Others	1 956	1.26

Source: Pakistan Census of Agricultural Machinery, 1984.

Farmers' Awareness

A study was conducted by M/s Inner View, Karachi during 1985 to investigate the level of awareness of farmers about the latest implements. Table 3 shows the degree of awareness computed from the results of the above study.

Table 3 Farmers' Awareness about Latest Tractor Implements

Implements	Not Aware	Aware	
		Not suitable	Financial constraints
	(%)	(%)	(%)
Moldboard plough	6.5	32.6	60.9
Disc plough	2.7	20.7	76.6
Disc harrow	9.8	21.1	69.1
Rotary tiller	11.6	17.7	70.7
Rotary Thresher	20.2	16.5	63.3
Ridger	12.1	17.0	70.9
Front and rear levelling blade	15.8	0.0	84.2
Post-hole digger	20.5	23.1	56.4
Rabi drill	13.4	14.2	72.4
Kharif planter	14.2	13.5	72.3
Boom sprayer	14.7	9.3	76.0
Cutter binder	9.2	15.8	75.0
Combine harvester	11.9	15.9	72.2
Trolley	2.8	8.6	88.6
Fertilizer broadcaster	12.6	18.5	68.9

The above data show that:

Level of awareness of farmers about the latest agricultural implements is quite high. It ranges between 79.5 to 97.3%.

Main reason for not using the latest implements is the financial constraints.

Farmers who are aware but not using the latest implements due to unsuitability are of considerable percentage i.e.; zero to 32.6.

The unawareness ranges between 2.7 to 20.5%.

Financial Analysis

Table 4 shows the price hike for major agricultural machinery that occurred during the last six years. Yield trend of major crops since 1982-83 to 1986-87 and the support prices of the main commodities fixed by the Government are given in Tables 5 and 6, respectively.

Data presented in the above Tables 4, 5 and 6 indicate that:

Price hike percentage of agricultural machinery is much higher as compared to increase in support prices of main commodities fixed by the Government. On the average, the increase in prices of agricultural machinery took place by about

Table 4 Price Hike for Main Agricultural Machinery, 1982-1988

Machinery	Price (Rs./unit) 1982	Price (Rs./unit) 1988	% increase of price over 1982
Tractor			
i) MF 240	88 000	141 500	60.80
ii) Fiat 480	104 710	157 900	50.80
iii) Fiat 640	139 900	189 900	35.74
Chisel plow, 3 tines (local)	6 000	7 850	30.83
Rotavator, 50" width (imported)	15 000	30 300	102.00
Reversible, 2 bottom moldboad plow (imported)	12 000	28 500	137.50
Ridger, 3 rows (imported)	5 000	8 350	67.00
Cultivator, 11 tines (local)	3 000	4 000	33.33
Disc harrow, 16 discs (imported)	15 000	20 000	33.33
Thresher (local)	20 000	23 000	15.00
Average:			56.63

Source: M/S Millat Tractors Ltd, Lahore.

Table 5 Yield Trend for Major Crops

Year	Wheat kg/ha	Wheat % increase over base year	Rice kg/ha	Rice % increase over base year	Cotton (lint) kg/ha	Cotton (lint) % increase over base year	Sugarcane t/ha	Sugarcane % increase over base year
1982-83	1 678	–	1 736	–	338	–	38.6	–
1983-84	1 482	−11.68	1 741	0.29	364	7.70	35.7	−7.51
1984-85	1 881	12.10	1 671	−3.74	223	−34.02	38.2	−1.04
1985-86	1 643	− 2.09	1 685	−2.94	450	33.14	35.5	−8.03
1986-87	1 680	0.12	1 567	−9.74	515	52.37	35.7	−7.51

Source: NCA report, 1988.

Table 6 Support Prices of Main Commodities

Commodity	Support price (Rs./40 kg) 1982	Support price (Rs./40 kg) 1988	% increase over 1982
Wheat	58	82.50	42.24
Cotton	197	207.00	5.08
Rice (paddy)			
i. Coarse	49	58.00	18.37
ii. Fine	85	130.00	52.94
Sugarcane	9.65	11.28	16.89
Average			35.70

Source: Government support prices notification, 1982 and 1988.

100% during the last six years comparable to the support prices of main commodities.

Prices of imported agricultural machinery have increased at far higher percentage than the local-made ones.

Yield trend of major crop is not upward except that of cotton.

It is evident that farmers are not very well off financially to afford costly implements. The financial constraint is, therefore, a big impediment in the promotion of agricultural mechanization in Pakistan.

Conclusions

1. There is greater trend towards tractorization and, comparatively, less emphasis has been given to real mechanization so far.
2. Farmers mainly own and use cultivator, trolley, scraping blade and thresher with tractor.
3. A high degree of awareness about the improved agricultural machinery prevails amongst the farmers but their use is minimal mainly due to financial constraints.
4. Farmers' level of unawareness about the latest agricultural machinery is also of considerable magnitude.
5. Financial constraint is the major factor impeding the promotion of agricultural mechanization in Pakistan.

Suggestions

The following suggestions are advanced for the promotion of agricultural mechanization in Pakistan:

1. The government should establish "Implements Pools" at appropriate places from where these could be provided to the farmers on custom-hire service. It is, therefore, essential that government may consider placing 3-4 sets of implements, to begin with, at union council level.

2. The government should bind tractor manufacturers to arrange frequent demonstrations of whole range of implements through their dealer network at farmers' fields. It should be made obligatory that each tractor manufacturing establishment create a mobile demonstration unit in every *tehsil* in the country.

3. A comprehensive study should be carried out to understand the problems of the manufacturers of implements about (a) technical knowhow; (b) availability of material of required quality and specifications; and (c) any problem about import of material or higher cost due to custom duty or sales tax etc. Based on the results of the study, the government may provide incentives to the implements/equipment manufacturers through exemption from custom duty, sale tax, etc.

4. The manufacturers of implements/ equipment has essentially to import some of the components

as these are not available to them in the country of required standard, quality and specifications. Import of such components may be exempted from custom duty, sales tax, etc.

5. In order to popularize the use of such implements/equipment, the government may provide sets of implements to such people at cheaper rates. Interest-free loans may also be given to small farmers.

6. The government should make it obligatory on the part of tractor manufacturers to expand the repair and maintenance facility in the rural area. The Government may also provide incentives to the "rural artisans" in the form of interest-free loan recoverable in easy instalments for the purchase of tool kits and some workshop equipment for repair and maintenance of tractors and implements. The tractor manufacturers should be required to provide training to the rural artisans about the repair and service of their makes/models.

7. It is time that the Government seriously consider establishing agricultural engineering extension service in the public sector. Left to the private sector, the promotion of agricultural mechanization shall remain nothing but lip service.

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1991 International Agricultural Mechanization Conference
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Industrial Constantly Variable Transmission

This article describes a newly developed CVT suitable for agricultural tractors, mining machinery, towmotors, light locomotives, earth moving and industrial machinery, variable speed pumps and other heavy duty transmission usages.

The principle of the operation of the heavy duty transmission in the first prototype form is fully mechanical and uses counter-weighted continuously variable throw crank arms mounted on a crankshaft in an inverted Vee Six configuration and will produce stepless ratio changes from zero to maximum engine r.p.m. (direct drive). Normally 0 to 2 000 the main operating one way clutches were designed to be loaded to 1 500 Nm. at varying r.p.m. with a life-span of 10 000 hours.

It was designed and developed over the last three years by Mick Egan, with assistance from Silsoe College Bedfordshire, England, Ricardo Engineering, Brighton, England, TNO Institute, Holland, Tsubakimoto, Japan, Sir Jack Brabham and was manufactured by Vernier Engineering Wollongong, Australia.

The prototype is currently coupled to a Basildon 444 Ford diesel engine and is connected to

the flywheel via a damper plate and does not require a clutch or torque converter. The entire unit is mounted on a Heenan and Froud 350 b.h.p water brake dynamometer and coupled direct via a Cardan shaft to the output flange of the transmission. For the initial tests the engine was set at 15 000 r.p.m. and the output shaft has been tested under various loads up to 42kW and between 0 and 750 r.p.m. on the output shaft.

Ultimately it was concluded that an expression of the unloaded, against loaded, fuel consumption would be adequate to prove the overall efficiency of the prototype. At this speed range an 82% efficiency was achieved. No unevenness or vibration was experienced through the range of ratios with a smooth transition between ratios being performed under load. The noise level did not exceed that of a conventional transmission.

The dimensions of the unit are 1200 mm L x 450 W x 500 mm D. The lubrication is pressure-fed via an input shaft pump. Six multiplate clutches were used for forward, reverse and engine braking operations that are also activated by the input shaft pump.

A second prototype has been designed and will incorporate alterations that will reduce the overall size and weight by 30%. The one way clutches will be back stopping and not indexing and the number of mechanical components will also be reduced by approximately 30%.

NEWS

There is no doubt that this development does prove that the principle used is sound and with further refinement could find applications in many areas. It appears to be better in performance, compared to hydrostatic drives commonly used for these types of application.

Review of Literature Published in AMA

This article was written by Gajendra Singh, Prof. of Agric. Engg., Div. of Agric. and Food Engg., Asian Institute of Technology, Bangkok, Thailand

The first issue of AMA was published in Spring 1971 under the name "Agricultural Mechanization in Southeast Asia" which in the second issue adopted the name of "Agricultural Mechanization in Asia". Due to its immense popularity and relevance to all developing countries, in 1981, it was renamed "Agricultural Mechanization in Asia, Africa and Latin America" all along retaining the abbreviation as AMA.

The AMA journal has opened new channels of communication for agricultural mechanization in developing countries of the world. It meets a unique and growing need for the exchange of technical information and ideas among the agricultural mechanization experts. The following is a brief summary of research papers published so far in AMA covering broadly: human and animal power, field implements, handling and processing, mechanization management, irrigation and education in the field of agricultural engineering.

Human and Animal Power: About 10 research papers on human power and 16 papers on animal power have been published. Papers on human power include development and testing as well measurement of human energy expenditure in operating various equipments like hand pumps, sickle, rice transplanter, and dung cleaner. Ergonomics of certain field operations and an anthropometric survey of Indian farm workers are also covered. Manually operated seeding attachment, hand drill for sugar beet and soybean have been reported. Papers published on animal power deal with potential of draft power in developing countries in general and specifically in India, Bangladesh, Chile, Mexico and Pakistan. Improving the utilization of animal power through better harnesses as well as performance (physiological response) of bullocks and buffaloes under different load and climatic conditions while performing various field operations including transportation has been reported mainly from India.

Field Implements: There are about 200 papers on field implements and they report a variety of traditional and modern hand, animal and power operated implements used for tillage, seeding and plant protection in different developing countries. The evolution steps of plowing and tractorization and implements connected with them have been studied. Implements connected with rice cultivation have been widely reported as rice is the most important crop in most developing countries. Tillage practices of Bangladesh, India and Pakistan have been reported extensively. Papers on tillage implements report individual and comparative performance of traditional, mouldboard, disc and chisel ploughs and disc and float harrow. Studies on the mechanics of puddling operations with different implements with regard to soil characteristics have been reported. Soil-bin investigations are also covered. Minimum and zero tillage concepts are investigated, compared with conventional tillage practices and reported. The combinations of various animal and tractor drawn tillage implements including oscillatory tools and attachments are also evaluated. Mechanized and animal powered tillage practices are compared. Studies on tractive performance of cage wheels and pneumatic tyres have been reported. Field performance of tractors in Pakistan and India have been studied. Different soils have been evaluated with regard to their tillage characteristics. Many papers report on different direct sowing techniques and their potential in developing countries in general and specifically in Pakistan. The paddy transplanters developed and modified at different places have been reported. Hand and animal operated seed, seed-cum-fertilizer drills for paddy, wheat, soybean, sugar-beet and jute are covered. Planting equipment for potato, sugarcane, cassava, corn and oil palm have been developed and evaluated. Manual planting methods have also been studied. Different manual, motorized and tractor mounted sprayers and their performance have been reported. Laboratory studies on spray distribution have been carried out. Bullock and tractor-drawn potato diggers have been widely reported.

Handling and Processing: There are about 200 papers reporting on handling and processing of various crops. Most of these papers deal with rice. The drying methods for paddy, peanuts and rapeseed are investigated. Rice parboiling techniques have been widely discussed. Post-harvest losses in different countries have been investigated and grain storage methods have been proposed. Mechanized harvesting methods for fruit crops, grass seed, cassava and jute have been reported. Reapers for different crops have been evaluated. Development and evaluation of multi-crop thresher has been reported. Self propelled and tractor mounted combines have been compared. Pulse processing machinery has been reported from India.

Mechanization Management: Research papers on management, economics and general issues related to agricultural machanization outnumber the contribution from any other area. There are about 450 papaers in this category and they report mostly on historical development, problems, present status and future prospects of agricultural mechanization in almost all developing countries covered by AMA. The general characteristics of individual countries' agriculture and proposed mechanization policies have also been discussed widely. The problems, status and improvements in the manufacturing sector of agricultural machinery in different countries have also been reported. The economics of farm operations with machines has been compared with other methods and optimization of operation cost has been reported. Computerized machinery selection models have been proposed. Socio-economic, institutional and energy problems associated with mechanization have been discussed in the context of various developing countries. Views of mechanization experts from both developed and developing countries have been expressed.

Irrigation: About 60 papers have been published on irrigation and related issues. These papers cover studies on irrigation pumps, sprinklers, canal irrigation systems, effects of irrigation on crop production and socio-economic aspects of irrigated agriculture, etc. Equipment needs of irrigation in India have been indentified. Socio-economic problems associated with irrigation have been discussed. The energy demand of irrigation and potential of renewable energy sources for irrigation have been investigated. Performance studies of axial-flow, centrifugal and wind pumps have been reported. Tube well irrigation has been evaluated. The sprinkler irrigation systems of India, Iraq and Sudan have also been evaluated and reported. Lining of irrigation canals with asphaltic materials to minimize the water losses in Bangladesh has been proposed. The drainage problems of a selected location in Saudi Arabia and mole drainage systems have been discussed. Effects of irrigation on wheat, maize, cotton and corn production have been studied.

Education: There are about 15 research papers on education in agricultural engineering and mechanization. The educational programs of the Agricultural Engineering Departments at Michigan State University, USA and selected Indian agricultural universities have been reported. The activities of Institute of Agricultural Machinery and Japanese universities are covered. An International Agricultural Mechanization Institute, an Asian Agricultural Machinery Institute and Agricultural Engineering programs suitable for developing countries students have been proposed. The need for vocational and training courses on farm machinery use in Iran, and Pakistan has been emphasised.

15th Annual Meeting of Korean Society for Agricultural Machinery

Prof. Koh

The 15th annual meeting of the Korean Society for Agricultural Machinery was held on July 13-14th at Chonnam National University.

Yoshisuke Kishida, president of Shin-Norinsha Co., Ltd. and chief editor of AMA, presented a special lecture on "Prospects for Agricultural Mechanization in Japan" on July 14th.

The meeting selected Dr. Hak Kyun Koh, professor of agricultural engineering, Seoul National University, as the new president of the society, Dr. Y.K. Lee, professor of agricultural engineering, Sung Kyun Kwan University, Dr. H.K. Song, Chung-Buk National University, Mr. Tae-Hoon Chung, chairman of Korea Farm Machinery Tool Ind. Cooperative, as vice presidents. Dr. H.K. Koh expressed his hopes to promote the exchange with other societies outside Korea in his view for the course of the society. ■■

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BACK ISSUES

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

INSTRUCTIONS TO AMA CONTRIBUTORS

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

Criteria for Article Selection

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

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

Rejected/Accepted Articles

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

Procedure

a. Articles for publication (original and one-copy) must be sent to AMA through the Co-operating Editor in the country where the article originates. (Please refer to the names and addresses of Co-operating Editors in any issue of the AMA). However, in the absence of any Co-operating Editor, the article may be sent directly to the AMA Chief Editor in Tokyo.
b. Contributors of articles for the AMA for the first time are required to attach a passport-size ID photograph (black and white print preferred) to the article. The same applies to those who have contributed articles three years earlier. In either case, ID photographs taken within the last 6 months are preferred.
c. The article must bear the writer(s) name, title/designation, office/organization, nationality and complete mailing address.

Format/Style Guidance

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

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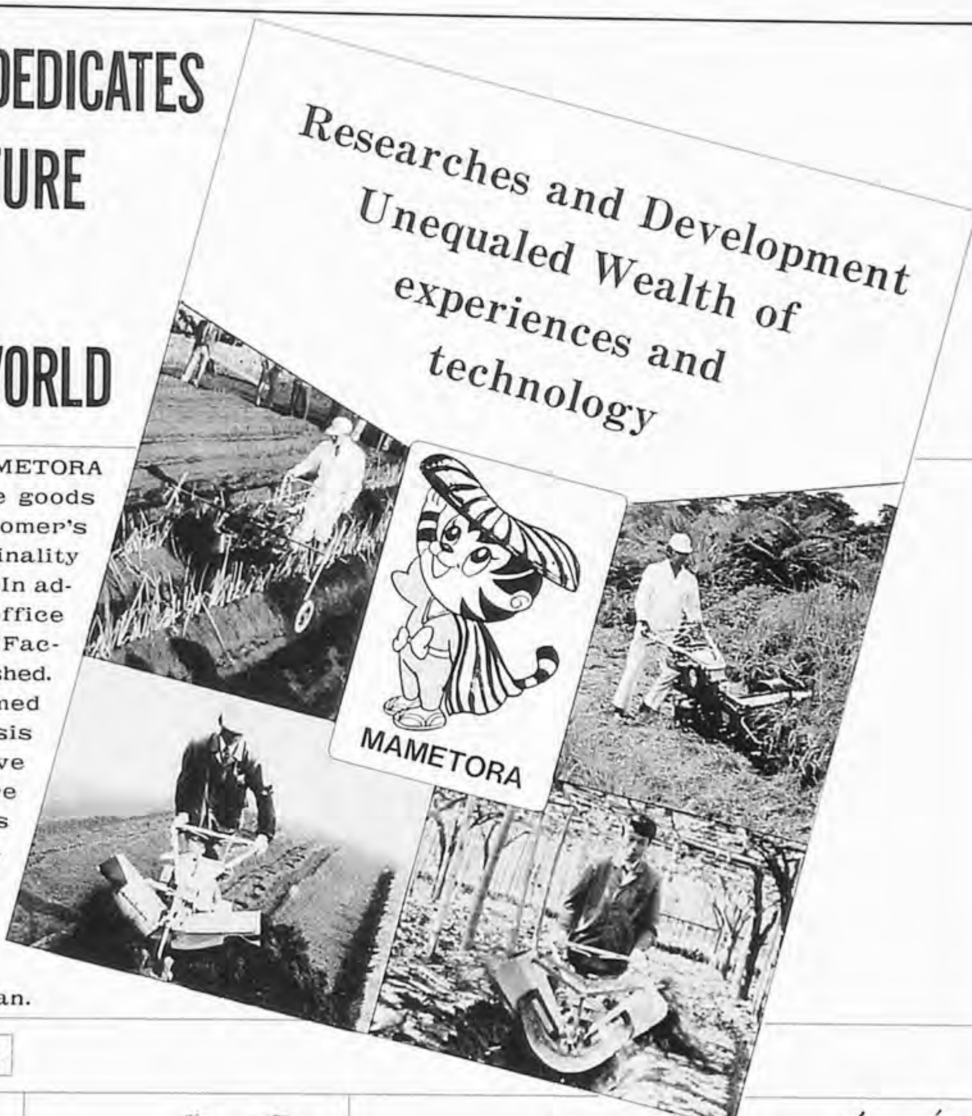

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